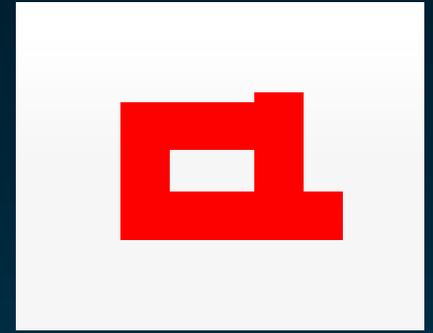




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UMLS in biomedical text processing



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U.S. National Library of Medicine



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Overview

- ◆ An example
- ◆ Types of resources for mining biomedical text
- ◆ Three types of resources
 - Lexical resources – SPECIALIST Lexicon, *norm*
 - Terminological resources – Metathesaurus, *MetaMap*
 - Ontological resources – Semantic Network, *SemRep*



An example

Neurofibromatosis 2

Neurofibromatosis 2

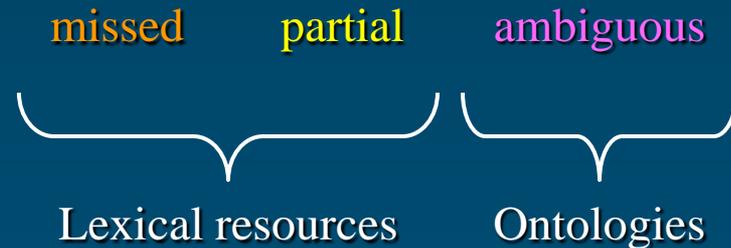
Neurofibromatosis type 2 (NF2) is often not recognised as a distinct entity from peripheral neurofibromatosis. NF2 is a predominantly intracranial condition whose hallmark is bilateral vestibular schwannomas. NF2 results from a mutation in the gene named merlin, located on chromosome 22.

[Uppal, S., and A. P. Coatesworth. "Neurofibromatosis Type 2." *Int J Clin Pract*, 57, no. 8, 2003, pp. 698-703.]



Entity recognition

Neurofibromatosis type 2 (NF2) is often not recognised as a distinct entity from peripheral neurofibromatosis. NF2 is a predominantly intracranial condition whose hallmark is bilateral vestibular schwannomas. NF2 results from a mutation in the gene named merlin, located on chromosome 22.



Relation extraction

Neurofibromatosis type 2 (NF2) is often not recognised as a distinct entity from peripheral neurofibromatosis. NF2 is a predominantly intracranial condition whose hallmark is bilateral vestibular schwannomas. NF2 results from a mutation in the gene named merlin, located on chromosome 22.

- vestibular schwannomas *manifestation of* neurofibromatosis 2
- neurofibromatosis 2 *associated with* mutation of NF2 gene
- NF2 gene *located on* chromosome 22

Types of resources for mining biomedical text

Types of resources

◆ Lexical resources

- Collections of lexical items
- Additional information
 - Part of speech
 - Spelling variants
- Useful for entity recognition
- UMLS SPECIALIST Lexicon, WordNet

◆ Ontological resources

- Collections of
 - kinds of entities (substances, qualities, processes)
 - relations among them
- Useful for **relation extraction**
- UMLS Semantic Network, BioTop



◆ Terminological resources

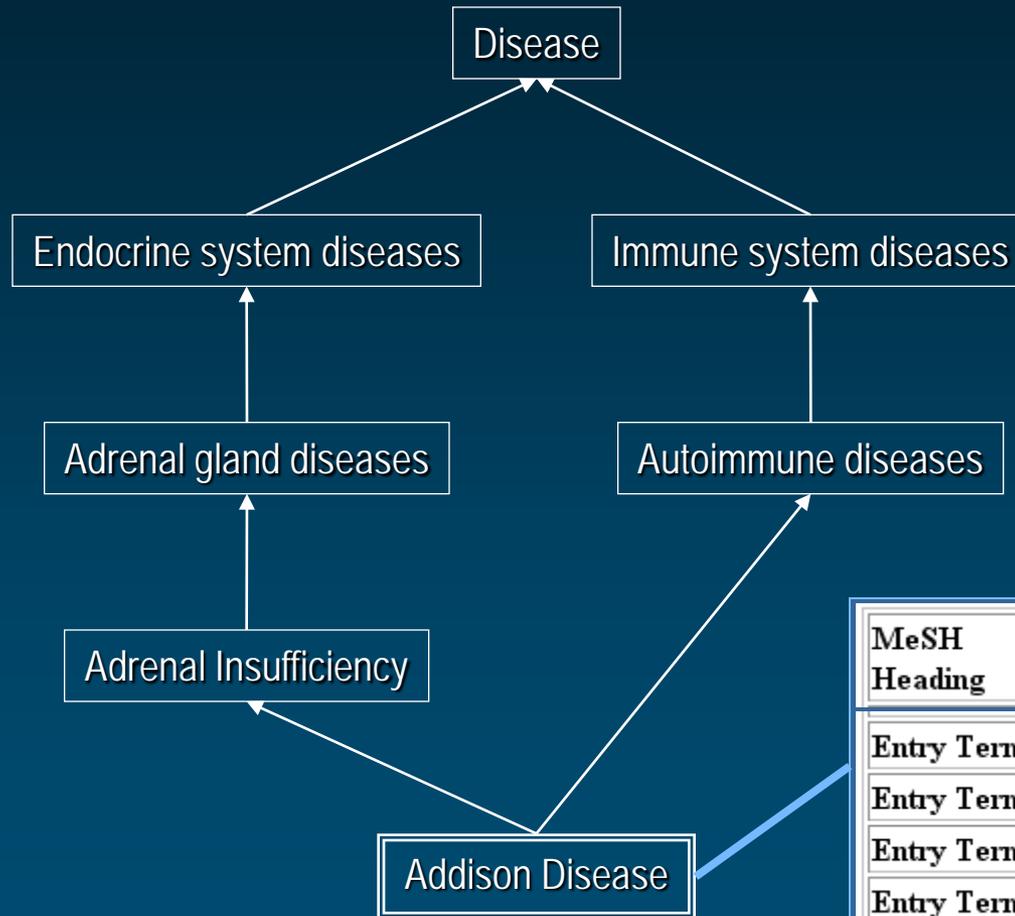
- Collections lexical items + identifiers
- Useful for **entity resolution**
- UMLS Metathesaurus

Types of resources (revisited)

- ◆ Lexical and terminological resources
 - Mostly collections of names for biomedical entities
 - Often have some kind of hierarchical organization (e.g., relations)
- ◆ Ontological resources
 - Mostly collections of relations among biomedical entities
 - Sometimes also collect names

Lexical / Ontological MeSH

<http://www.nlm.nih.gov/mesh/2007/MBrowser.html>



MeSH Heading	Addison Disease
Entry Term	Addison's Disease
Entry Term	Primary Adrenal Insufficiency
Entry Term	Primary Adrenocortical Insufficiency
Entry Term	Primary Hypoadrenalism



Lexical / Ontological FMA

<http://fme.biostr.washington.edu/index.html>



Foundational Model Explorer

Options

Help

Search

Select navigation tree type: subclass

- Anatomical entity
 - Physical anatomical entity
 - Material anatomical entity
 - Anatomical structure
 - + Body
 - + Cardinal body part
 - + Organ system
 - + Subdivision of cardinal body part
 - + Organ system subdivision
 - Organ
 - + Solid organ
 - Cavitated organ
 - + Organ with organ cavity
 - Organ with cavitated organ parts
 - Heart
 - + Cavernous organ
 - + Bone organ
 - Cardinal organ part
 - Organ component
 - + Wall of organ
 - + Organ component layer

PREFERRED NAME:

Heart

NON-ENGLISH EQUIVALENT:

name	language
Cor	Latin
Corazon	Spanish
Coeur	French
Herz	German
Cuore	Italian
Puso	Filipino

FMAID:

7088

DEFINITION:

Organ with cavitated organ parts, which is continuous with the systemic and pulmonary arterial and venous trees. Examples: There is only one heart.

Unified Medical Language System



◆ SPECIALIST Lexicon

- 650,000 lexical items
- Part of speech and variant information

◆ Metathesaurus

- ~10M names from over 100 terminologies
- ~3M concepts
- >10M relations

◆ Semantic Network

- 133 high-level categories
- 7000 relations among them

Lexical
resources

LVG / Norm

Terminological
resources

MetaMap

Ontological
resources

SemRep



Lexical resources

SPECIALIST Lexicon and lexical tools



Lexical Systems Group

<http://umlslex.nlm.nih.gov/>

SPECIALIST Lexicon

- ◆ Content
 - English lexicon
 - Many words from the biomedical domain
- ◆ 650,000 lexical items
- ◆ Word properties
 - morphology
 - orthography
 - syntax
- ◆ Used by the lexical tools



Morphology

◆ Inflection

- noun nucleus, nuclei
- verb cauterize, cauterizes, cauterized, cauterizing
- adjective red, redder, reddest

◆ Derivation

- verb ↔ noun cauterize -- cauterization
- adjective ↔ noun red -- redness



Orthography

◆ Spelling variants

- oe/e oesophagus - esophagus
- ae/e anaemia - anemia
- ise/ize cauterise - cauterize
- genitive mark Addison's disease
Addison disease
Addisons disease



Syntax

◆ Complementation

- verbs

- intransitive I'll treat.
- transitive He treated the patient.
- ditransitive He treated the patient with a drug.

- nouns

- prepositional phrase

Valve of coronary sinus

◆ Position for adjectives



SPECIALIST Lexicon record

```
{  
  base=hemoglobin      (base form)  
  spelling_variant=haemoglobin  
  entry=E0031208      (identifier)  
  cat=noun            (part of speech)  
  variants=uncount    (no plural)  
  variants=reg        (plural: hemoglobins, hemoglobins)  
}
```

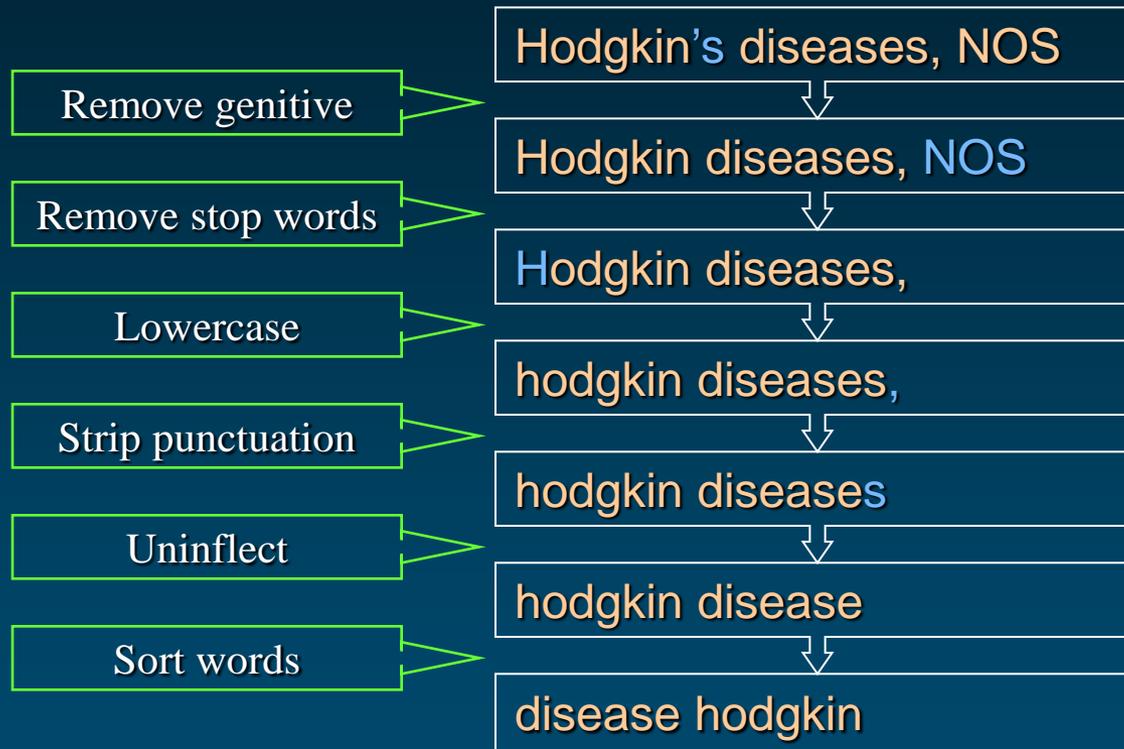


Lexical tools

- ◆ To manage lexical variation in biomedical terminologies
- ◆ Major tools
 - Normalization
 - Indexes
 - Lexical Variant Generation program (lvg)
- ◆ Based on the SPECIALIST Lexicon
- ◆ Used by noun phrase extractors, search engines



Normalization



Normalization: Example

Hodgkin Disease
HODGKINS DISEASE
Hodgkin's Disease
Disease, Hodgkin's
Hodgkin's, disease
HODGKIN'S DISEASE
Hodgkin's disease
Hodgkins Disease
Hodgkin's disease NOS
Hodgkin's disease, NOS
Disease, Hodgkins
Diseases, Hodgkins
Hodgkins Diseases
Hodgkins disease
hodgkin's disease
Disease, Hodgkin

normalize

disease hodgkin



Normalization Applications

- ◆ Model for lexical resemblance
- ◆ Help find lexical variants for a term
 - Terms that normalize the same usually share the same LUI
- ◆ Help find candidates to synonymy among terms
- ◆ Help map input terms to UMLS concepts



Indexes

- ◆ Word index
 - word to Metathesaurus strings
 - one word index per language
- ◆ Normalized word index
 - normalized word to Metathesaurus strings
 - English only
- ◆ Normalized string index
 - normalized term to Metathesaurus strings
 - English only



Lexical Variant Generation program

- ◆ Tool for specialists (linguists)
- ◆ Performs atomic lexical transformations
 - generating inflectional variants
 - lowercase
 - ...
- ◆ Performs sequences of atomic transformations
 - a specialized sequence of transformations provides the normalized form of a term (the *norm* program)

Related NLM tools



Lexical Systems Group

<http://umlslex.nlm.nih.gov/>

Public Projects

- ◆ [SPECIALIST Lexicon](#)
- ◆ [LexAccess](#)
- ◆ [Lexical Tools](#)
- ◆ [Text Tools](#)
- ◆ [Text Categorization](#)
- ◆ [GSpell](#)
- ◆ [dTagger](#)

The SPECIALIST Text Tools includes tokenizers that analyze text into word, term, phrase, sentence and section pieces. The tools also include a variant lookup module that retrieves variant ways of expressing the phrases found in the text. The tools are intended to analyze documents into instances of document objects.

The tools are written in Java. These tools include the following:

- ◆ [a word/Sentence/section Tokenizer](#)
- ◆ [a term tokenizer](#)
- ◆ [a phrase tokenizer](#)
- ◆ [a term variant lookup](#)
- ◆ [a part-of-speech tagger \(client\)](#)
- ◆ [a document index maker](#)
- ◆ [a tool to create the textTool indexes](#)

The SPECIALIST spelling resources include two programs GSpell a spelling suggestion tool and BagOWordsPlus a phrase retrieval tool.

GSpell uses several word similarity algorithms to suggest correct spellings for misspelled words. Unlike other spelling suggestion programs GSpell treats space as it would any other letter so that GSpell can correct errors in word compounding. GSpell also be used in word similarity tasks that do not involve misspelling.

BagOWordsPlus uses the word similarity algorithms of GSpell to perform word similarity based phrase level information retrieval.

The dTagger is a Part of Speech (POS) tagger. A POS tagger assigns part of speech tags such as noun, adjective, adverb to sentences. Such tag assignments are a needed component to determining phrase boundaries and head assignment. The dTagger includes the following features: It can tokenize text into single or multi-word terms. It is built specifically for use with the SPECIALIST Lexicon. A default trained model is included, trained on a set of annotated MEDLINE abstracts in the genomics field, (the MedPost corpus). The trainer and updater programs are included to allow the creation of new trained models. Models can be updated with lots of untagged text. Can be trained with just untagged text, if need be. The dTagger is an open source resource and is freely available subject to these [terms and conditions](#).



Lexical resources

Other resources

Need for additional resources

- ◆ More generic
 - WordNet
- ◆ More specific
 - Lexical items specific to specialized subdomains
 - Not listed in biolexicons
 - Not amenable to normalization
 - Examples
 - Genes, proteins
 - MAPK3 / Mapk3 / mapk3
 - Chemicals
 - 5'-3' exonuclease / 3'-5' exonuclease
 - Drugs
 - Acronyms



Gene and protein names

◆ Additional resources

HGNC	http://www.genenames.org/
Entrez Gene	http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=gene
UniProt	http://www.ebi.uniprot.org/index.shtml

◆ Additional identification methods

- e.g., ABGene (Tanabe & Wilbur, NCBI)
- BioCreAtIvE
 - Gene mention identification
 - Gene normalization



Chemical names

◆ Additional resources

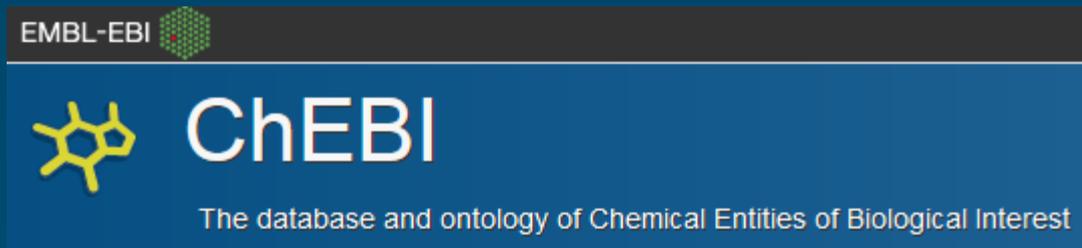
PubChem	http://pubchem.ncbi.nlm.nih.gov/
ChemIDplus	http://chem.sis.nlm.nih.gov/chemidplus/chemidlite.jsp
ChEBI	http://www.ebi.ac.uk/chebi/



The screenshot shows the PubChem homepage. At the top is the PubChem logo. Below it are three navigation buttons: BioAssay, Compound, and Substance. A search bar is located at the bottom with a 'Go' button and a link to 'Advanced Search'.



The screenshot shows the ChemIDplus website. It features the NIH U.S. National Library of Medicine logo and the TOXNET TOXICOLOGY DATA NETWORK logo. Navigation links include TOXNET Home, ChemIDplus Lite, Browse ChemIDplus, and ChemIDplus Advanced. A 3D ball-and-stick molecular model is displayed next to the ChemIDplus logo, which is described as 'A TOXNET DATABASE'.



The screenshot shows the ChEBI website. It features the EMBL-EBI logo at the top left. The ChEBI logo is prominently displayed in the center, with the text 'The database and ontology of Chemical Entities of Biological Interest' below it.



Drug names

- ◆ Covered by UMLS
- ◆ Specialized resource: RxNorm
 - Branded names / generic names
 - Various levels of aggregation
 - Ingredient
 - Ingredient + dose
 - Ingredient + form
 - Ingredient + dose + form
 - Codes in various reference systems
- ◆ Mostly US drugs, no “over-the-counter” drugs



Acronyms

◆ Many resources available

- AcroMine

<http://www.nactem.ac.uk/software/acromine/>

- Stanford Biomedical Abbreviation Server

<http://www.medlingmap.org/taxonomy/term/120>

- AcroMed

<http://www.medstract.org/>

- SaRAD

<http://www.hpl.hp.com/research/idl/projects/abbrev.html>



Terminological resources

UMLS Metathesaurus



<http://www.nlm.nih.gov/research/umls/>

Source Vocabularies

(2014AA)

- ◆ 139 families of source vocabularies
 - Not counting translations
- ◆ 21 languages
- ◆ Broad coverage of biomedicine
 - 8.6M names (normalized)
 - ~3M concepts
 - >10M relations
- ◆ Common presentation



Biomedical terminologies

◆ General vocabularies

- anatomy (FMA, Neuronames)
- drugs (RxNorm, ATC, First DataBank, Micromedex)
- medical devices (UMD, SPN)

◆ Several perspectives

- clinical terms (SNOMED CT)
- information sciences (MeSH)
- administrative terminologies (ICD-9/10-CM, CPT-4)
- data exchange terminologies (HL7, LOINC)



Biomedical terminologies (cont'd)

- ◆ Specialized vocabularies
 - nursing (NIC, NOC, NANDA, Omaha, ICNP)
 - dentistry (CDT)
 - oncology (PDQ)
 - psychiatry (DSM, APA)
 - adverse reactions (MedDRA, WHO ART)
 - primary care (ICPC)
- ◆ Terminology of knowledge bases (AI/Rheum, DXplain, QMR)



Organize terms

- ◆ Synonymous terms clustered into a concept
- ◆ Preferred term
- ◆ Unique identifier (CUI)

Addison Disease	MeSH	D000224
Primary hypoadrenalism	MedDRA	10036696
Primary adrenocortical insufficiency	ICD-10	E27.1
Addison's disease (disorder)	SNOMED CT	363732003

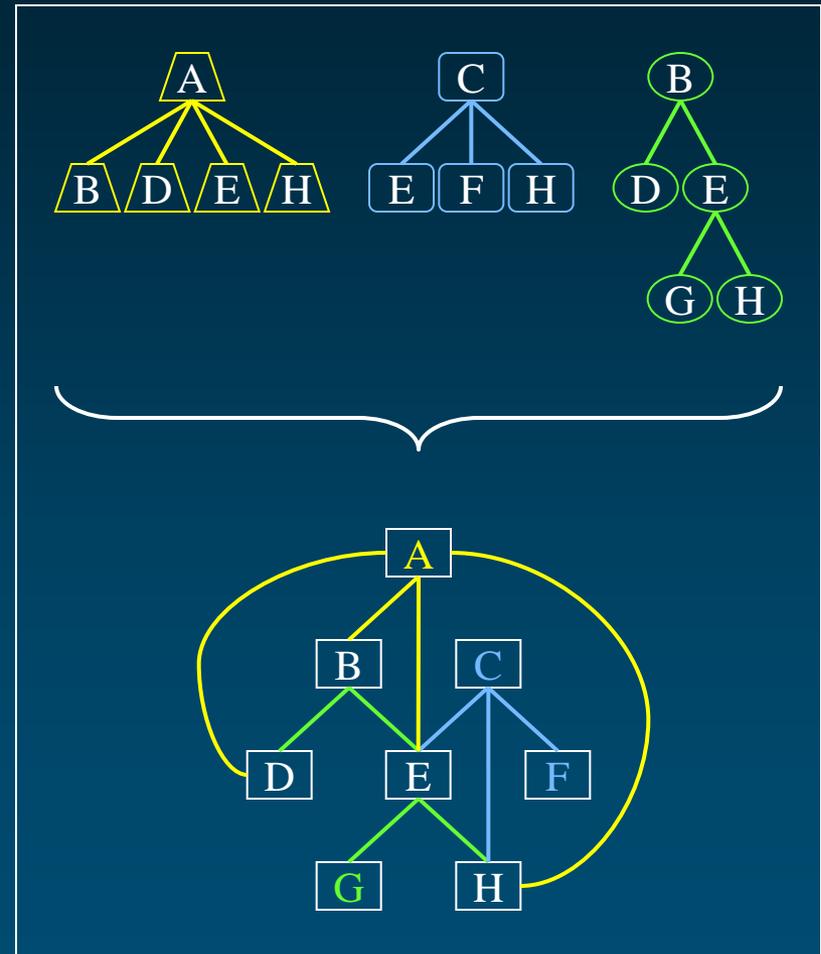
C0001403

Addison's disease

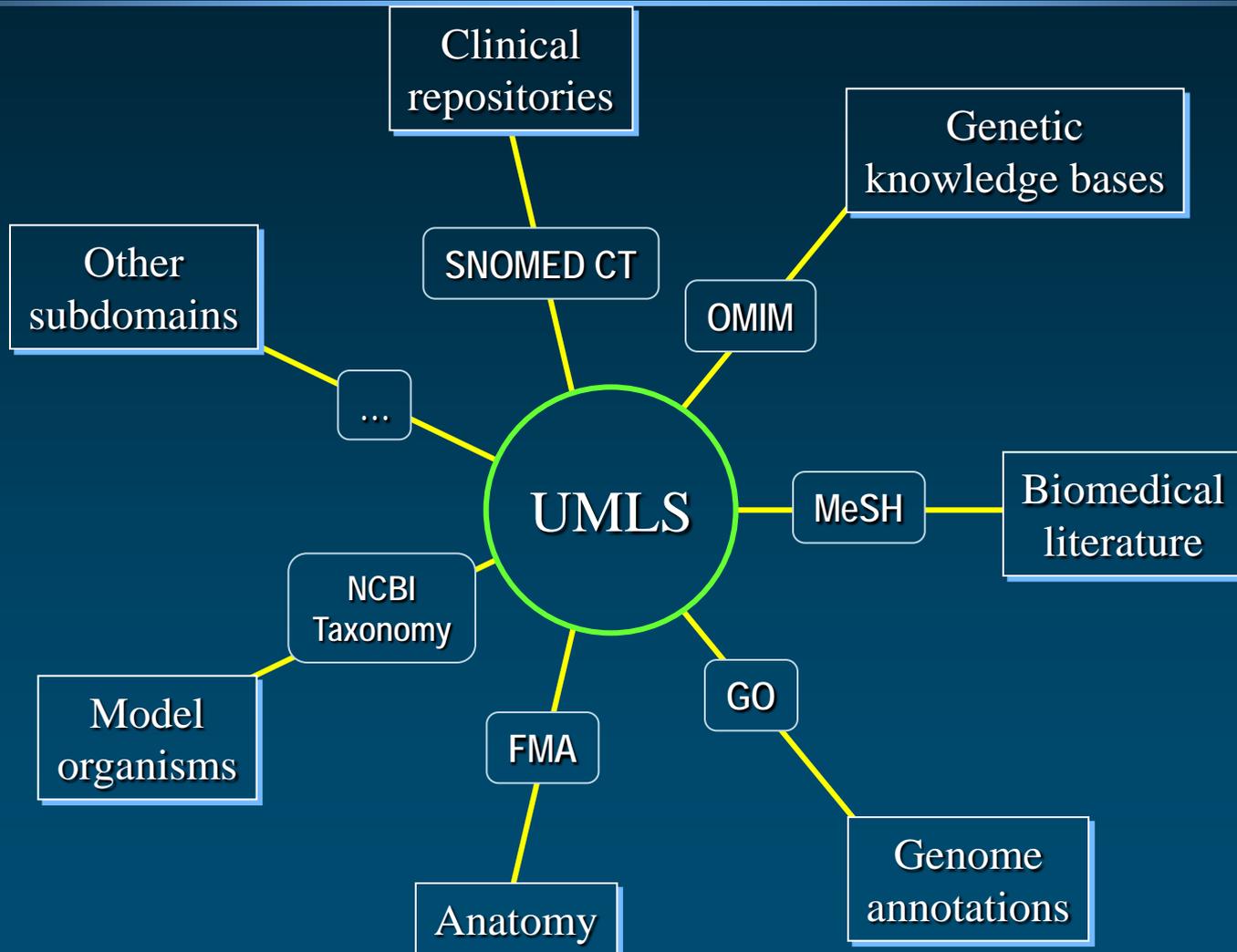


Organize concepts

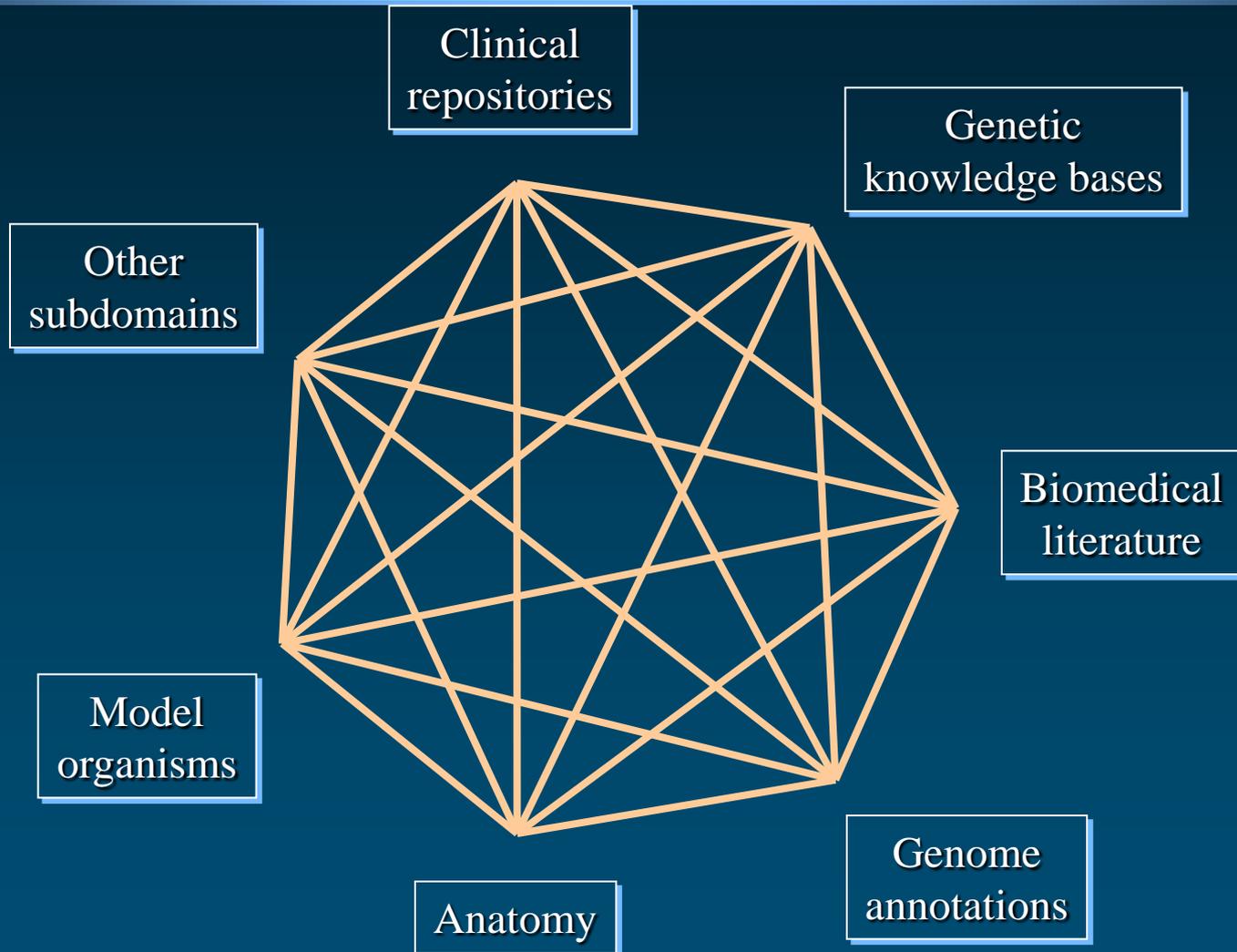
- ◆ Inter-concept relationships: hierarchies from the source vocabularies
- ◆ Redundancy: multiple paths
- ◆ One graph instead of multiple trees (multiple inheritance)



Integrating subdomains



Integrating subdomains



Entity mention vs. resolution

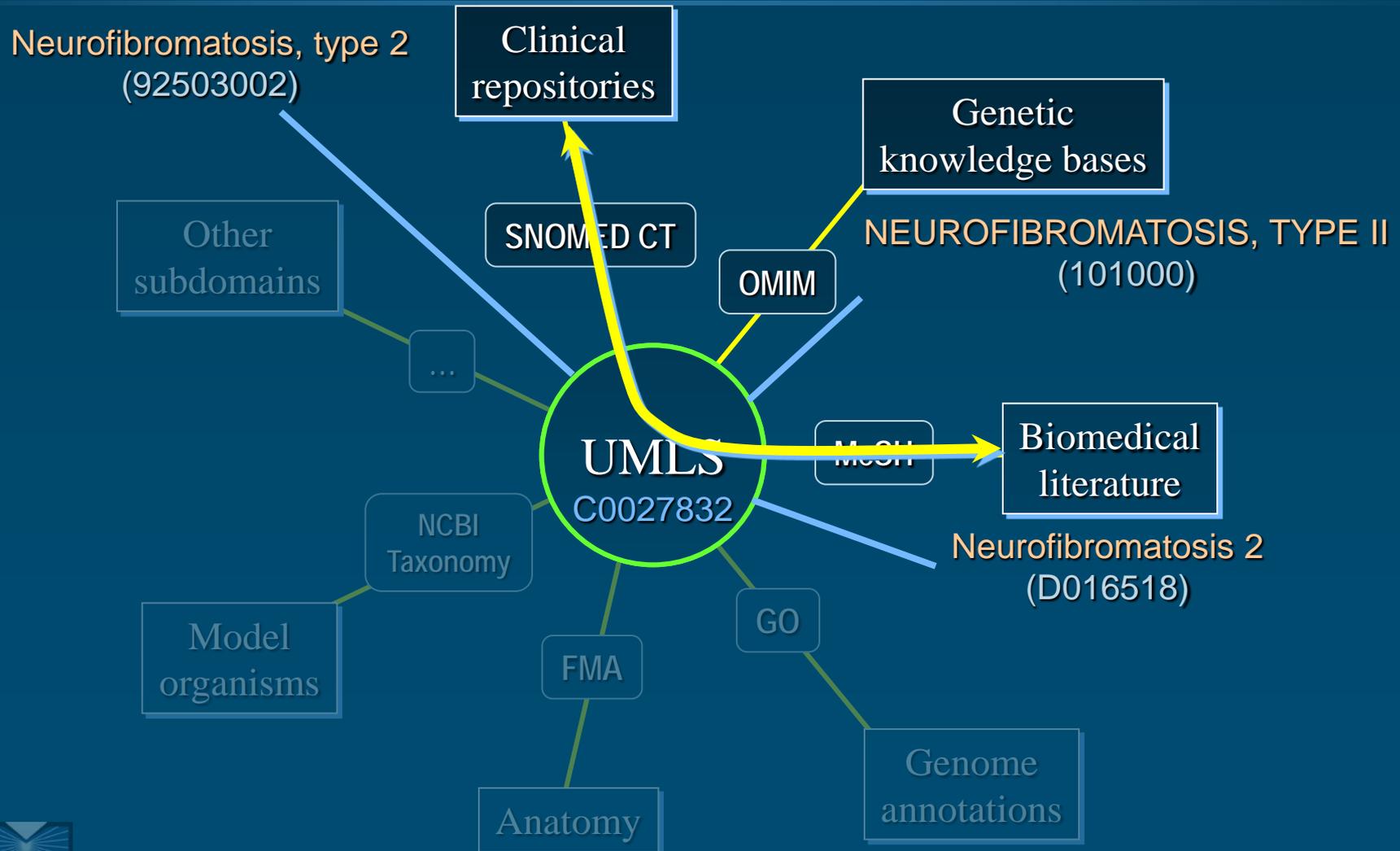
Neurofibromatosis type 2 (NF2) is often not recognised as a distinct entity from peripheral neurofibromatosis. NF2 is a predominantly intracranial condition whose hallmark is bilateral vestibular schwannomas. NF2 results from a mutation in the gene named merlin, located on chromosome 22.

UMLS:C0027832
MeSH:D016518
SNOMEDCT:92503002
OMIM:101000

UMLS:C0254123
EG:4771
HGNC:7773
UniProt:P35240



Trans-namespace resolution (1)



Trans-namespace resolution (2)

Source: Multum
[generic drug]

Nizoral, 200 mg oral tablet
(MMSL:2140)

RxNorm

Ketoconazole 200 MG Oral Tablet [Nizoral]
(RxNorm:201896)

Nizoral
(RxNorm:202692)

tradename of

has ingredient

tradename of

Ketoconazole 200 MG Oral Tablet
(RxNorm:197853)

Ketoconazole
(RxNorm:6135)

Target: Medi-Span
[generic drug]

Ketoconazole Tab 200 MG
(MDDB:13317)



<http://rxnav.nlm.nih.gov/>



Terminological resources

MetaMap

INDEXING INITIATIVE

<http://ii.nlm.nih.gov/>

MetaMap

- ◆ UMLS-based entity recognition system
 - Linguistically motivated
 - Exploits both the SPECIALIST lexicon and Metathesaurus
- ◆ In practice, used to identify UMLS concepts in biomedical text
- ◆ Freely available (UMLS license)
- ◆ Two versions
 - Web-based
 - Standalone (MMTx)



MetaMap Example

Neurofibromatosis type 2 (NF2) is often not recognised as a distinct entity from peripheral neurofibromatosis. NF2 is a predominantly intracranial condition whose hallmark is bilateral vestibular schwannomas. NF2 results from a mutation in the gene named merlin, located on chromosome 22.

C0254123

Neurofibromin 2	MeSH
Merlin	SNOMED CT
Schwannomin	MeSH
Schwannomerlin	NCI Thesaurus



Terminological resources

Other resources

TerMine (C-value) analysis

[Service
questionnaire](#)

Found 5 terms in 2.2 seconds - all terms ([in table](#)) ([in text](#)) - threshold:

Neurofibromatosis type 2 (**NF2**) is often not recognised as a distinct entity from peripheral neurofibromatosis. NF2 is a predominantly intracranial condition whose hallmark is bilateral vestibular schwannomas. NF2 results from a mutation in the gene named merlin , located on chromosome 22.

Thank you for using TerMine. Please now complete a [questionnaire](#) to let us know your views about this service.

Other NER systems DocProWI (Beta)

Neurofibromatosis type 2 (NF2) is often not recognised as a distinct entity from peripheral neurofibromatosis. NF2 is a predominantly intracranial condition whose hallmark is bilateral vestibular schwannomas. NF2 results from a mutation in the gene named merlin, located on chromosome 22.

NLP BIO Clean

Gene OntologyEntry

Other NER systems Whatizit

The logo for Whatizit, with the word 'Whatizit' in a stylized font where 'What' is blue and 'izit' is red.

3

Select a pipeline:

whatizitEBIMedDiseaseChemicals

Resulting tagged text

Neurofibromatosis type 2 (NF2) is often not recognised as a distinct entity from peripheral neurofibromatosis . NF2 is a predominantly intracranial condition whose hallmark is bilateral vestibular schwannomas . NF2 results from a mutation in the gene named merlin, located on chromosome 22 .

Other NER systems NCBO Annotator

 BioPortal [Browse](#) [Search](#) [Mappings](#) [Recommender](#) [Annotator](#) [Resource Index](#) [Projects](#)

Annotator

Get annotations for biomedical text with concepts from the ontologies [?](#)

[insert sample text](#)

Neurofibromatosis type 2 (NF2) is often not recognised as a distinct entity from peripheral neurofibromatosis. NF2 is a predominantly intracranial condition whose hallmark is bilateral vestibular schwannomas. NF2 results from a mutation in the gene named merlin, located on chromosome 22.

Select Ontologies

[clear selection](#) [select from list](#)

Select UMLS Semantic Types

Match longest only

Include Manual Mappings

Include Ancestors Up To Level:

[Get Annotations](#)

Annotations

total results 14 (direct 14 / ancestor 0 / mapping 0)

CLASS filter	ONTOLOGY filter	TYPE filter	CONTEXT	MATCHED CLASS filter	MATCHED ONTOLOGY filter
neurofibromatosis type 2 (NF2)	Physician Data Query	direct	Neurofibromatosis type 2 (NF2) is often not ...	neurofibromatosis type 2 (NF2)	Physician Data Query
Entity	Situation-Based Access Control Ontology	direct	... a distinct entity from peripheral neurofibromatosis. ...	Entity	Situation-Based Access Control Ontology
Neurofibromatosis Type 2	National Cancer Institute Thesaurus	direct	... peripheral neurofibromatosis. NF2 is a predominantly ...	Neurofibromatosis Type 2	National Cancer Institute Thesaurus
Neurofibromatosis Type 2	National Cancer Institute Thesaurus	direct	... vestibular schwannomas. NF2 results from a ...	Neurofibromatosis Type 2	National Cancer Institute Thesaurus
Is a	Systematized Nomenclature of Medicine - Clinical Terms	direct	... neurofibromatosis. NF2 is a predominantly intracranial condition ...	Is a	Systematized Nomenclature of Medicine - Clinical Terms
Intracranial	Systematized Nomenclature of Medicine - Clinical Terms	direct	... a predominantly intracranial condition whose hallmark ...	Intracranial	Systematized Nomenclature of Medicine - Clinical Terms
Condition	Neglected Tropical Disease Ontology	direct	... predominantly intracranial condition whose hallmark is ...	Condition	Neglected Tropical Disease Ontology
BILATERAL	Dermatology Lexicon	direct	... hallmark is bilateral vestibular schwannomas. NF2 ...	BILATERAL	Dermatology Lexicon
Neuroma, Acoustic	Medical Subject Headings	direct	... is bilateral vestibular schwannomas . NF2 results from ...	Neuroma, Acoustic	Medical Subject Headings
Results	Ontological Knowledge Base Model for Cystic Fibrosis	direct	... schwannomas. NF2 results from a mutation ...	Results	Ontological Knowledge Base Model for Cystic Fibrosis
Mutation	Logical Observation Identifier Names and Codes	direct	... from a mutation in the gene ...	Mutation	Logical Observation Identifier Names and Codes
gene	Single-Nucleotide Polymorphism (SNP) Ontology	direct	... in the gene named merlin, located ...	gene	Single-Nucleotide Polymorphism (SNP) Ontology
Falco columbarius	Systematized Nomenclature of Medicine, International Version	direct	... gene named merlin , located on chromosome ...	Falco columbarius	Systematized Nomenclature of Medicine, International Version
Chromosome 22	National Cancer Institute Thesaurus	direct	... located on chromosome 22 .	Chromosome 22	National Cancer Institute Thesaurus

Ontological resources

Ontological resources

- ◆ Provide background knowledge
 - For resolving ambiguity in entity recognition
 - Merlin: Protein or Bird?
 - For relation extraction
 - Template relations between high-level concepts
 - Used in combination with clues from linguistic phenomena in text

Ontological resources

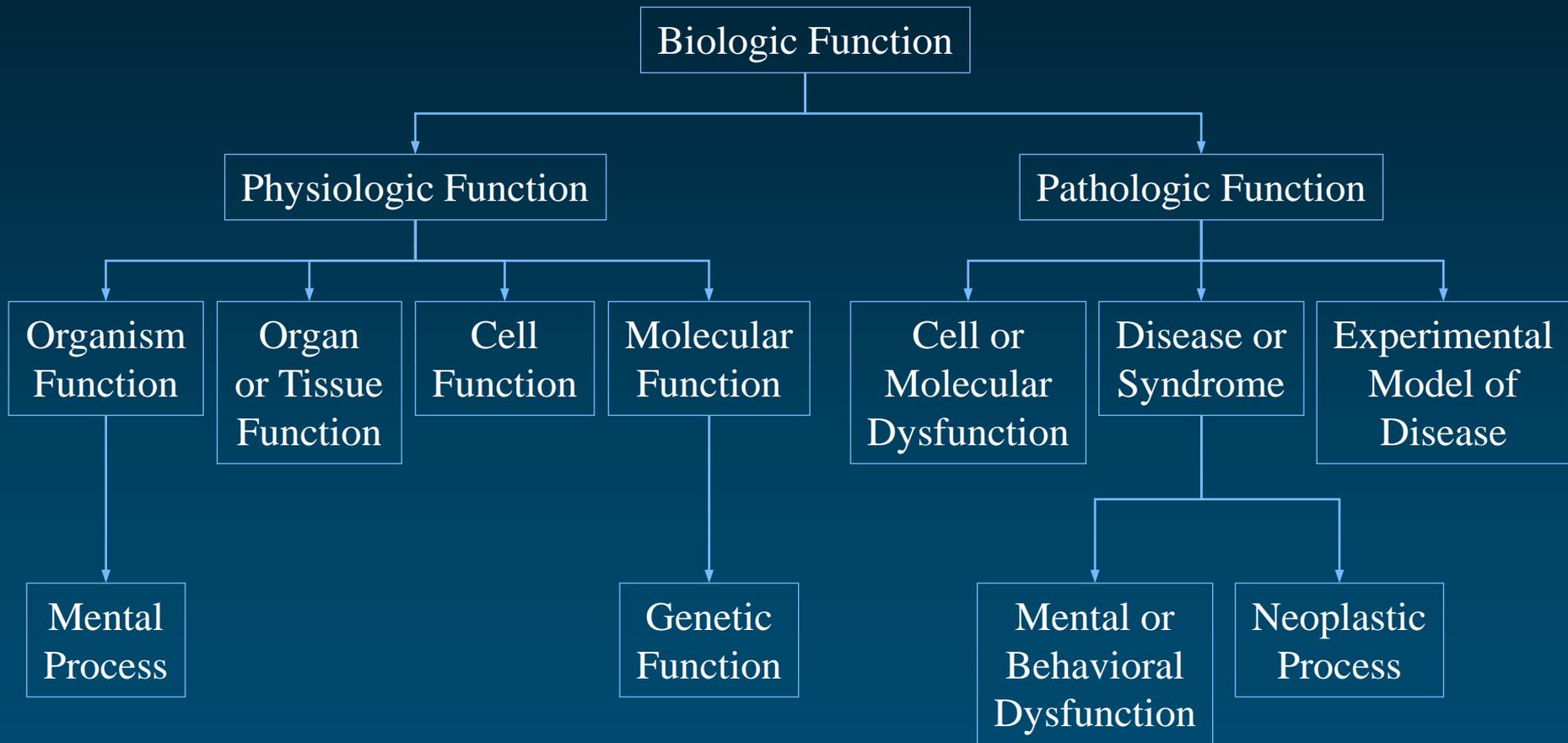
- ◆ Various level of formality
 - Formal top-level ontologies (e.g., BioTop)
 - Informal top-level ontologies (e.g., UMLS Semantic Network)
 - Domain-Range constraints for roles in DL-based terminologies (e.g., SNOMED CT, NCI Thesaurus)
 - Relations in terminologies
- ◆ Various level of granularity
 - UMLS Semantic Network: 133 types
 - Foundational Model of Anatomy: 70,000 classes



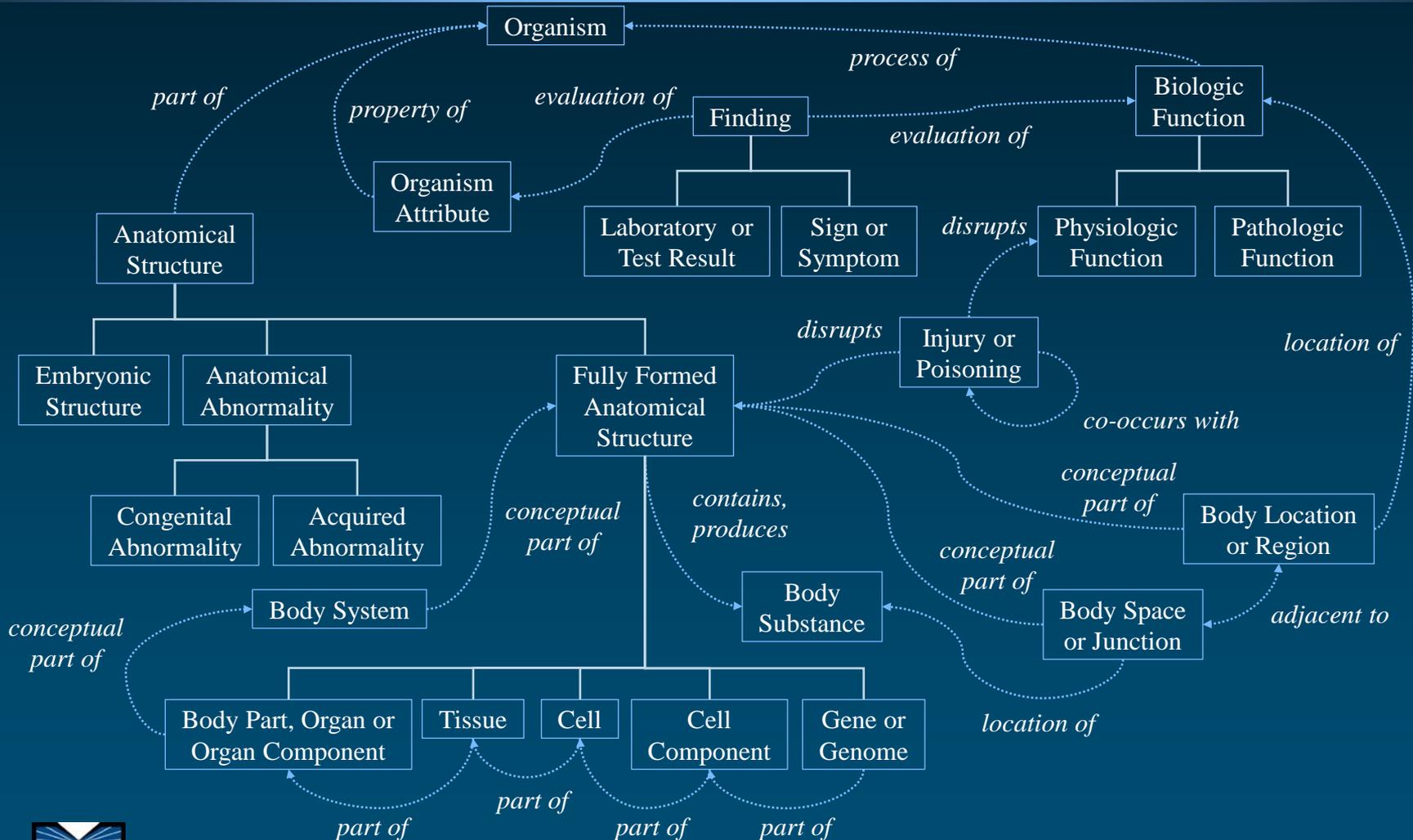
Ontological resources

UMLS Semantic Network

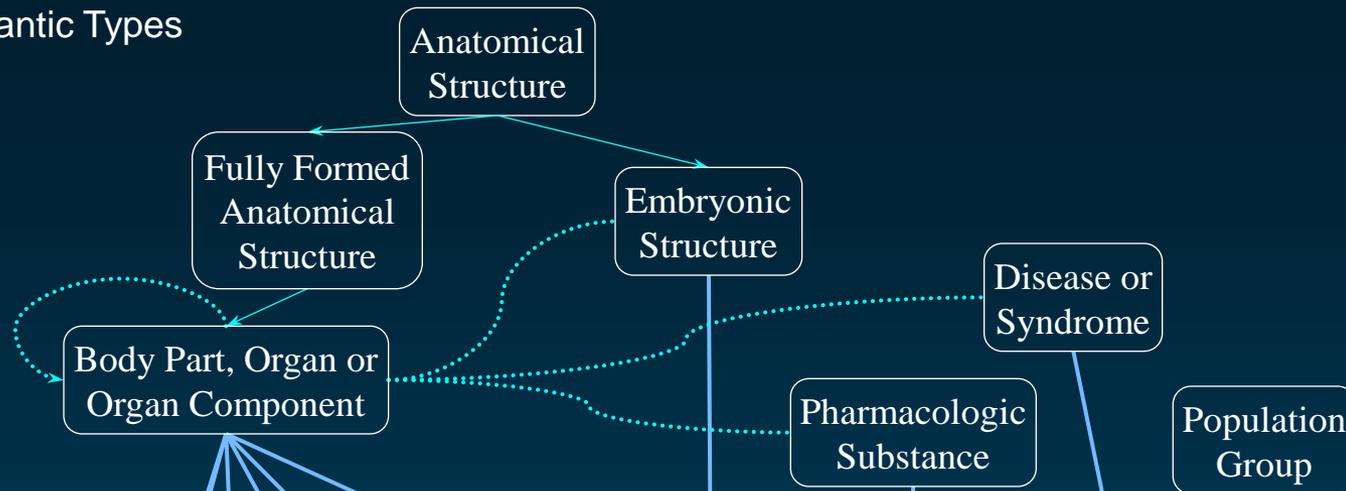
“Biologic Function” hierarchy (isa)



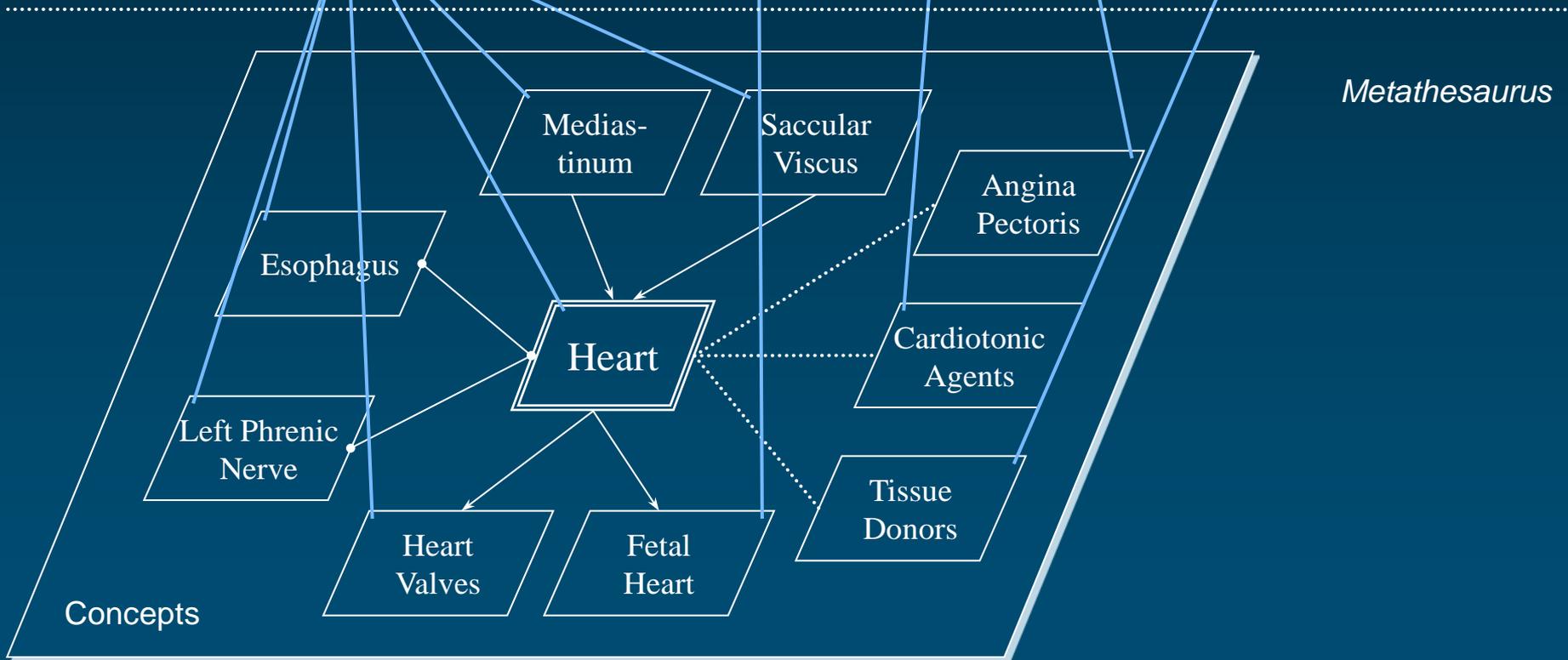
Associative (non-isa) relationships



Semantic Types



Semantic Network



Metathesaurus

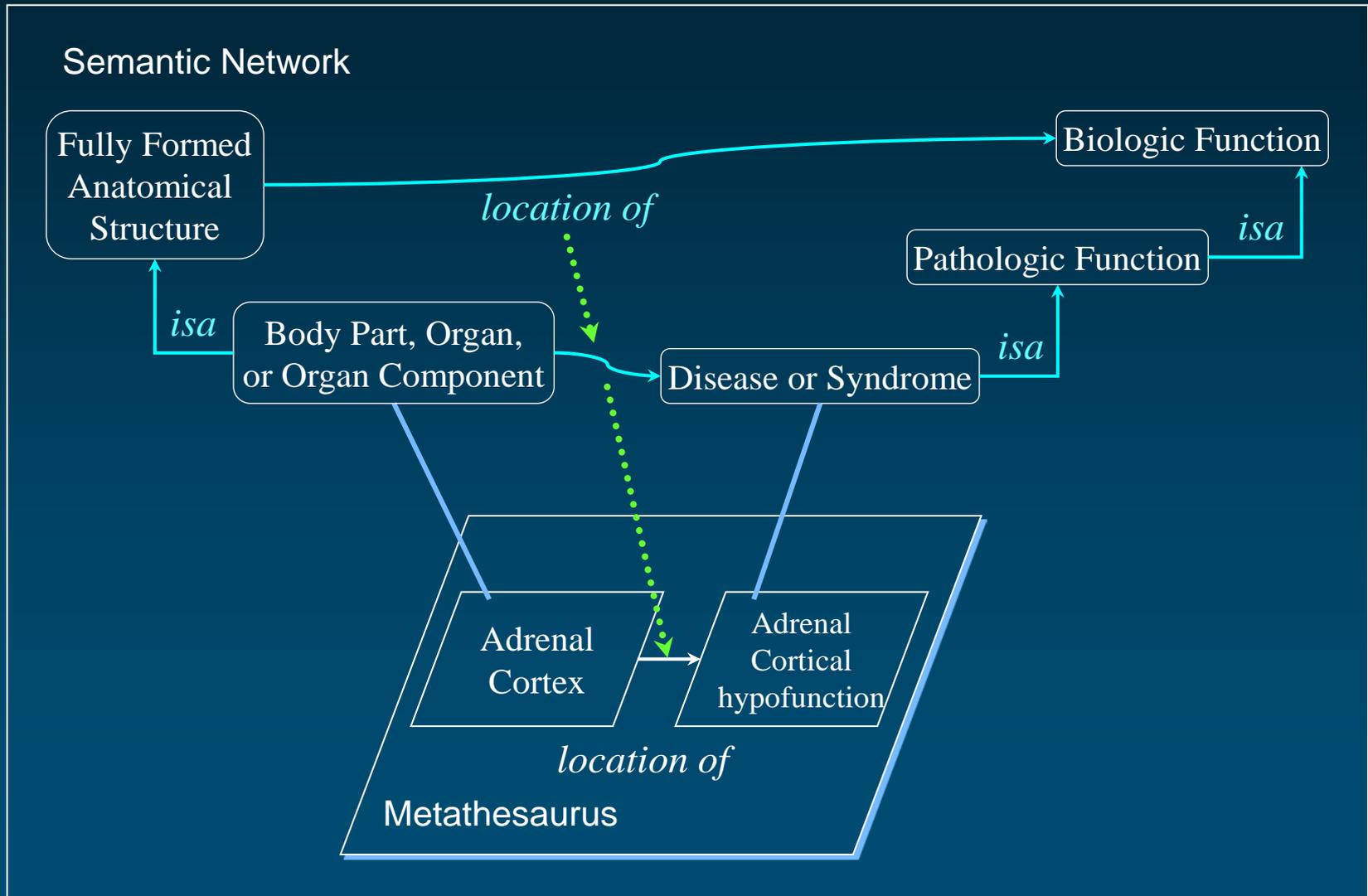
Concepts

Why a semantic network?

- ◆ Semantic Types serve as high level categories assigned to Metathesaurus concepts, *independently of their position in a hierarchy*
- ◆ A relationship between 2 Semantic Types (ST) is a possible link between 2 concepts that have been assigned to those STs
 - The relationship may or may not hold at the concept level
 - Other relationships may apply at the concept level



Relationships *may* inherit semantics

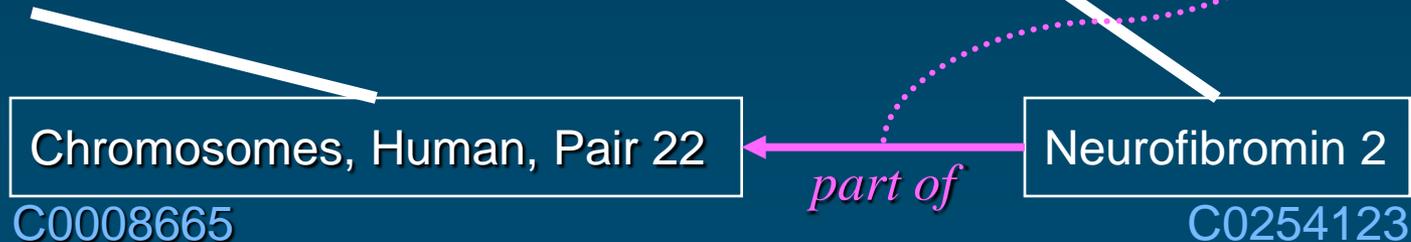


Ontological resources

SemRep

SemRep Relation extraction

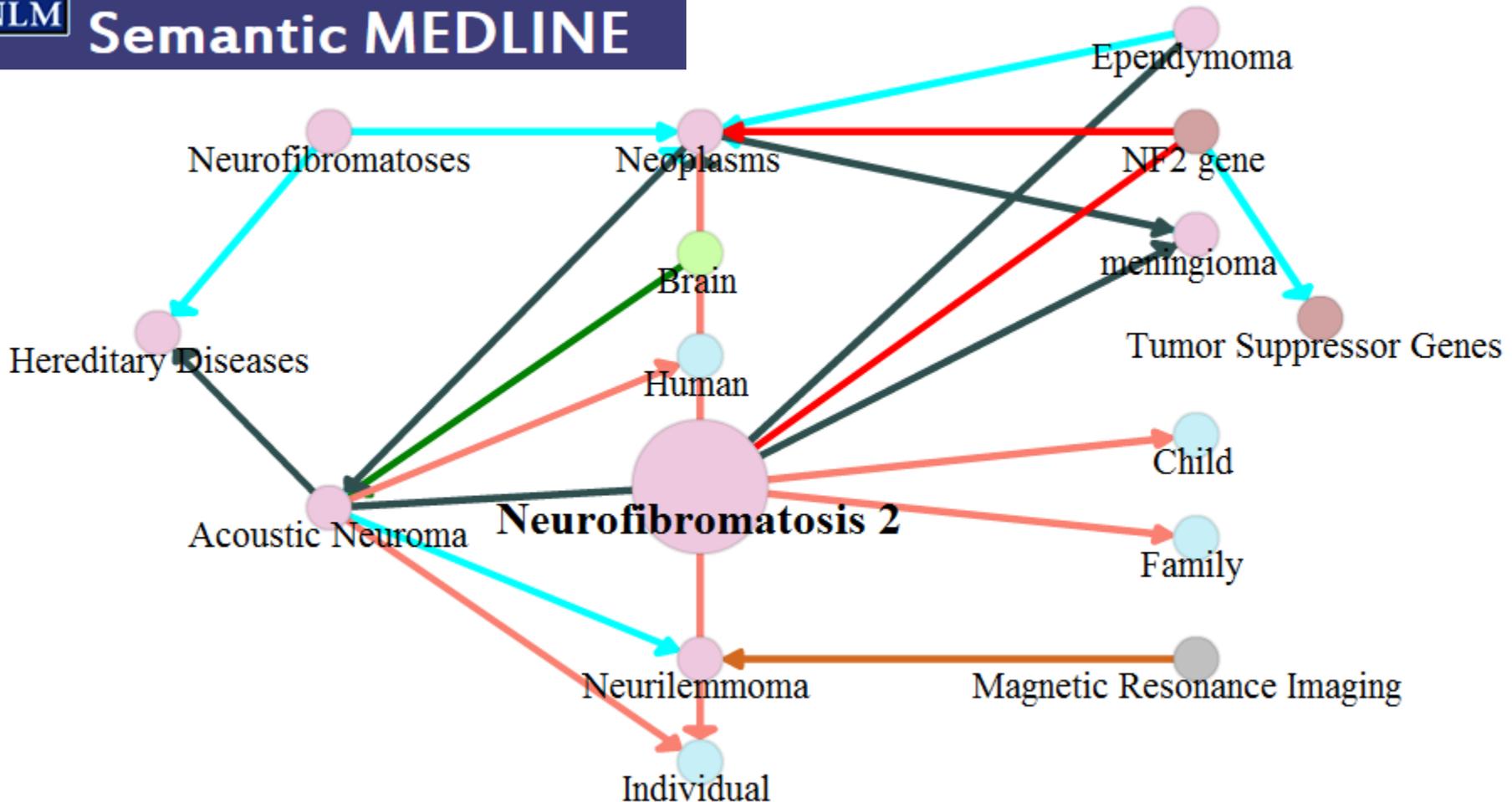
Neurofibromatosis type 2 (NF2) is often not recognised as a distinct entity from peripheral neurofibromatosis. NF2 is a predominantly intracranial condition whose hallmark is bilateral vestibular schwannomas. NF2 results from a mutation in the gene named merlin, located on chromosome 22.



Relation extraction "in action"



Semantic MEDLINE



Ontological resources

Other resources

Other ontological resources

◆ Ontologies

- Top-level ontologies (e.g., BioTop)
- Domain ontologies (e.g., FMA, SNOMED CT, NCI Thesaurus, OBO family of ontologies)

◆ Many information extraction systems available

- Specialized
 - Protein-protein interaction (e.g., Info-PubMed, TextPresso, ...)
 - BioCreAtIvE (task 2)
- More generic (e.g., MedLEE / BioMedLEE)
- Commercial systems (TeSSI, Linguamatics, ...)



Summary

Summary

- ◆ Lexical and terminological resources enable entity recognition
 - Terminological resources enable entity *resolution*
- ◆ Terminological and ontological resources enable relation extraction

But...

- ◆ Text mining techniques can also benefit
 - Specialized lexicons: NER based on machine learning techniques
 - Terminologies: term extraction / computational terminology
 - Ontologies: ontology population



References

- ◆ Bodenreider O.
Lexical, terminological and ontological resources for biological text mining.
In: Ananiadou S, McNaught J, editors. Text mining for biology and biomedicine: Artech House; 2006. p. 43-66.

UMLS References

◆ Recent overviews

- Bodenreider O. (2004). The Unified Medical Language System (UMLS): Integrating biomedical terminology. *Nucleic Acids Research*; D267-D270.
- Nelson, S. J., Powell, T. & Humphreys, B. L. (2002). The Unified Medical Language System (UMLS) Project. In: Kent, Allen; Hall, Carolyn M., editors. *Encyclopedia of Library and Information Science*. New York: Marcel Dekker. p.369-378.



UMLS References

◆ UMLS as a research project

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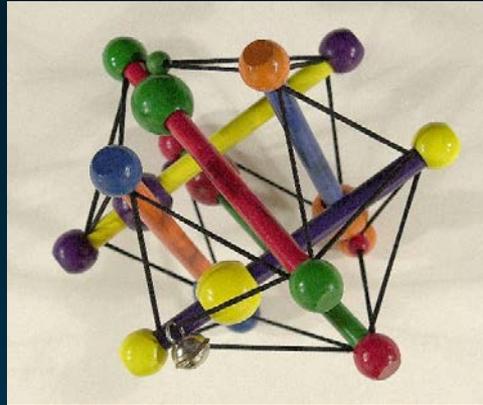


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