



**Weill Cornell  
Medicine**

Weill Cornell Medicine  
Division of Health Informatics  
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*Health Informatics Seminar*

**Aligning biomedical terminologies**  
*From lexical models to supervised learning*

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# Disclaimer

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# Outline

- ◆ Introduction to the UMLS Metathesaurus
- ◆ Lexical model of synonymy
- ◆ Supervised machine learning for synonymy prediction



# Introduction to the UMLS Metathesaurus

# What does UMLS stand for?

- ◆ Unified
- ◆ Medical
- ◆ Language
- ◆ System



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

# Motivation

- ◆ Started in 1986
- ◆ National Library of Medicine

«[...] the UMLS project is an effort to overcome two significant barriers to effective retrieval of machine-readable information.

- The first is **the variety of ways the same concepts are expressed** in different machine-readable sources and by different people.
- The second is the **distribution** of useful information among many disparate databases and systems.»



# UMLS Metathesaurus

(2021AA)

- ◆ 157 families of source vocabularies
  - Not counting 58 translations
- ◆ 25 languages
- ◆ Broad coverage of biomedicine
  - 12.5M names (normalized)
  - ~4.4M concepts
  - >10M relations
- ◆ Common presentation

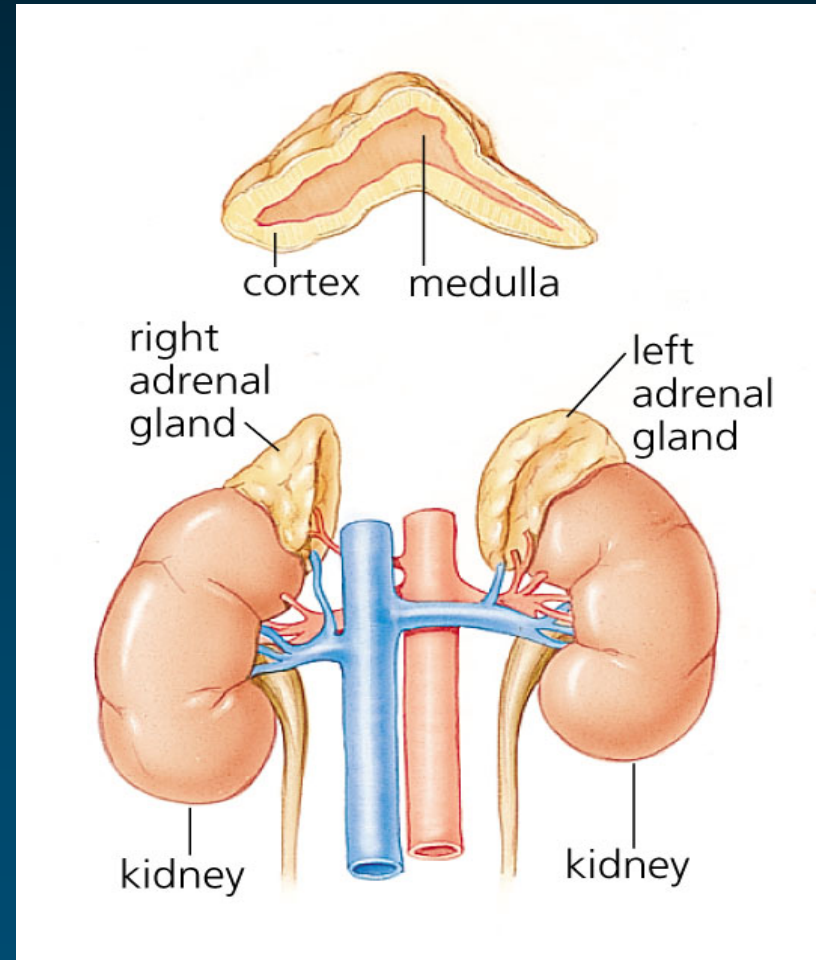
# UMLS Metathesaurus

*Overview through an example*



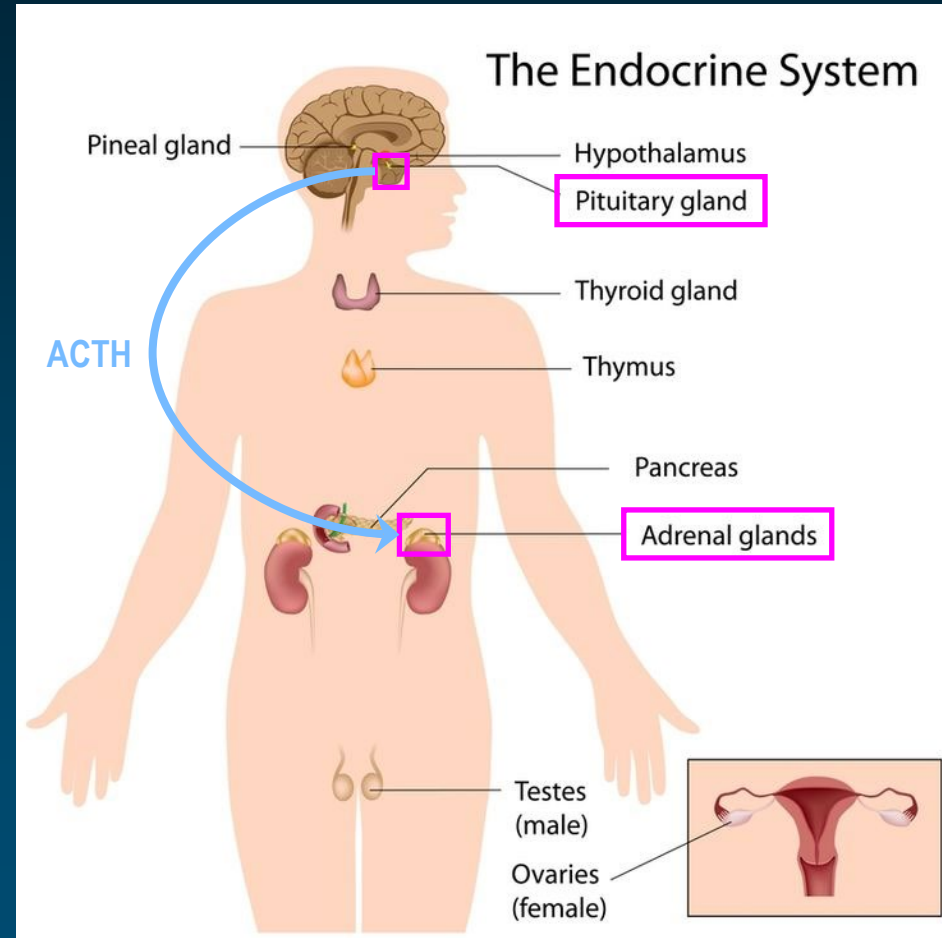
# Addison's disease

- ◆ Addison's disease is a rare endocrine disorder
- ◆ Addison's disease occurs when the adrenal glands do not produce enough of the hormone cortisol
- ◆ For this reason, the disease is sometimes called chronic adrenal insufficiency, or hypocortisolism



# Adrenal insufficiency Clinical variants

- ◆ Primary / Secondary
  - Primary: lesion of the adrenal glands themselves
  - Secondary: inadequate secretion of ACTH by the pituitary gland
- ◆ Acute / Chronic
- ◆ Isolated / Polyendocrine deficiency syndrome



# Addison's disease: Symptoms

- ◆ Fatigue
- ◆ Weakness
- ◆ Low blood pressure
- ◆ Pigmentation of the skin (exposed and non-exposed parts of the body)
- ◆ ...



# AD in medical vocabularies

## ◆ Synonyms: different terms

- Addisonian syndrome
  - Bronzed disease
  - Melasma addisonii
  - Asthenia pigmentosa
  - Primary adrenal deficiency
  - Primary adrenal insufficiency
  - Primary adrenocortical insufficiency
  - Chronic adrenocortical insufficiency
- )} eponym  
)} symptoms  
)} clinical variants

## ◆ Contexts: different hierarchies

# 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

# Metathesaurus Concepts (2020AA)

- ◆ Concept (4.3M) CUI
  - Set of synonymous concept names
- ◆ Term (12.1M) LUI
  - Set of normalized names
- ◆ String (13.2M) SUI
  - Distinct concept name
- ◆ Atom (15.5M) AUI
  - Concept name in a given source

A0066000	Headache	(MeSH)
A0065992	Headache	(ICD-10)
<b>S0046854</b>		

A0066007	Headaches	(MedDRA)
A12003304	Headaches	(OMIM)
<b>S0046855</b>		

**L0018681**

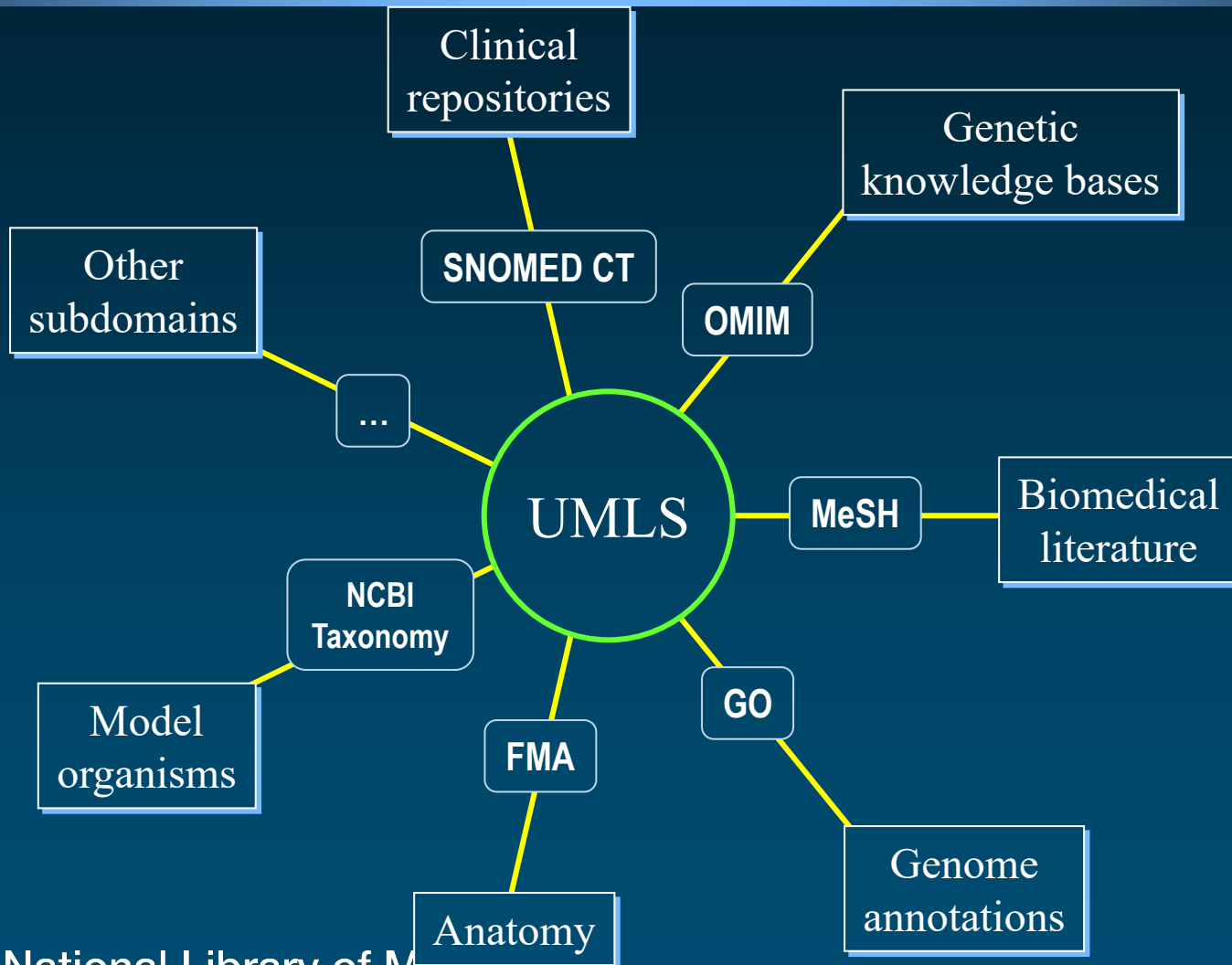
A0540936	Cephalodynia	(MeSH)
<b>S0475647</b>		

**L0380797**

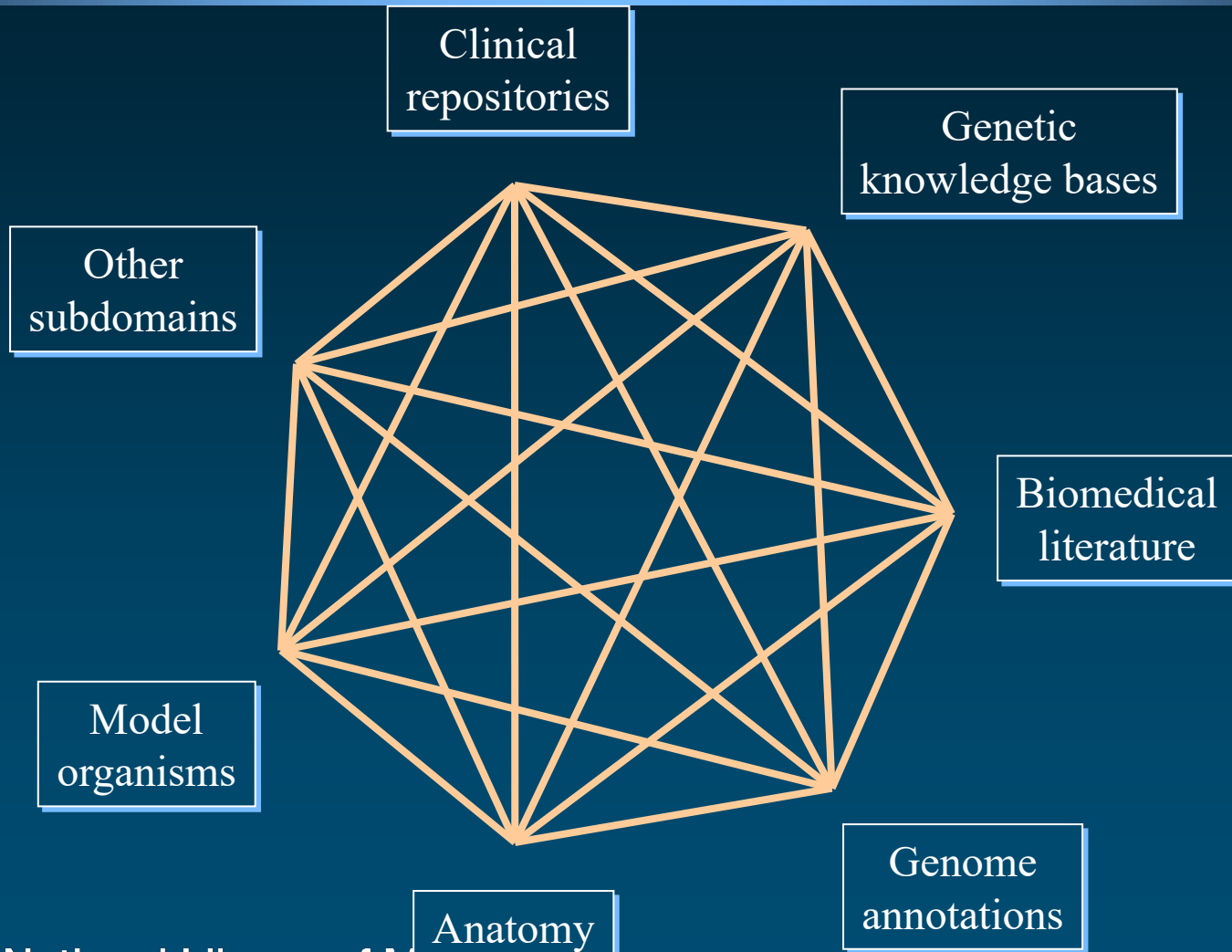
**C0018681**



# Integrating subdomains

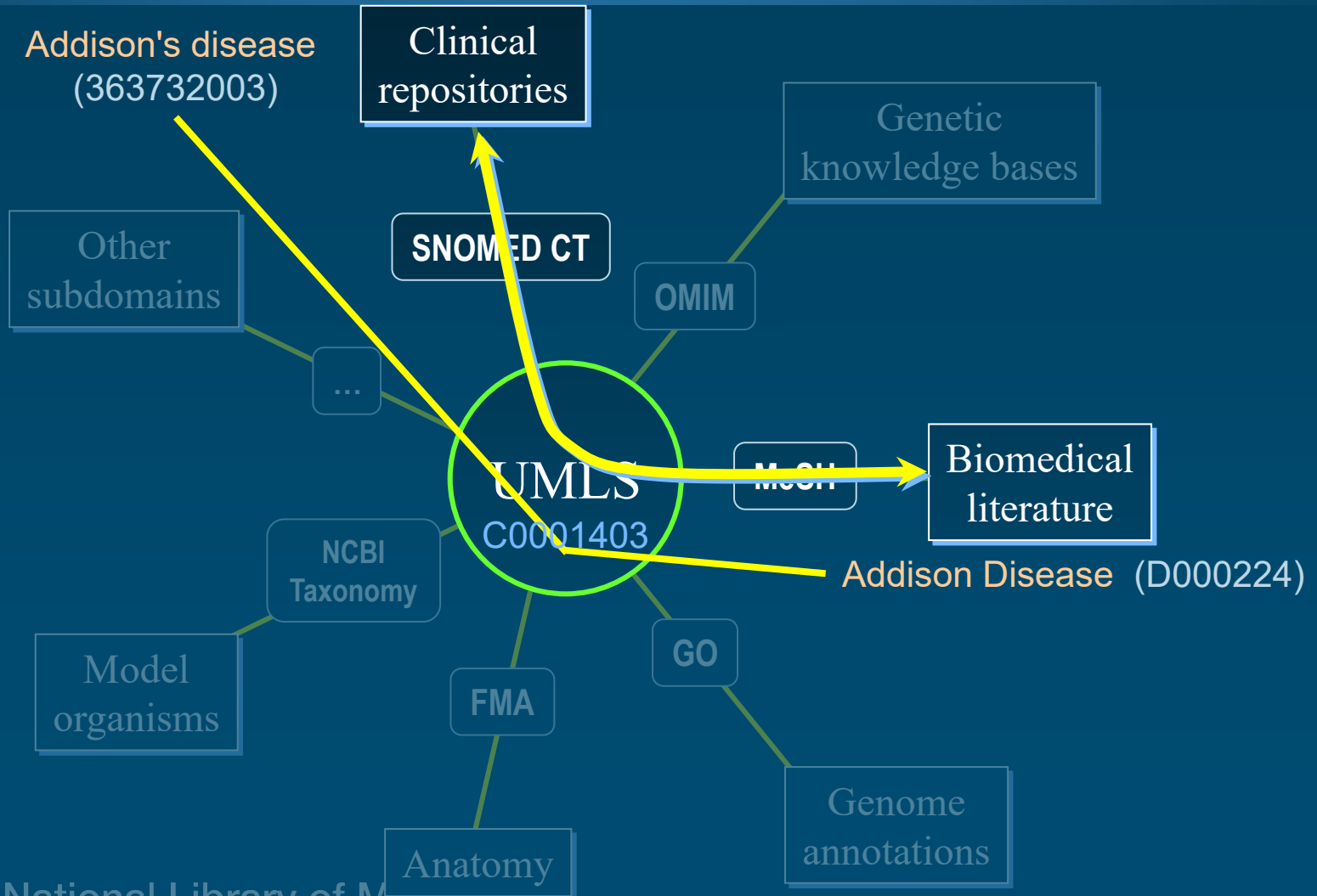


# Integrating subdomains





# Trans-namespace integration



# Lexical model of synonymy

# From lexical features to synonymy

Adrenal gland diseases

Adrenal disorder

Disorder of adrenal gland

Diseases of the adrenal glands

C0001621



# Lexical resources

*SPECIALIST Lexicon  
and lexical tools*

<https://lhncbc.nlm.nih.gov/LSG/index.html>

# SPECIALIST Lexicon

- ◆ Content
  - English lexicon
  - Many words from the biomedical domain
- ◆ Over 500,000 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

# 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)  
}
```



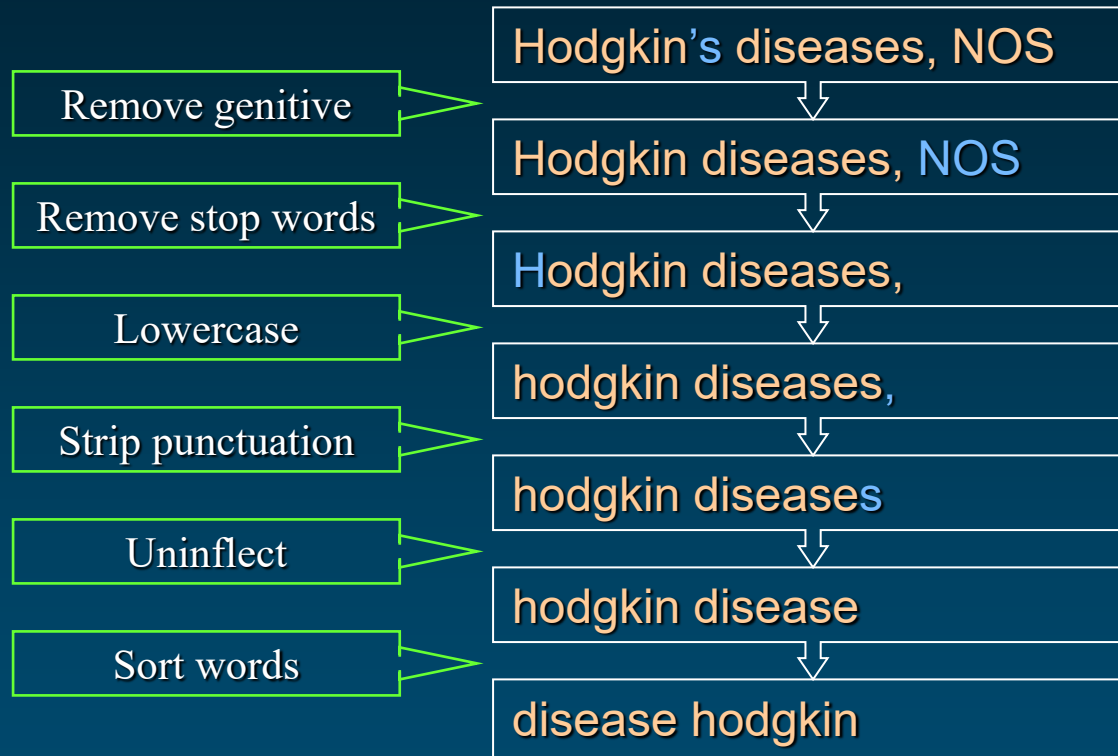


# Lexical tools

- ◆ 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



# Principles for asserting synonymy in the UMLS Metathesaurus

- ◆ Lexical similarity is used to identify candidates for synonymy
  - Atoms that do not share a common semantics are prevented from being recognized as synonymous and grouped into the same concept
- ◆ Synonymy asserted between atoms in a source vocabulary tends to be conserved in the Metathesaurus

# Example

String	Source	SCUI	AUI	LUI
Headache	MSH	M0009824	A0066000	L0018681
Headaches	MSH	M0009824	A0066008	L0018681
Cranial Pains	MSH	M0009824	A1641924	L1406212
Cephalodynia	MSH	M0009824	A26628141	L0380797
Cephalodynia	SNOMEDCT_US	25064002	A2957278	L0380797
Headache (finding)	SNOMEDCT_US	25064002	A3487586	L3063036

# Metathesaurus building process

- ◆ All terms from source vocabularies are processed
  - Terms that have the same normalized form are candidates for synonymy
    - Unless they bear different semantics
  - Synonymy indicated by source vocabularies tends to be preserved
- ◆ All candidates (from normalization or sources) are reviewed manually
- ◆ Synonyms are assigned the same CUI
- ◆ Labor-intensive and error-prone

# Supervised machine learning for synonymy prediction



# Intuition

- ◆ Large collection of synonymy assertions in Metathesaurus can be used for supervised learning
  - Positive examples: terms from the same concept
  - Negative examples: terms from different concepts
- ◆ Possible features
  - Lexical (words in a term)
  - Semantic (semantics of the source)
  - Relations to other terms

# Synonymy function

Addison Disease  
Primary hypoadrenalism  
Primary adrenocortical insufficiency  
Addison's disease (disorder)  
[...]

C0001403

Hodgkin Disease  
Granuloma, Malignant  
Hodgkin lymphoma  
Malignant lymphoma, Hodgkin's  
[...]

C0019829

$\text{syn}(\text{"Addison Disease"}, \text{"Primary hypoadrenalism"}) = 1$

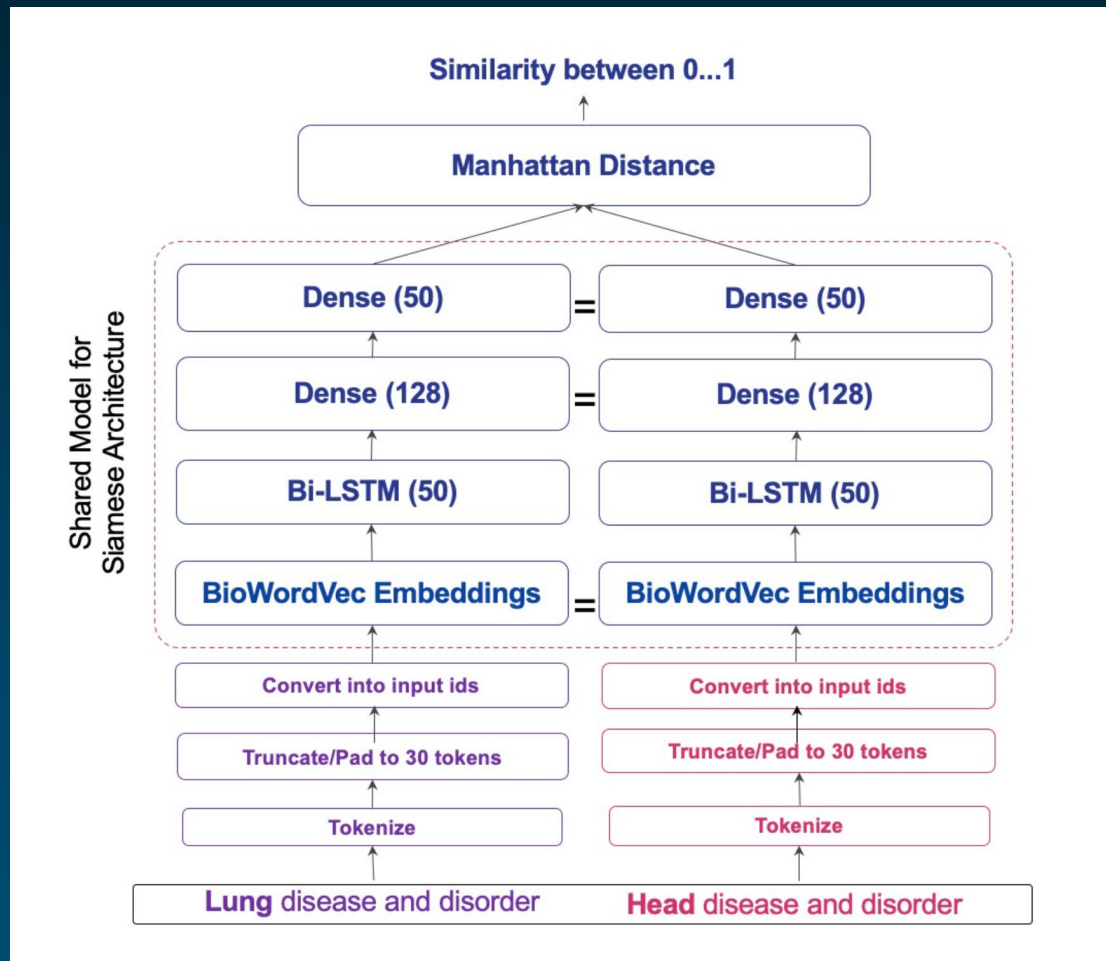
$\text{syn}(\text{"Addison Disease"}, \text{"Hodgkin Disease"}) = 0$



# Neural network architecture

- ◆ Word embeddings
  - Word vectors for representing terms
  - Using BioWordVec
- ◆ Siamese LSTM network
- ◆ Similarity function = Manhattan distance

# Neural network architecture



# Learning experiments

## ◆ Hypotheses

- More difficult to predict synonymy among lexically different terms than lexically similar terms
- More difficult to predict non-synonymy among lexically similar terms than among lexically different terms

## ◆ Experiments

- Different degrees of lexical similarity among negative examples used for learning



# Datasets

Type	Positive	Negative	All
High similarity	22,324,834	55,909,551	78,234,385
Low similarity	22,324,834	55,909,551	78,234,385
No similarity	22,324,834	58,256,526	80,581,360
High+Low+No	22,324,834	170,075,628	192,400,462

*Positive (selected pairwise **within** concepts)*

(“Addison Disease”, “Primary hypoadrenalism”)

*Negative (selected pairwise **between** concepts)*

- *high sim:* (“Addison Disease”, “Hodgkin Disease”)
- *low sim:* (“Fracture of left rib”, “Traumatic hematoma of left kidney”)
- *no sim:* (“Addison Disease”, “Hodgkin lymphoma”)



# All models show good performance

Type	F1 Training	F1 Validation
High similarity	0.9521	0.9333
Low similarity	0.9887	0.9784
No similarity	<b>0.9958</b>	<b>0.9899</b>
High+Low+No	0.9480	0.9287

*Good performance against unseen data from the same dataset*

# Some models generalize poorly

Model used for testing

Model used for testing	Type	F1 High	F1 Low	F1 No	F1 H+L+N
	High similarity	0.8740	0.9117	0.9217	0.7954
Low similarity	<b>0.5678</b>	<b>0.9654</b>	0.9768	<b>0.5572</b>	
No similarity	<b>0.3593</b>	0.7943	<b>0.9816</b>	<b>0.3286</b>	
High+Low+No	<b>0.8974</b>	0.9469	0.9549	<b>0.9061</b>	

*Models not trained on high lexical similarity  
negative examples do not generalize well*



# Deep learning vs. normalization and source synonymy

Type	F1 High	F1 Low	F1 No	F1 H+L+N
Deep learning (High+Low+No)	<b>0.8974</b>	<b>0.9469</b>	<b>0.9549</b>	<b>0.9061</b>
Normalization+ Source synonymy	0.7672	0.8109	0.8145	0.7651

*Deep learning model largely outperforms normalization+source synonymy*



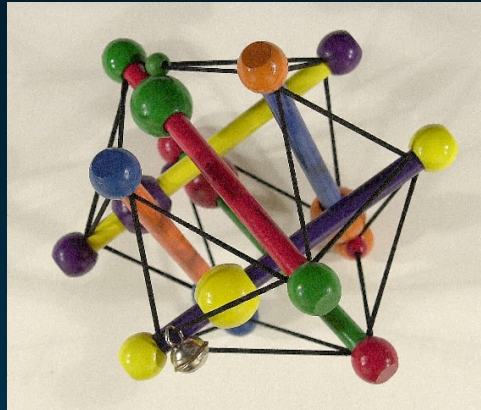
# Discussion

- ◆ Encouraging results
  - Outperforms Normalization+Source synonymy
- ◆ Inclusion of lexically similar terms among negative examples is key to performance
- ◆ Areas for improvement
  - More sophisticated embeddings (e.g., BERT)
  - Integration of context (source synonymy, relations)
- ◆ Applications
  - Integration of new terminology into Metathesaurus

# Summary

# Summary

- ◆ The UMLS Metathesaurus is a biomedical terminology integration system
- ◆ Metathesaurus construction has relied on a lexical model for synonymy and human review
- ◆ Supervised machine learning approaches to predicting synonymy have shown promising results



# Medical Ontology Research

Contact: [olivier@nlm.nih.gov](mailto:olivier@nlm.nih.gov)

Web: [mor.nlm.nih.gov](http://mor.nlm.nih.gov)

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**National Library of Medicine**

*Lister Hill National Center for Biomedical Communications*

# References

## ◆ UMLS overview

- Bodenreider O. (2004). The Unified Medical Language System (UMLS): Integrating biomedical terminology. *Nucleic Acids Research*; D267-D270.

## ◆ Supervised learning approach

- Nguyen V, Yip HY and Bodenreider O. Biomedical vocabulary alignment at scale in the UMLS Metathesaurus. *Proceedings of the Web Conference 2021 (WWW'21)*; 2672-2683.

