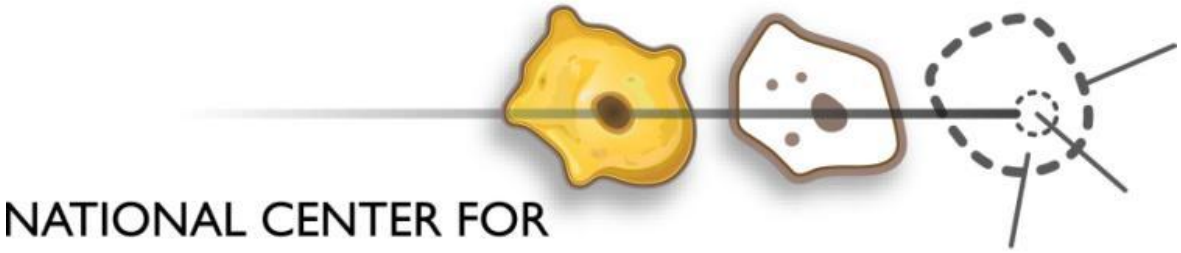
Cinical Informatics and Decision Making:

Challenges for Large-Scale Analytics and Intelligent Services

Mark Musen
Stanford University
musen@stanford.edu

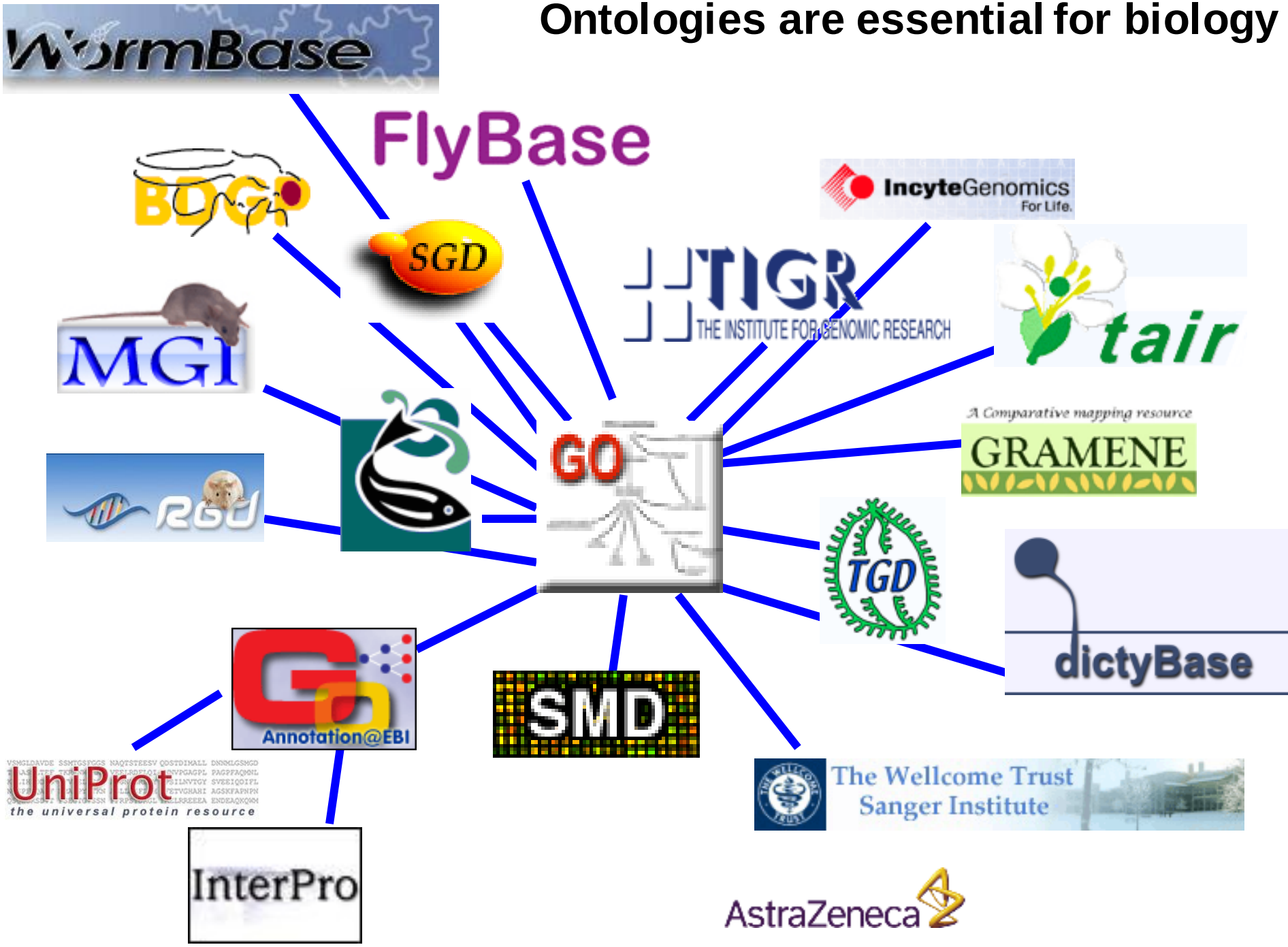


NATIONAL CENTER FOR
BIOMEDICAL ONTOLOGY

What are the gaps?

- Intelligent services based on individual **rule bases will never scale**
- It is difficult to characterize the **feature space** that leads to a diagnosis
- It is difficult to characterize the **category space** when you decide on a diagnosis
- Imprecision in the category spaces mean **imprecision in therapeutics**
- The underlying information infrastructure is evolving—very slowly—from a 19th century model

Ontologies are essential for biology



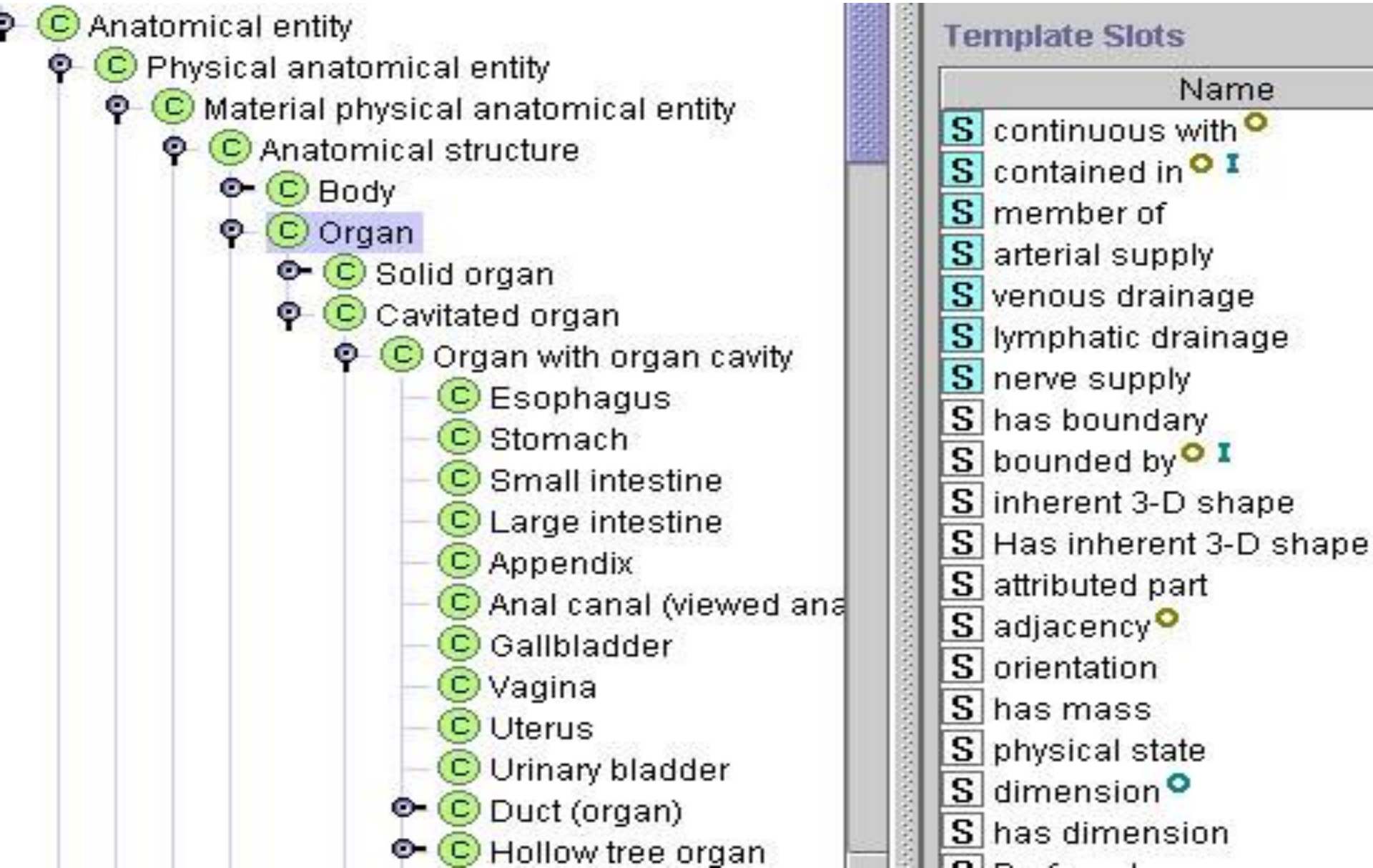
Search GO:

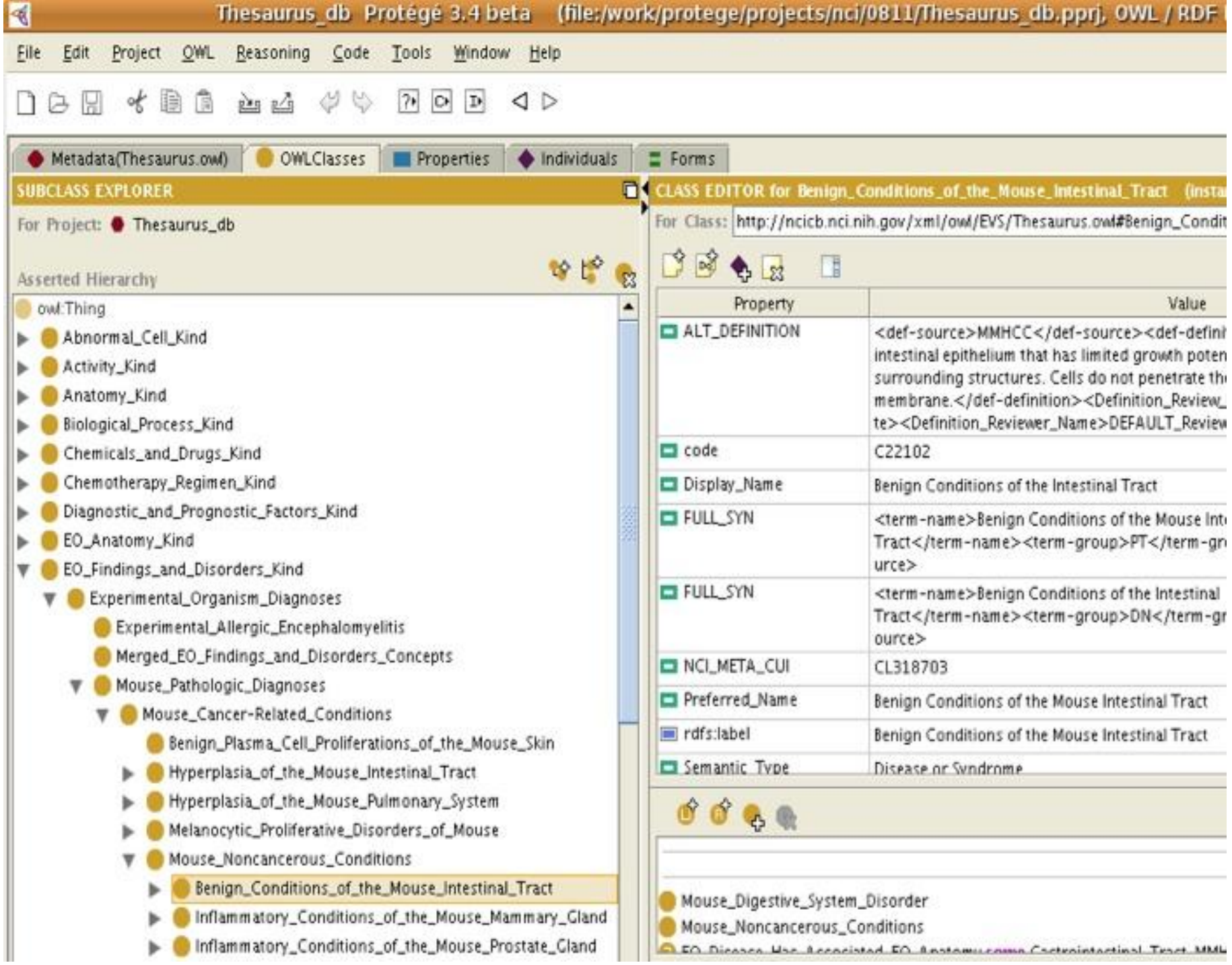
Terms Gene Products

Top Docs Gene Ontology GO Links GO Summary

- **GO:0003673 : Gene Ontology (92932)**
  - **GO:0008150 : biological process (56952)**
    - GO:0007610 : behavior (566)
    - GO:0000004 : biological process unknown (6152)
    - **GO:0007154 : cell communication (11916)**
      - GO:0007155 : cell adhesion (830)
      - GO:0030260 : cell invasion (0)
      - GO:0008037 : cell recognition (210)
      - **GO:0007267 : cell-cell signaling (1318)**
        - GO:0045168 : cell-cell signaling involved in cell fate commitment (0)
        - **GO:0030072 : peptide hormone secretion (6)**
          - GO:0030252 : growth hormone secretion (2)
          - GO:0030073 : insulin secretion (4)
          - GO:0030103 : vasopressin secretion (2)
        - GO:0019226 : transmission of nerve impulse (688)
      - GO:0030383 : host-pathogen interaction (12)

The Foundational Model of Anatomy




Thesaurus_db Protégé 3.4 beta (file:/work/protege/projects/nci/0811/Thesaurus_db.pprj, OWL / RDF
File Edit Project OWL Reasoning Code Tools Window Help
Metadata(Thesaurus.owl) OWLClasses Properties Individuals Forms
SUBCLASS EXPLORER
For Project: Thesaurus_db
Asserted Hierarchy
owl:Thing
Abnormal_Cell_Kind
Activity_Kind
Anatomy_Kind
Biological_Process_Kind
Chemicals_and_Drugs_Kind
Chemotherapy_Regimen_Kind
Diagnostic_and_Prognostic_Factors_Kind
EO_Anatomy_Kind
EO_Findings_and_Disorders_Kind
Experimental_Organism_Diagnoses
Experimental_Allergic_Encephalomyelitis
Merged_EO_Findings_and_Disorders_Concepts
Mouse_Pathologic_Diagnoses
Mouse_Cancer-Related_Conditions
Benign_Plasma_Cell_Proliferations_of_the_Mouse_Skin
Hyperplasia_of_the_Mouse_Intestinal_Tract
Hyperplasia_of_the_Mouse_Pulmonary_System
Melanocytic_Proliferative_Disorders_of_Mouse
Mouse_Noncancerous_Conditions
Benign_Conditions_of_the_Mouse_Intestinal_Tract
Inflammatory_Conditions_of_the_Mouse_Mammary_Gland
Inflammatory_Conditions_of_the_Mouse_Prostate_Gland
CLASS EDITOR for Benign_Conditions_of_the_Mouse_Intestinal_Tract
For Class: http://ncicb.nci.nih.gov/xml/owl/EVS/Thesaurus.owl#Benign_Condit
Property
Value
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intestinal epithelium that has limited growth poten
surrounding structures. Cells do not penetrate th
membrane.</def-definition><Definition_Review_
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C22102
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Tract</term-name><term-group>DN</term-gr
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NCI_META_CUI
CL318703
Preferred_Name
Benign Conditions of the Mouse Intestinal Tract
rdfs:label
Benign Conditions of the Mouse Intestinal Tract
Semantic_Type
Disease or Syndrome
Mouse_Digestive_System_Disorder
Mouse_Noncancerous_Conditions

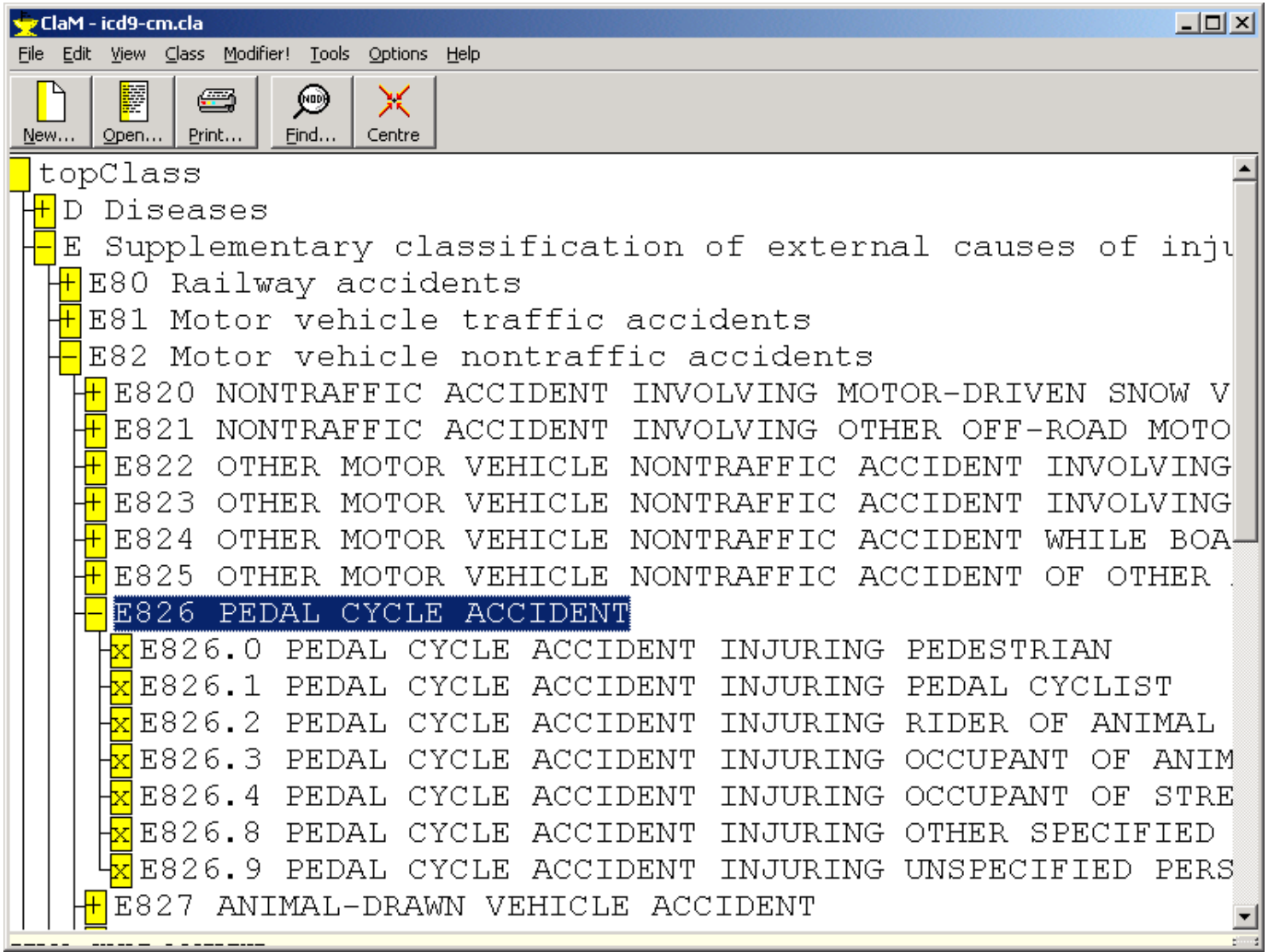
Biomedical scientists have adopted ontologies

- To provide canonical representation of scientific knowledge
- To annotate experimental data to enable interpretation, comparison, and discovery across databases
- To facilitate knowledge-based applications for
  - Decision support
  - Natural language-processing
  - Data integration

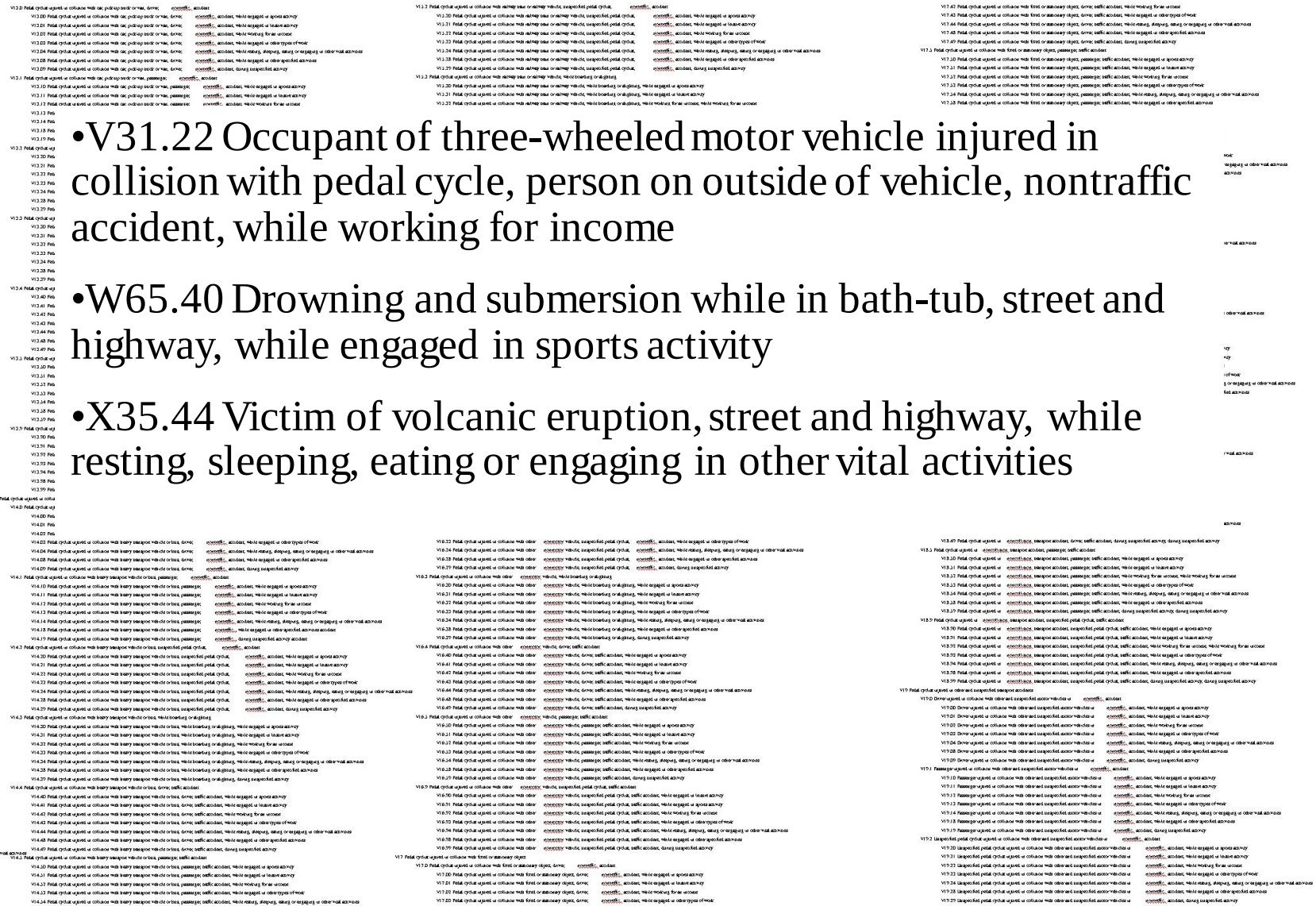
The International Classification of Diseases

724	Unspecified disorders of the back
724.0	Spinal stenosis, other than cervical
724.00	Spinal stenosis, unspecified region
724.01	Spinal stenosis, thoracic region
724.02	Spinal stenosis, lumbar region
724.09	Spinal stenosis, other
724.1	Pain in thoracic spine
724.2	Lumbago
724.3	Sciatica
724.4	Thoracic or lumbosacral neuritis
724.5	Backache, unspecified
724.6	Disorders of sacrum
724.7	Disorders of coccyx
724.70	Unspecified disorder of coccyx
724.71	Hypermobility of coccyx
724.71	Coccygodynia
724.8	Other symptoms referable to back
724.9	Other unspecified back disorders

ICD9 (1977): A handful of codes for traffic accidents



ICD10 (1999):
587 codes for such accidents



- V31.22 Occupant of three-wheeled motor vehicle injured in collision with pedal cycle, person on outside of vehicle, nontraffic accident, while working for income
- W65.40 Drowning and submersion while in bath-tub, street and highway, while engaged in sports activity
- X35.44 Victim of volcanic eruption, street and highway, while resting, sleeping, eating or engaging in other vital activities

There is a plethora of controlled terminologies!

- Diseases: ICD-9, ICD-9-CM, ICD-10, ICD-10-CM, DRG
- Procedures: CPT-4, ICD-10-PCS
- Laboratory tests: LOINC
- Nursing activities: NIC, NOC, HHCC, Omaha
- Drugs: NDC, Multum, Micromedex, NDDF,
- Biomedical literature: MeSH
- Clinical documentation: Medcin, Purkinjie
- Cross-references among terminologies: UMLS

REPORT TO THE PRESIDENT REALIZING THE FULL POTENTIAL OF HEALTH INFORMATION TECHNOLOGY TO IMPROVE HEALTHCARE FOR AMERICANS: THE PATH FORWARD

Executive Office of the President

President's Council of Advisors on Science and Technology

What are some of the Advisors recommendations?

- Continue incentives for “meaningful use” of EHRs
- Encourge exchange of information across health-care facilities
- Establish a “universal exchange language” for clinical data
- Initiate pilot projects to allow the approach to scale

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Of Current Interest

- **News**: Study Extracts Vioxx Heart-Attack Risk from EMRs, Shift from Ontology Development to Use
- **Webinar**: Wed, Sep 21, 10:00am PT, Sean Mooney, The Buck Institute
- **Recent Publication**: Whetzel, PL, Noy, N, Shah, NH, et al. (2011): BioPortal: enhanced functionality via new Web services to access and use ontologies in software applications
- **Recent Release**: BioPortal 3.2 (Sep 1, 2011)
- **NCBO Webinar Announcements - Subscribe**
- **NCBO Software Support - Mailing List Archive**
- More News & Events

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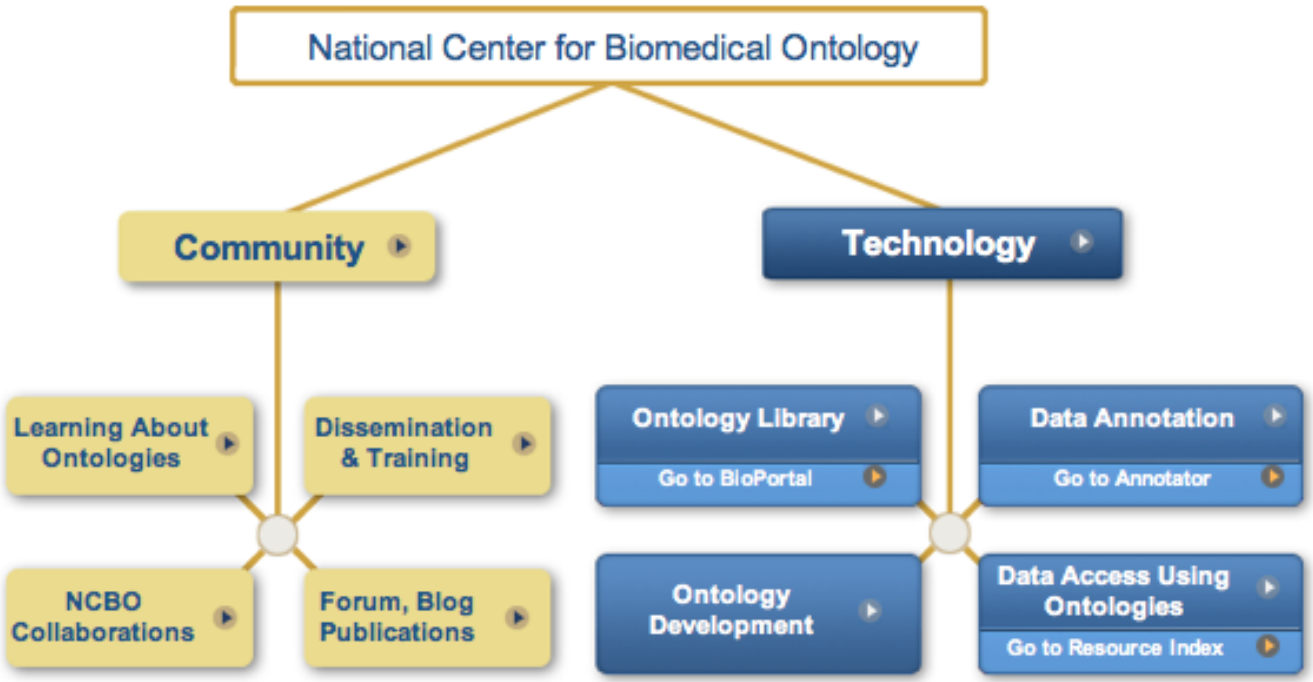


NCBO User Profile

Simon Twigger, Ph.D.
Medical College of Wisconsin

More >

Other profiles >

Video

Learn about Biomedical Ontologies. Watch a series of introductory videos.

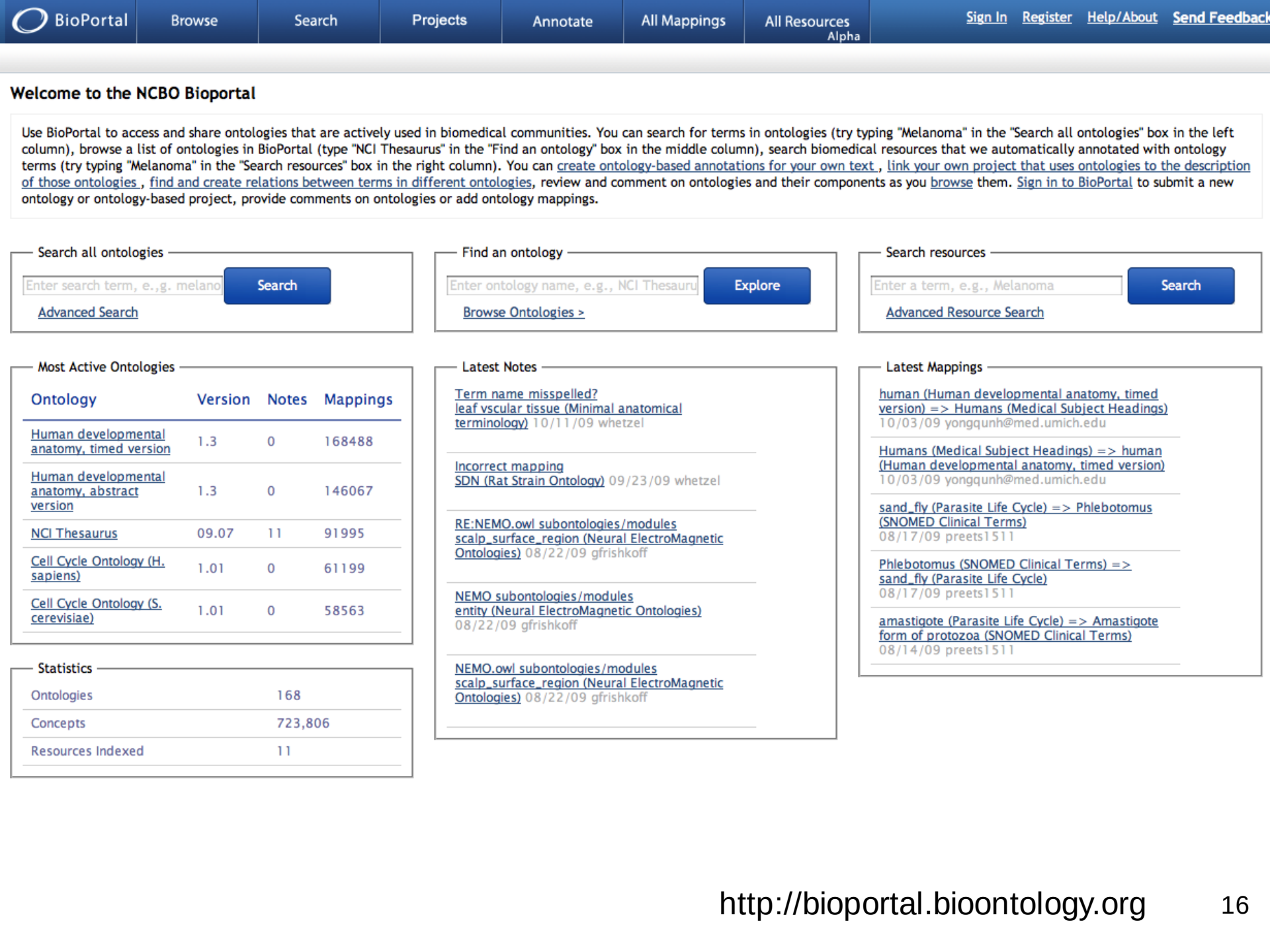
Browse ontologies in BioPortal!

BioPortal allows users to browse, search and visualize ontologies.

www.bioontology.org

NCBO: Key activities

- We **create and maintain a library** of biomedical ontologies and terminologies.
- We **build tools and Web services** to enable the use of ontologies and terminologies.
- We **collaborate with scientific communities** that develop and use ontologies and terminologies in biomedicine.

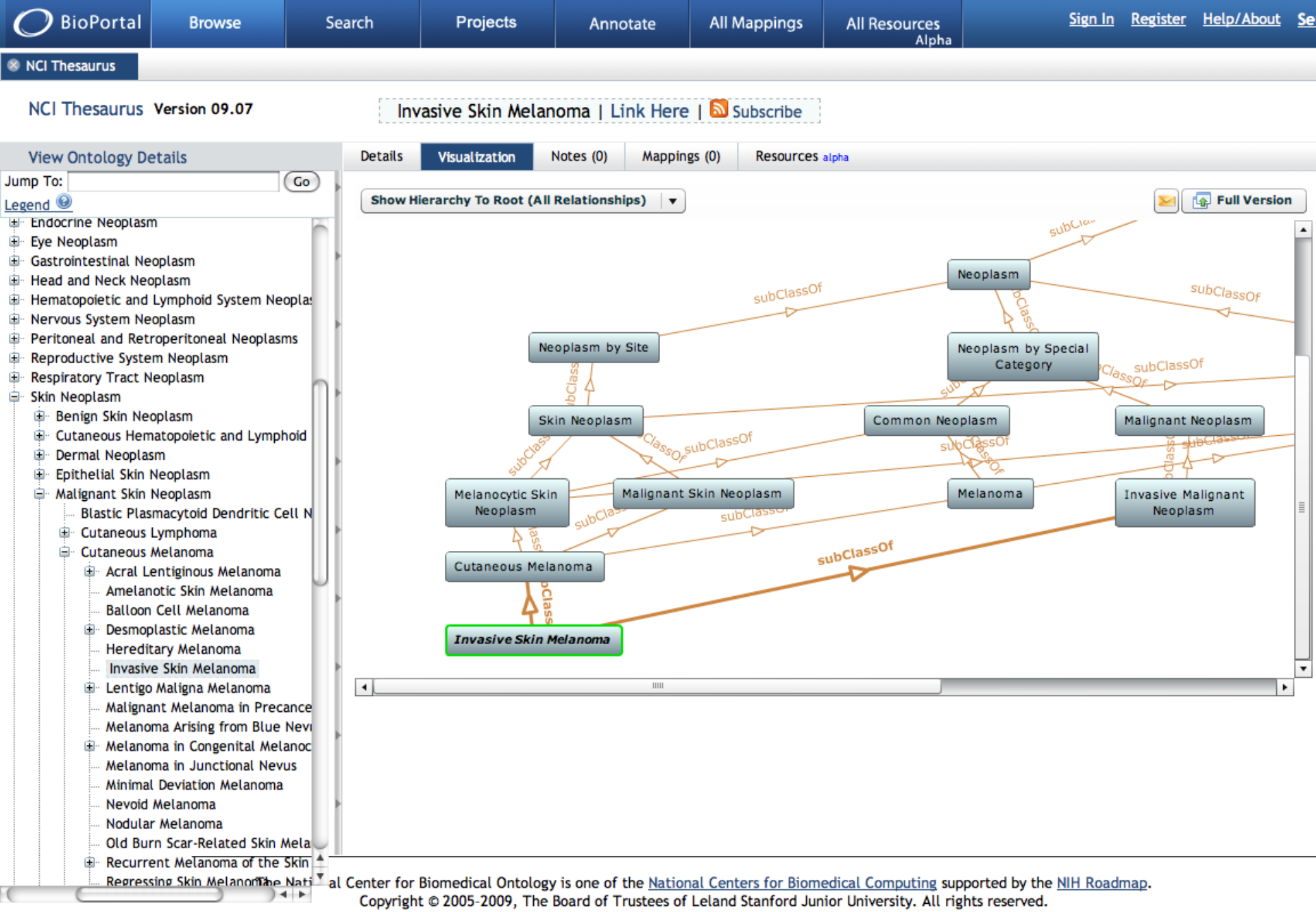

BioPortal
Browse
Search
Projects
Annotate
All Mappings
All Resources
Alpha
Sign In
Register
Help/About
Send Feedback
Welcome to the NCBO Bioportal
Use BioPortal to access and share ontologies that are actively used in biomedical communities. You can search for terms in ontologies (try typing "Melanoma" in the "Search all ontologies" box in the left column), browse a list of ontologies in BioPortal (type "NCI Thesaurus" in the "Find an ontology" box in the middle column), search biomedical resources that we automatically annotated with ontology terms (try typing "Melanoma" in the "Search resources" box in the right column). You can create ontology-based annotations for your own text , link your own project that uses ontologies to the description of those ontologies , find and create relations between terms in different ontologies, review and comment on ontologies and their components as you browse them. Sign in to BioPortal to submit a new ontology or ontology-based project, provide comments on ontologies or add ontology mappings.
Search all ontologies
Enter search term, e.,g. melano
Search
Advanced Search
Find an ontology
Enter ontology name, e.g., NCI Thesauru
Explore
Browse Ontologies >
Search resources
Enter a term, e.g., Melanoma
Search
Advanced Resource Search
Most Active Ontologies
Ontology
Version
Notes
Mappings
Human developmental anatomy, timed version
1.3
0
168488
Human developmental anatomy, abstract version
1.3
0
146067
NCI Thesaurus
09.07
11
91995
Cell Cycle Ontology (H. sapiens)
1.01
0
61199
Cell Cycle Ontology (S. cerevisiae)
1.01
0
58563
Latest Notes
Term name misspelled?
leaf vscular tissue (Minimal anatomical terminology) 10/11/09 whetzel
Incorrect mapping
SDN (Rat Strain Ontology) 09/23/09 whetzel
RE:NEMO.owl subontologies/modules
scalp_surface_region (Neural ElectroMagnetic Ontologies) 08/22/09 gfrishkoff
NEMO subontologies/modules
entity (Neural ElectroMagnetic Ontologies)
08/22/09 gfrishkoff
NEMO.owl subontologies/modules
scalp_surface_region (Neural ElectroMagnetic Ontologies) 08/22/09 gfrishkoff
Latest Mappings
human (Human developmental anatomy, timed version) => Humans (Medical Subject Headings)
10/03/09 yongqunh@med.umich.edu
Humans (Medical Subject Headings) => human (Human developmental anatomy, timed version)
10/03/09 yongqunh@med.umich.edu
sand_fly (Parasite Life Cycle) => Phlebotomus (SNOMED Clinical Terms)
08/17/09 preets1511
Phlebotomus (SNOMED Clinical Terms) => sand_fly (Parasite Life Cycle)
08/17/09 preets1511
amastigote (Parasite Life Cycle) => Amastigote form of protozoa (SNOMED Clinical Terms)
08/14/09 preets1511
Statistics
Ontologies 168
Concepts 723,806
Resources Indexed 11

Access all ontologies that are available in BioPortal: You can filter this list by category to display ontologies relevant for a certain domain (try selecting "Anatomy or Experimental Conditions" in the "Filter by category" menu below). You can also filter ontologies that belong to a certain group such as ontologies from the OBO Foundry, or ontologies from the Cancer Biomedical Informatics Grid (caBIG). Subscribe to the BioPortal RSS feed to receive alerts for submissions of new ontologies, new versions of ontologies, new notes, and new projects. You can subscribe to feeds for a specific ontology at the individual ontology page. Add a new biomedical ontology to BioPortal using the Submit New Ontology link (you need to sign in to see this link).

SUBMIT ONTOLOGY	Submit New Ontology
FILTER BY CATEGORY	All Categories
FILTER BY GROUP	All Groups — Link To This Filter
FILTER BY TEXT	

Subscribe to all updates

ONTOLOGY NAME	FORMAT	VERSION	AUTHOR	UPLOADED ON	GROUP	STATUS
ABA Adult Mouse Brain (ABA)	OWL	1.0	Allen Institute for Brain Science	08/08/2009		Explore
African Traditional Medicine (ATMO)	OBO Format	1.101	Ghislain Atemezing	06/28/2009		Explore
Amino Acid (amino-acid)	OWL	1.2	Nick Drummond, Georgina Moulton, Robert Stevens, Phil Lord	04/25/2009		Explore
Amphibian gross anatomy (AAO)	OBO Format	1.8	AmphiAnat list	07/30/2008	OBO Foundry	Explore
Amphibian taxonomy (ATO)	OBO Format	See Remote Site	AmphiAnat list	08/14/2009		
Animal natural history and life history (ADW)	PROTEGE	See Remote Site	Http://animaldiversity Administrators	04/27/2009		
Ascomycete phenotype ontology (APO)	OBO Format	1.6	Fungal_anatomy Administrators	09/01/2009		Explore
Basic Formal Ontology (BFO)	OWL	1.1		07/24/2009		Explore
Basic Vertebrate Anatomy (basic-vertebrate-gross-anatomy)	OWL	1.1		01/16/2007		Explore
Bilateria anatomy (BILA)	OBO Format	See Remote Site	Thorsten Heinrich	04/13/2009		
Biological imaging methods (FBbi)	OBO Format	1.1	Image Administrators	07/30/2008		Explore


BioPortal
Browse
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Annotate
All Mappings
All Resources
Alpha
Sign In
Register
Help/About
NCI Thesaurus
NCI Thesaurus Version 09.07
Invasive Skin Melanoma | Link Here | Subscribe
View Ontology Details
Jump To:
Go
Legend
Endocrine Neoplasm
Eye Neoplasm
Gastrointestinal Neoplasm
Head and Neck Neoplasm
Hematopoietic and Lymphoid System Neoplas
Nervous System Neoplasm
Peritoneal and Retroperitoneal Neoplasms
Reproductive System Neoplasm
Respiratory Tract Neoplasm
Skin Neoplasm
Benign Skin Neoplasm
Cutaneous Hematopoietic and Lymphoid
Dermal Neoplasm
Epithelial Skin Neoplasm
Malignant Skin Neoplasm
Blastic Plasmacytoid Dendritic Cell N
Cutaneous Lymphoma
Cutaneous Melanoma
Acral Lentiginous Melanoma
Amelanotic Skin Melanoma
Balloon Cell Melanoma
Desmoplastic Melanoma
Hereditary Melanoma
Invasive Skin Melanoma
Lentigo Maligna Melanoma
Malignant Melanoma in Precance
Melanoma Arising from Blue Nevi
Melanoma in Congenital Melanoc
Melanoma in Junctional Nevus
Minimal Deviation Melanoma
Nevoid Melanoma
Nodular Melanoma
Old Burn Scar-Related Skin Mela
Recurrent Melanoma of the Skin
Regressing Skin Melanoma
Details
Visualization
Notes (0)
Mappings (0)
Resources alpha
Show Hierarchy To Root (All Relationships)
Full Version
Neoplasm
Neoplasm by Site
Neoplasm by Special Category
Skin Neoplasm
Common Neoplasm
Malignant Neoplasm
Melanocytic Skin Neoplasm
Malignant Skin Neoplasm
Melanoma
Invasive Malignant Neoplasm
Cutaneous Melanoma
Invasive Skin Melanoma
subClassOf
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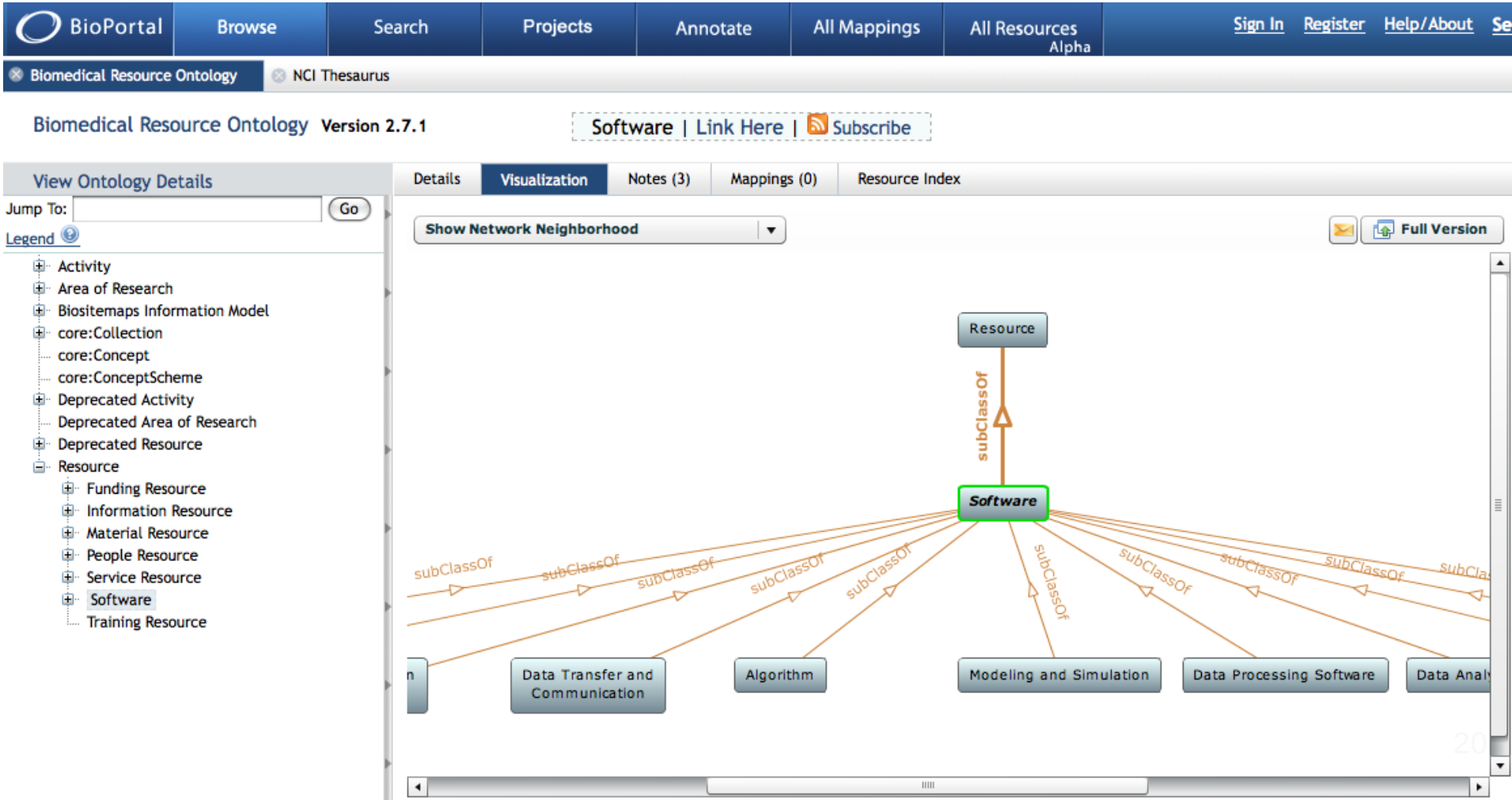
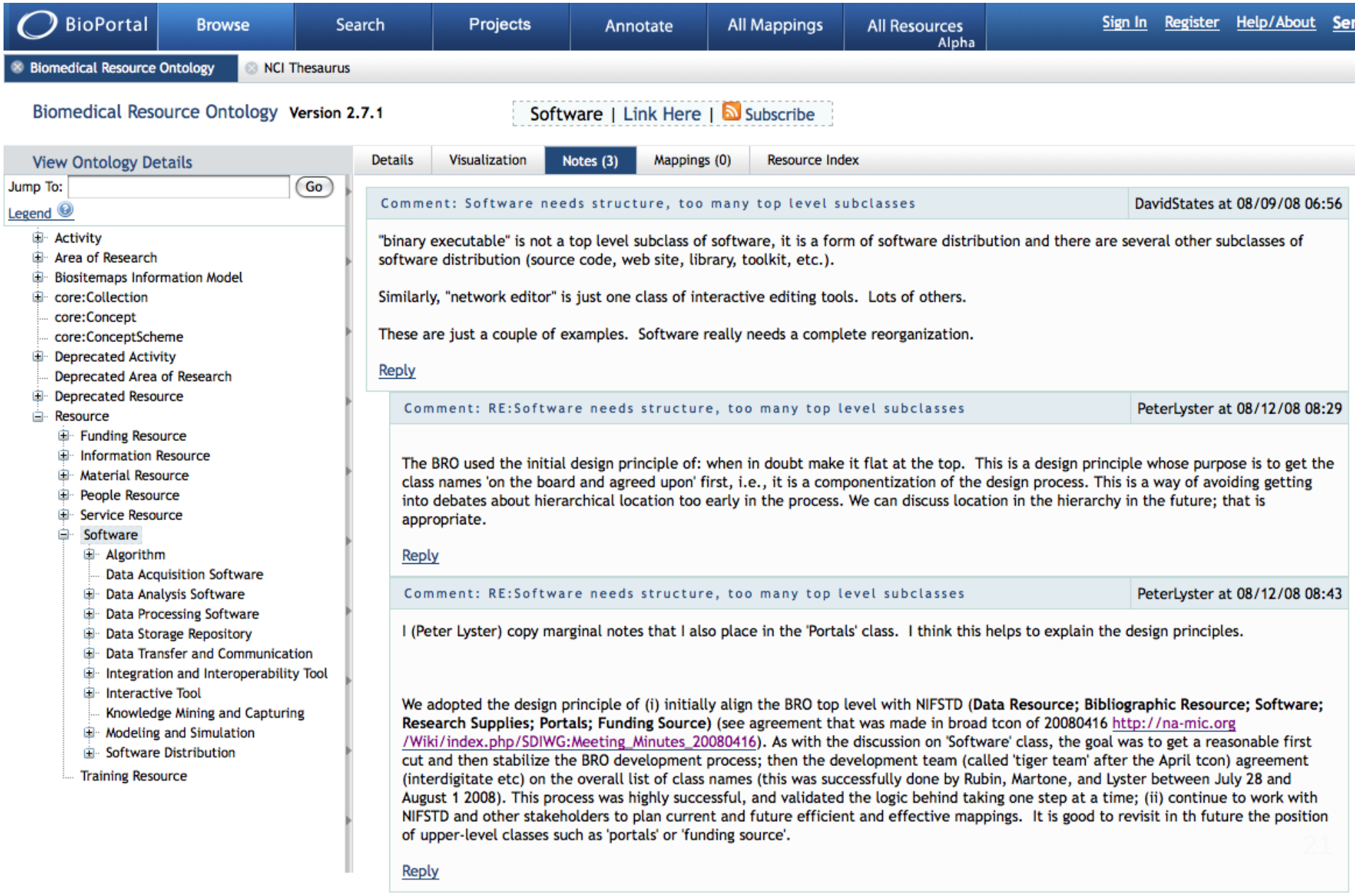
BioPortal allows us to experiment with new models for

- Dissemination of terminologies, ontologies, and knowledge on the Web
- Integration and alignment of online content
- Knowledge visualization and cognitive support
- Peer review of online content

Biomedical Resource Ontology in BioPortal

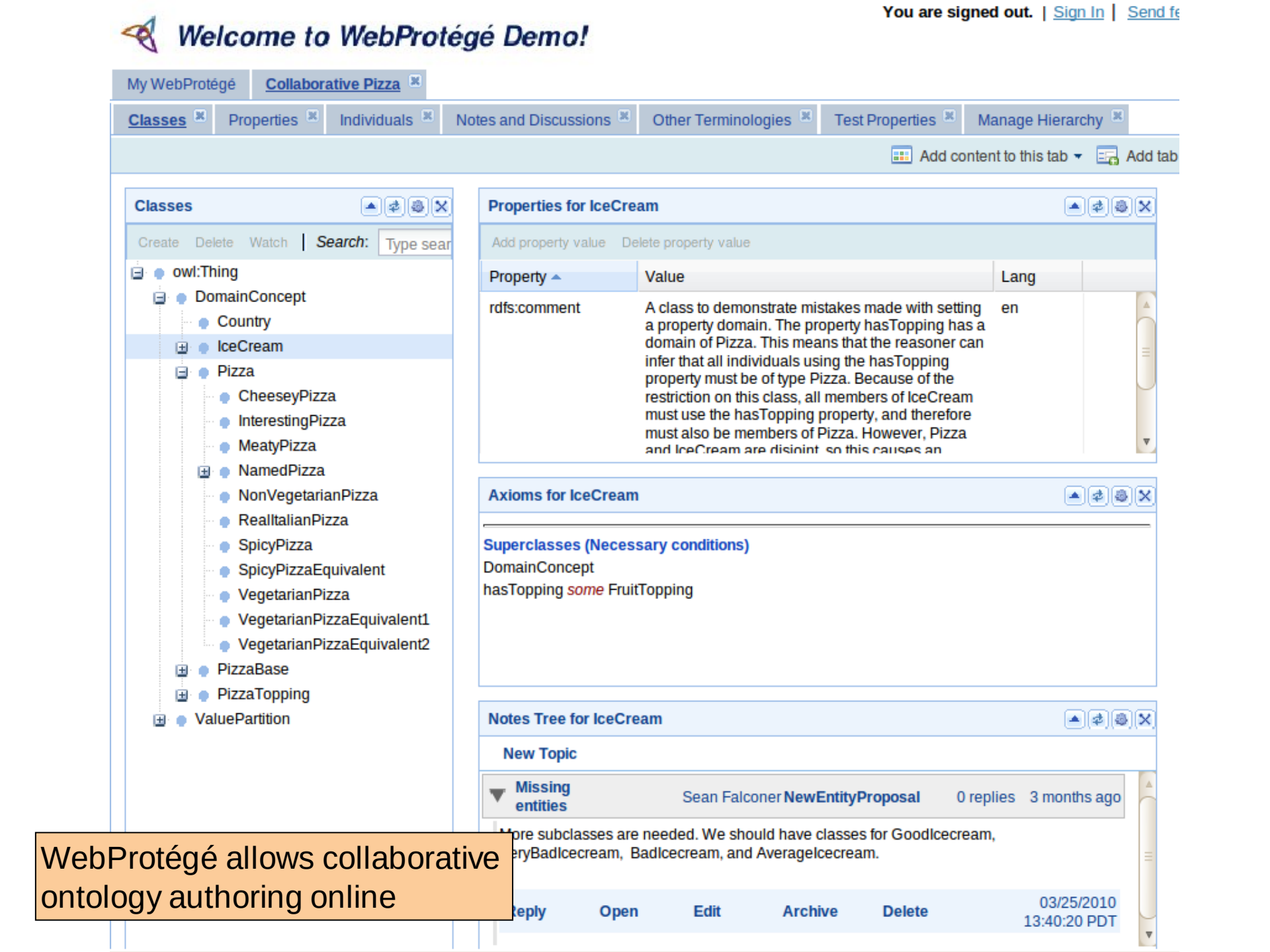


“Notes” in BioPortal



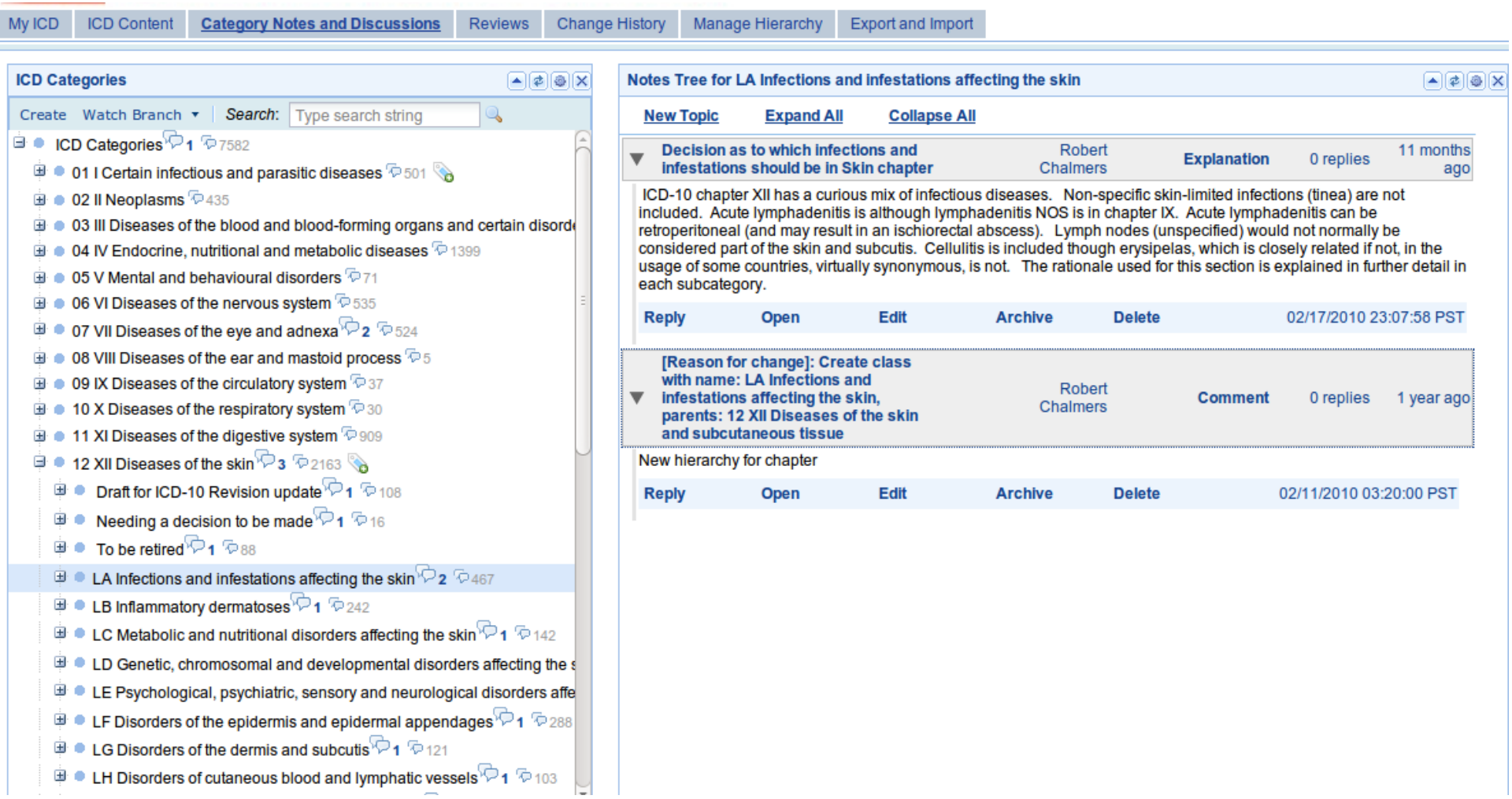
BioPortal is building an online community of users who

- Develop, upload, and apply ontologies
- Map ontologies to one another
- Comment on ontologies via “notes” to give feedback
  - To the ontology developers
  - To one another
- Make proposals for specific changes to ontologies
- Stay informed about ontology changes and proposed changes via “push” technology
- Incorporate BioPortal services into their own technologies



WebProtégé allows collaborative ontology authoring online

Like BioPortal, WebProtégé supports notes and threaded discussions



As with BioPortal, notes may include multimedia

WebProtégé - Mozilla Firefox

File Edit View History Bookmarks Tools Help

Send us feedback! Documentation | Protégé Web site | Protégé Wiki | About

My WebProtégé | Classes | Properties | Discussions

Ontology: ICD 11. Login for more features. Search

Class Tree

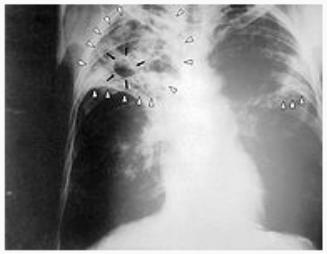
Create class Delete class

- owl:Thing
  - ICD11
    - ICD11 (A00-B99) Certain infectious and parasitic diseases (CHAPTER I)
      - ICD11 (A00-A09) Intestinal infectious diseases
      - ICD11 (A15-A19) Tuberculosis
      - ICD11 (A20-A28) Certain zoonotic bacterial diseases
      - ICD11 (A30-A49) Other bacterial diseases
      - ICD11 (A50-A64) Infections with a predominantly sexual mode of transmissio
      - ICD11 (A65-A69) Other spirochaetal diseases
      - ICD11 (A70-A74) Other diseases caused by chlamydiae
      - ICD11 (A75-A79) Rickettsioses
      - ICD11 (A80-A89) Viral infections of the central nervous system
      - ICD11 (A90-A99) Arthropod borne viral fevers and viral haemorrhagic fevers
      - ICD11 (B00-B09) Viral infections characterized by skin and mucous membra
      - ICD11 (B15-B19) Viral hepatitis
      - ICD11 (B20-B24) Human immunodeficiency virus (HIV) disease
      - ICD11 (B25-B34) Other viral diseases
      - ICD11 (B35-B49) Mycoses
      - ICD11 (B50-B64) Protozoal diseases
      - ICD11 (B65-B83) Helminthiases
      - ICD11 (B85-B89) Pediculosis acariasis and other infestations
      - ICD11 (B90-B94) Sequelae of infectious and parasitic diseases
      - ICD11 (B95-B97) Bacterial viral and other infectious agents
      - ICD11 (B99) Other infectious diseases

Notes for ICD11 (A15-A19) Tuberculosis

New Topic Reply Collapse <Previous Next> Displaying page 1 of 1 pages

Text	Author	Date
Example	Tania Tudorache	03/24/2009 12:12:22 PDT
Here is a picture from Wikipedia:		
>>RE: Example	Tania Tudorache	03/24/2009 12:14:32 PDT
Forgot to include the picture!		



T.

=== On 03/24/2009 11:12, Tania Tudorache wrote:

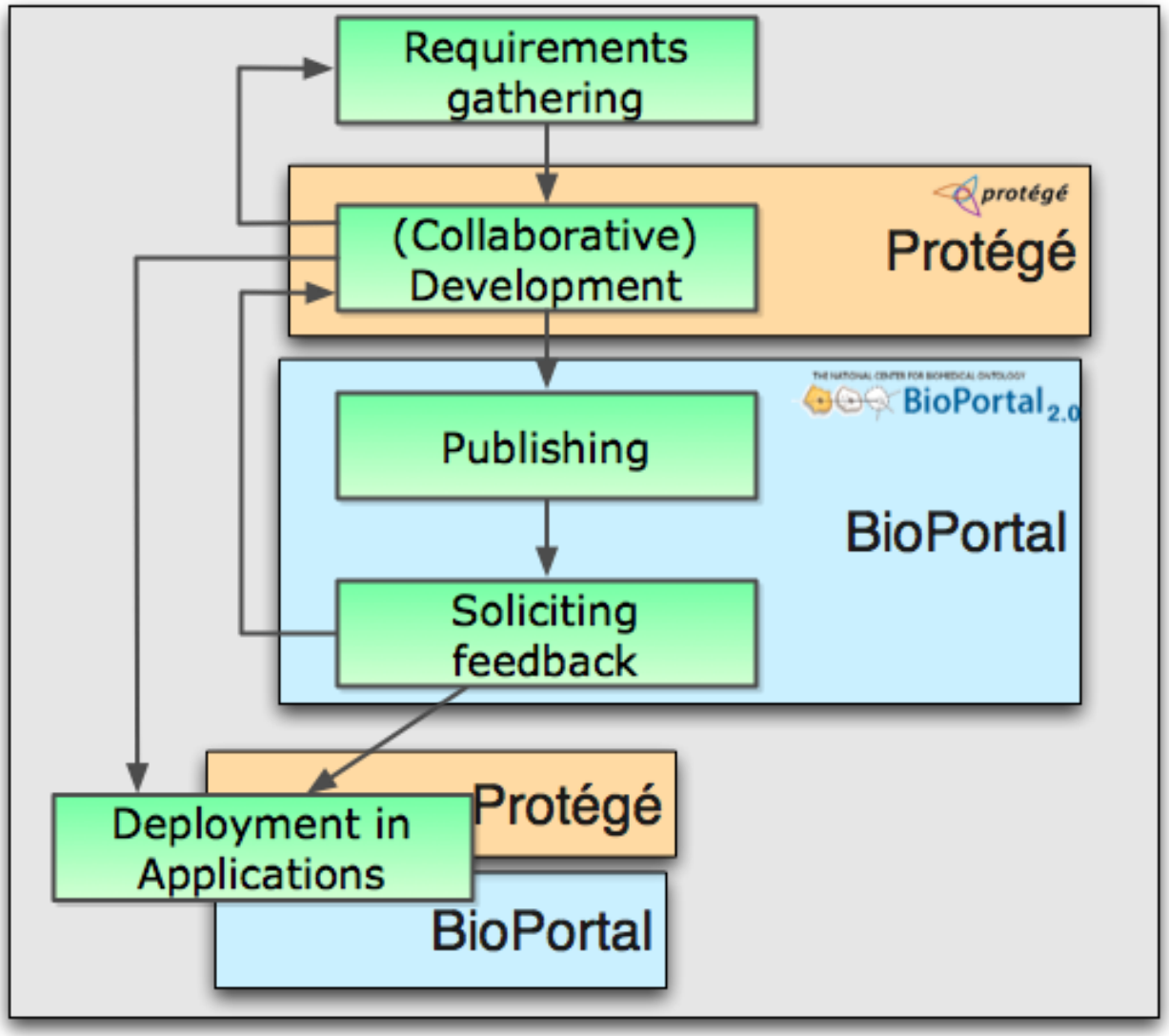
Here is a picture from Wikipedia:

>>RE: >>RE: Comment	icd1	03/24/2009 12:16:14 PDT
And here is the link to the article:		

http://en.wikipedia.org/wiki/Tuberculosis

Integration of Ontology Authoring, Publishing, and Peer Review

NCBO will support the complete ontology lifecycle



WINDOW FRAME

ATHENA Hypertension Advisory

References Sources

Patient Name XXXX-XX-XXXX View Patient Summary

Recommendations | Lifestyle | Adherence | Assumptions | Patient Summary

Blood Pressure apparently not under control:
Based on last measurement of **145/92** taken 87 days ago on mm/dd/yyyy

CARDIO RISK FACTOR* **23% High**

*Estimated 10 Year cardiovascular risk factor for this patient Explain

Enter a new BP: Update

Date: MM/DD/YR Write back to Vista

Recommendations

Other Patient Information and Alerts

- Consider intensifying drug treatment: **BP Elevated** based on most recent available BP
- There appears to be a **Strong Contraindication** to a currently prescribed drug, evaluate clinical significance
- Bronchospasm is a **Strong Contraindication** or use of beta adrenergic receptor antagonists, although many patients tolerate and teherefore benefit from this drug therapy

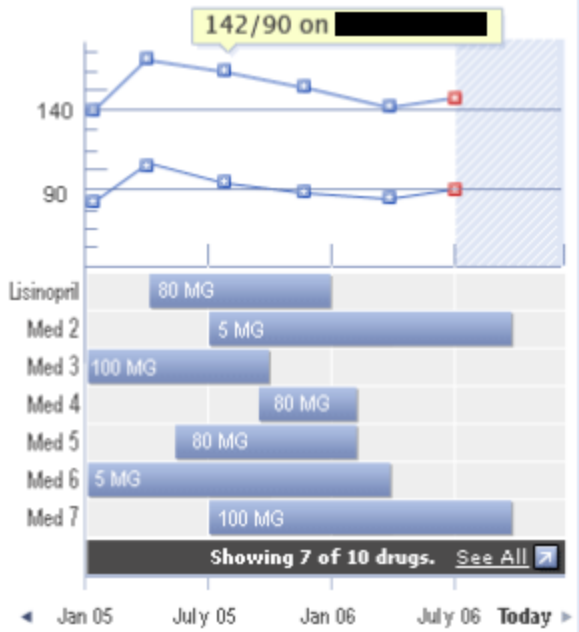
Review lifestyle modifications with the patient. See the Lifestyle page.

Therapeutic Possibilities (CLICK FOR IMPORTANT PRESCRIPTION INFORMATION)	Indications	Contraindications
Discontinue atenolol	Heart Failure EVIDENCE CKD	Brochospastic disease
AND start one of the following drugs		
ACE Inhibitors (lisinporil)	Heart Failure EVIDENCE CKD EVIDENCE	
(non-DHP) Calcium Channel Blocker (diltiazem)	CKD	Heart Failure
Add one or more of the following drugs		
ACE Inhibitors (lisinporil)	Heart Failure EVIDENCE CKD EVIDENCE	
(non-DHP) Calcium Channel Blocker (diltiazem)	CKD	Heart Failure
Increase dosage of hydroclorothiazide		

Compelling Indication | Relative Indication | Relative Contraindication | Strong Contraindication | Adverse Effects

Don't forget you know the patient better than we do message utpat lorem ipsum dolor sit amet, consecteteur adipiscing

Blood Pressure and Prescription History

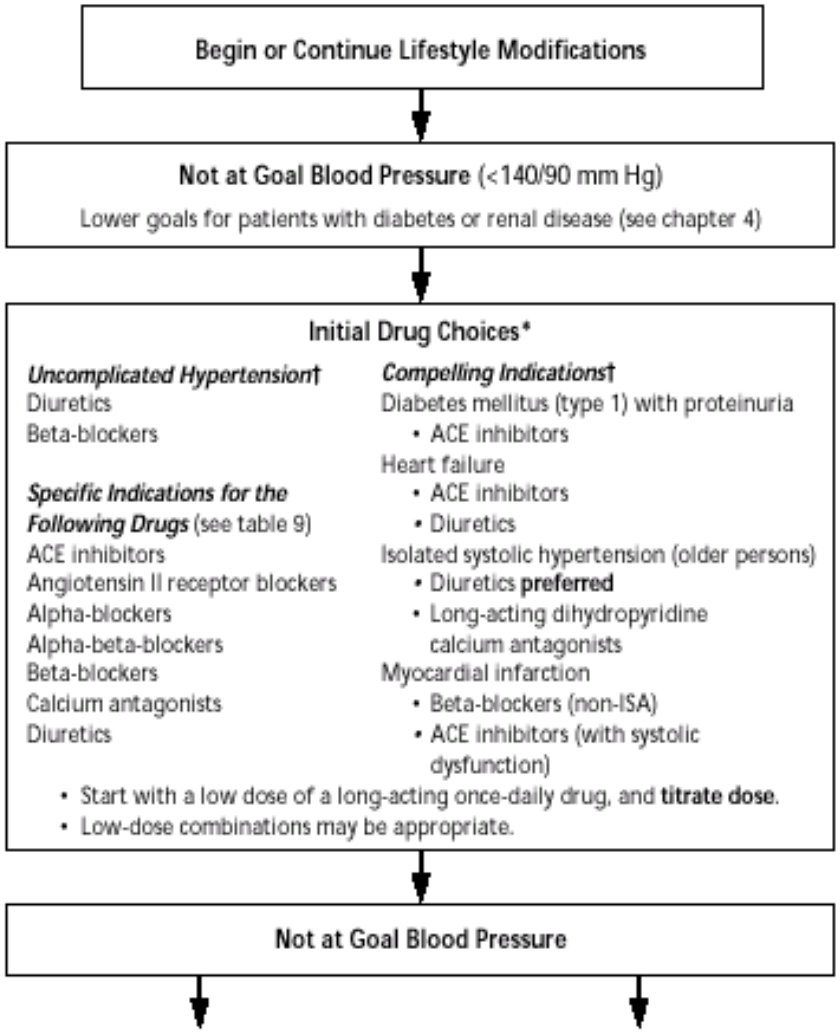


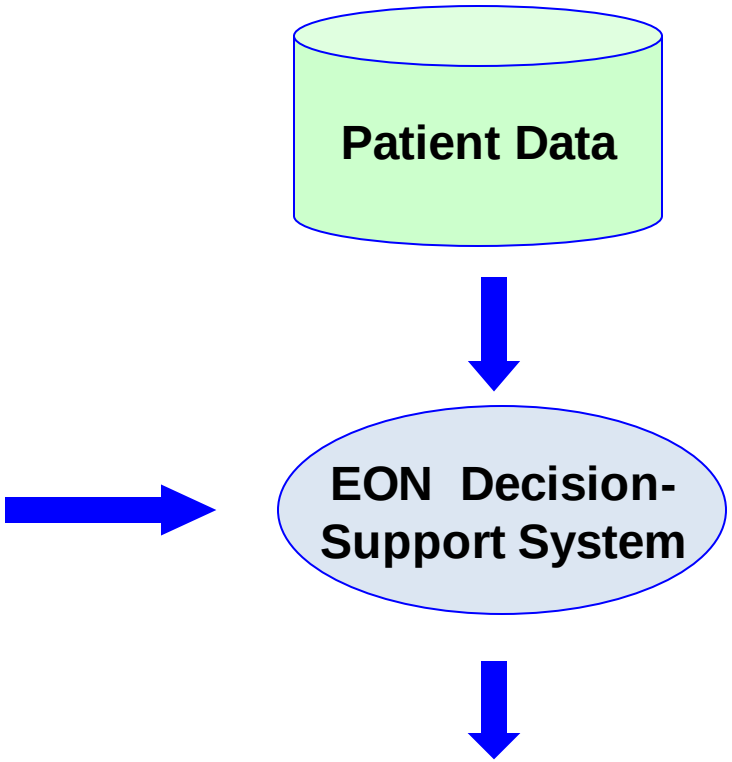
Do you have feedback for the Research team? Thank you!

Do not display advisory for this clinic visit again Exit

SYNTHETIC PATIENT DATA

The task: guideline-based patient management

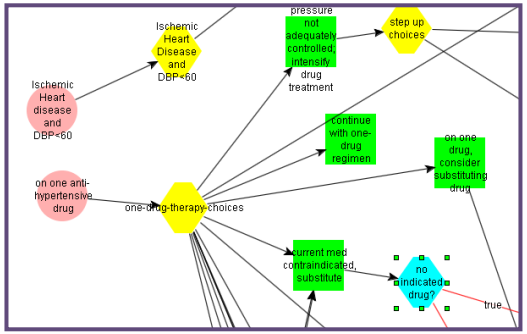




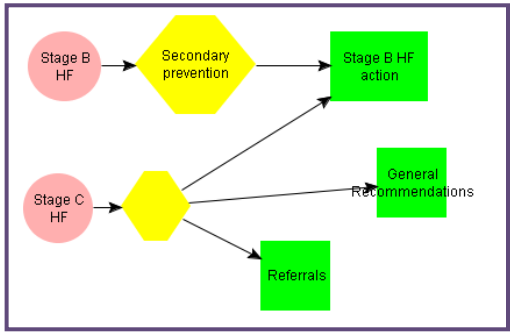
Consider adding an ACE Inhibitor because of a compelling indication (heart failure)

A handful of encoded guidelines gives you, well, a handful of encoded guidelines

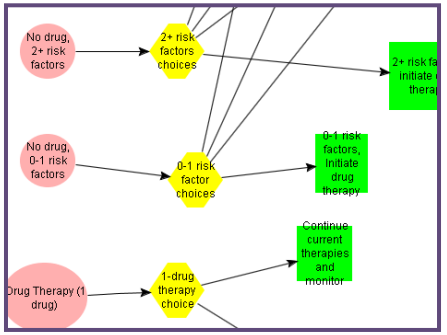
ATHENA Hypertension



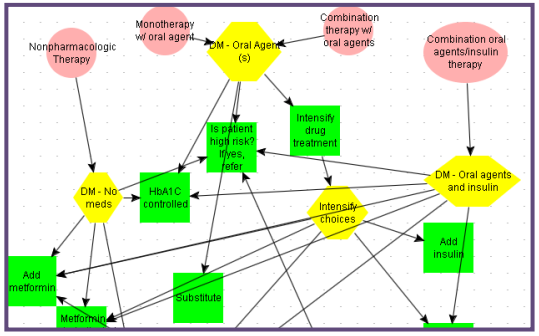
ATHENA Heart Failure



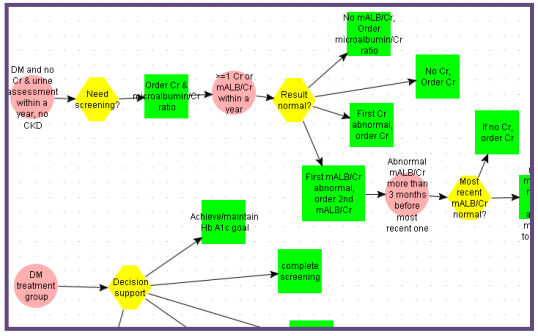
ATHENA Hyperlipidemia



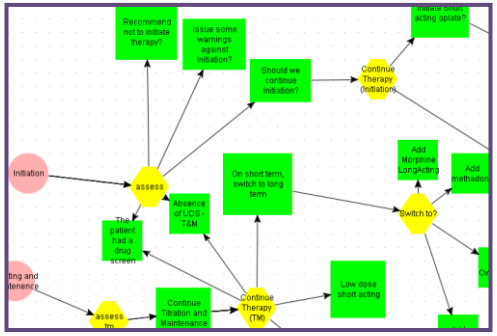
ATHENA Diabetes



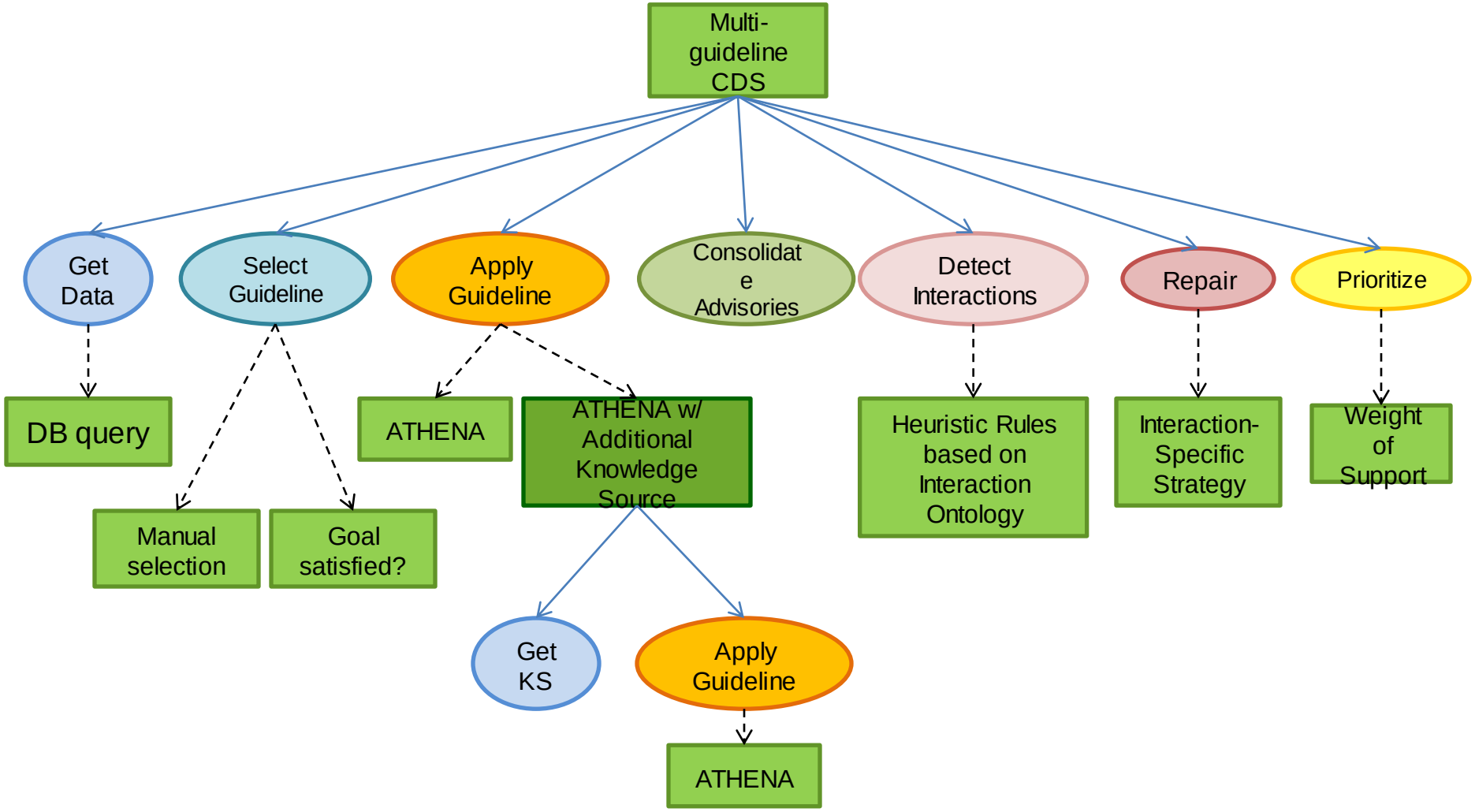
ATHENA Renal Disease



ATHENA Opioid Therapy



GLINDA Task–Method Decomposition

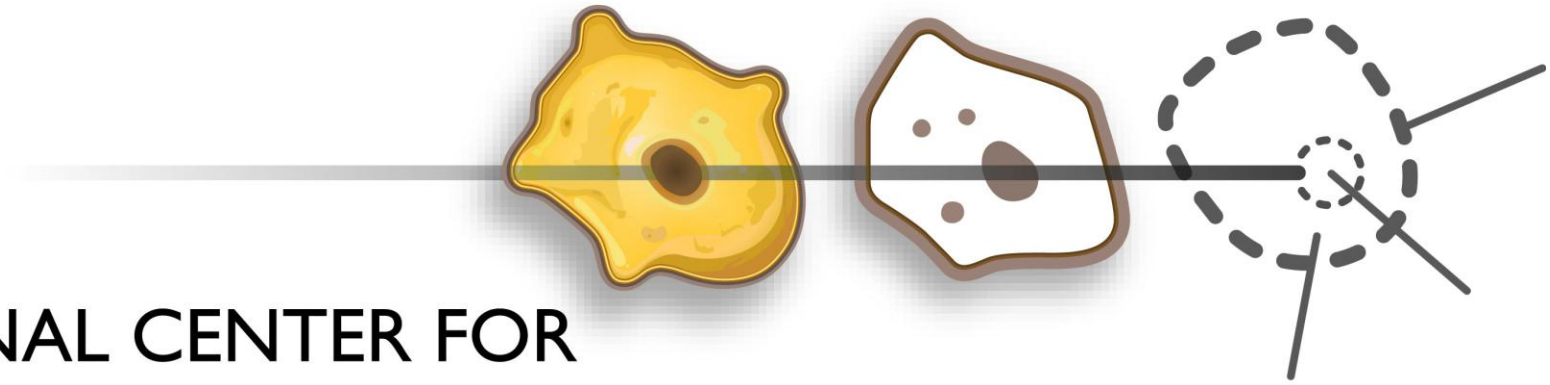


Semantic computing is crucial for biomedicine

- Myriad controlled terminologies in medicine are yielding to new ontologies
- Mandates for “meaningful use” of electronic patient records require processing of symbolic representations of patient data and situations
- The terabytes of data spewing from life-sciences laboratories cannot be managed without semantic organization and interpretation

What are the gaps?

- Intelligent services based on individual **rule bases will never scale**
- It is difficult to characterize the **feature space** that leads to a diagnosis
- It is difficult to characterize the **category space** when you decide on a diagnosis
- Imprecision in the category spaces mean **imprecision in therapeutics**
- The underlying information infrastructure is evolving—very slowly—from a 19th century model



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