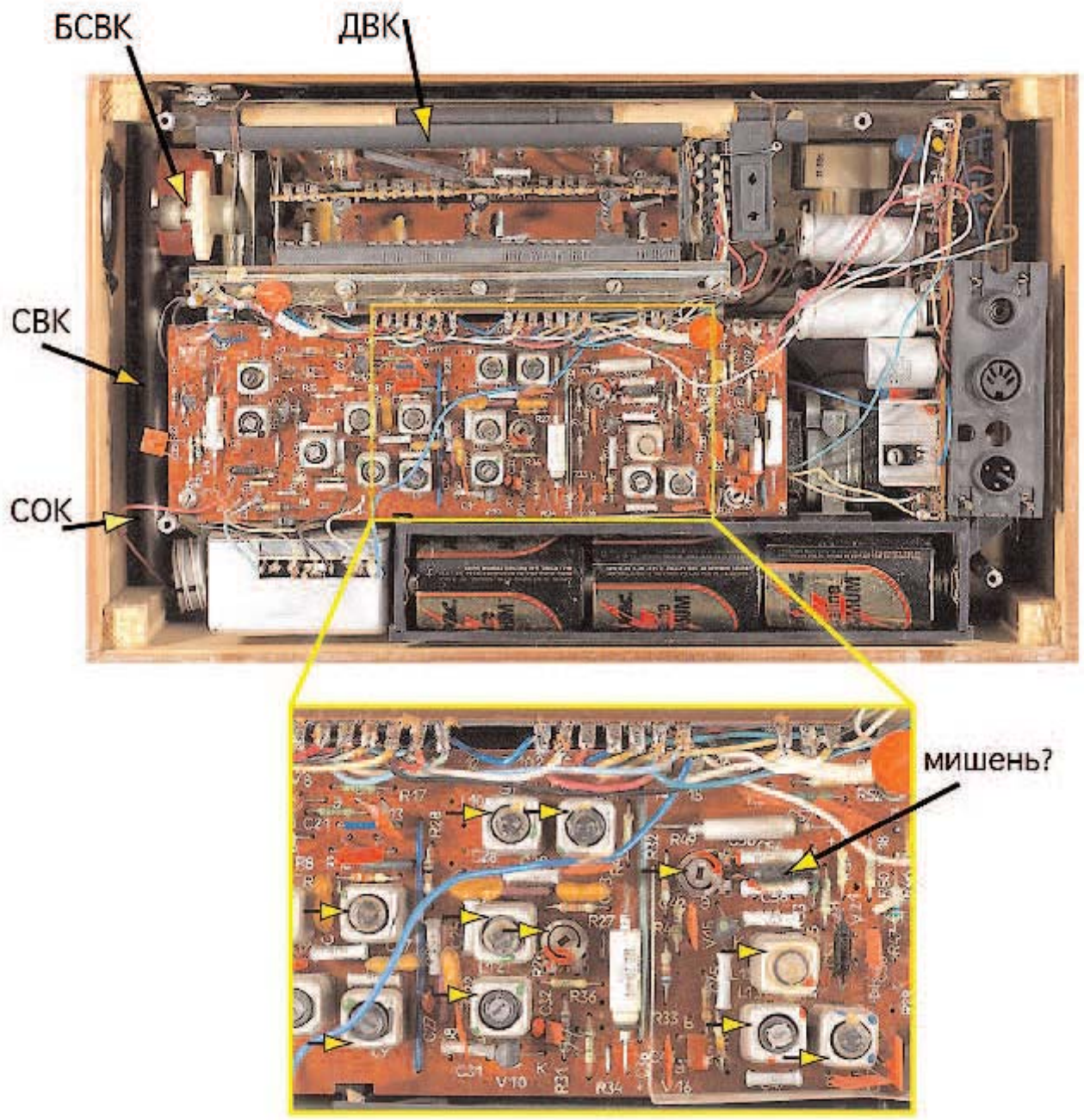
The W3C Health Care and Life Sciences Interest Group:
State of the Interest Group

M. Scott Marshall
co-chair HCLS IG
Leiden University Medical Center
&
University of Amsterdam

Biology in a nutshell: Bigger isn't better

- DNA Dogma
  - Transcription = DNA -> mRNA -> Protein
- Molecular pathways allow biologists to 'connect' one process to another.
- Huntington's mutation mapped in 1993 yet there is still no understanding of the mechanism that causes the neurodegeneration.
- Semantic models are necessary to create a 'systems view' of biology.

Can a Biologist Fix a Radio?



What is *knowledge* ?

“data”, “information”, “facts”, “knowledge”

Knowledge is a statement

that can be tested for truth.

(by a machine)

Otherwise, computing can’t add much

Knowledge Capture

- ***How will we acquire the knowledge?***
  - *Literature*
  - *Other forms of discourse*
  - *Data analysis*

- ***How will we represent and store it?***
  - *In Semantic Web formats such as RDF, OWL, RIF*

What will we do with knowledge?

- ***How will we use it?***
  - *Query it*
  - *Reason across it*
  - *Integrate it with other data*
    - ***Link it up***

Linked Data Principles

1. Use URIs as names for things.
2. Use HTTP URIs so that people can look up those names.
3. When someone looks up a URI, provide useful RDF information.
4. Include RDF statements that link to other URIs so that they can discover related things.

- Tim Berners-Lee 2007
- http://www.w3.org/DesignIssues/LinkedData.html

Background of the HCLS IG

- Originally chartered in 2005
  - Chairs: Eric Neumann and Tonya Hongsermeier
- Re-chartered in 2008
  - Chairs: Scott Marshall and Susie Stephens
  - Team contact: Eric Prud'hommeaux
- Broad industry participation
  - Over 100 members
  - Mailing list of over 600
- Background Information
  - http://www.w3.org/2001/sw/hcls/
  - http://esw.w3.org/topic/HCLSIG

Mission of HCLS IG

- The mission of HCLS is to develop, advocate for, and support the use of Semantic Web technologies for
  - Biological science
  - **Translational medicine**
  - Health care

- These domains stand to gain tremendous benefit by adoption of Semantic Web technologies, as they depend on the interoperability of information from many domains and processes for efficient decision support

Group Activities

- Document **use cases** to aid individuals in understanding the business and technical benefits of using Semantic Web technologies

- Document **guidelines** to accelerate the adoption of the technology

- Implement a selection of the use cases as proof-of-concept **demonstrations**

- Develop high-level **vocabularies**

- **Disseminate information** about the group's work at government, industry, and academic events

What are we about?

- Creating applications that solve *real* problems with *real* data and documenting what we did.
- Deliverables:
  - Software
  - Methodologies
  - Vocabularies
  - Documentation
    - Journals, workshops, conferences
    - W3C notes

Current Task Forces

- **BioRDF – integrated neuroscience knowledge base**
  - **Kei Cheung (Yale University)**
- **Clinical Observations Interoperability – patient recruitment in trials**
  - **Vipul Kashyap (Cigna Healthcare)**
- **Linking Open Drug Data – aggregation of Web-based drug data**
  - **Anja Jentzsch (Free University Berlin)**
- **Pharma Ontology – high level patient-centric ontology**
  - **Christi Denney (Eli Lilly)**
- **Scientific Discourse – building communities through networking**
  - **Tim Clark (Harvard University)**
- **Terminology – Semantic Web representation of existing resources**
  - **John Madden (Duke University)**

BioRDF Task Force

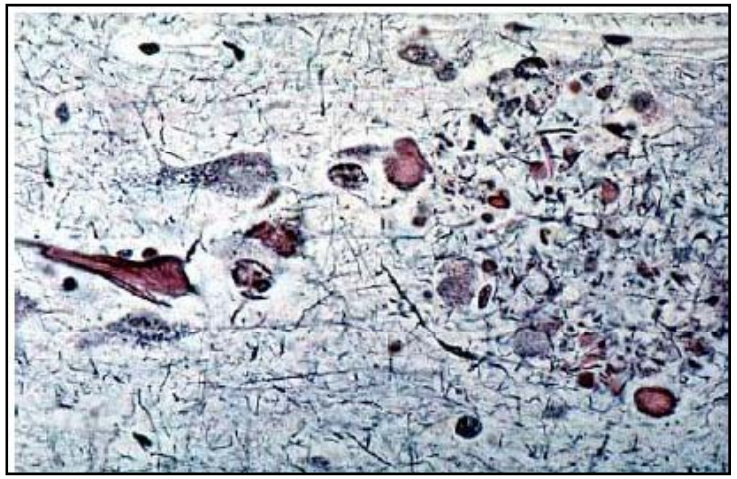
- Kei Cheung (Yale University)
- Helena Deus (University of Texas)
- Rob Frost (Vector C)
- Kingsley Idehen (OpenLink Software)
- Scott Marshall (University of Amsterdam)
- Adrian Paschke (Freie Universitat Berlin)
- Eric Prud'hommeaux (W3C)
- Satya Sahoo (Wright State University)
- Matthias Samwald (DERI and Konrad Lorenz Institute)
- Jun Zhao (Oxford University)

BioRDF: Answering Questions

- **Goals: Get answers to questions posed to a body of collective knowledge in an effective way**
- **Knowledge used: Publicly available databases, and text mining**
- **Strategy: Integrate knowledge using careful modeling, exploiting Semantic Web standards and technologies**

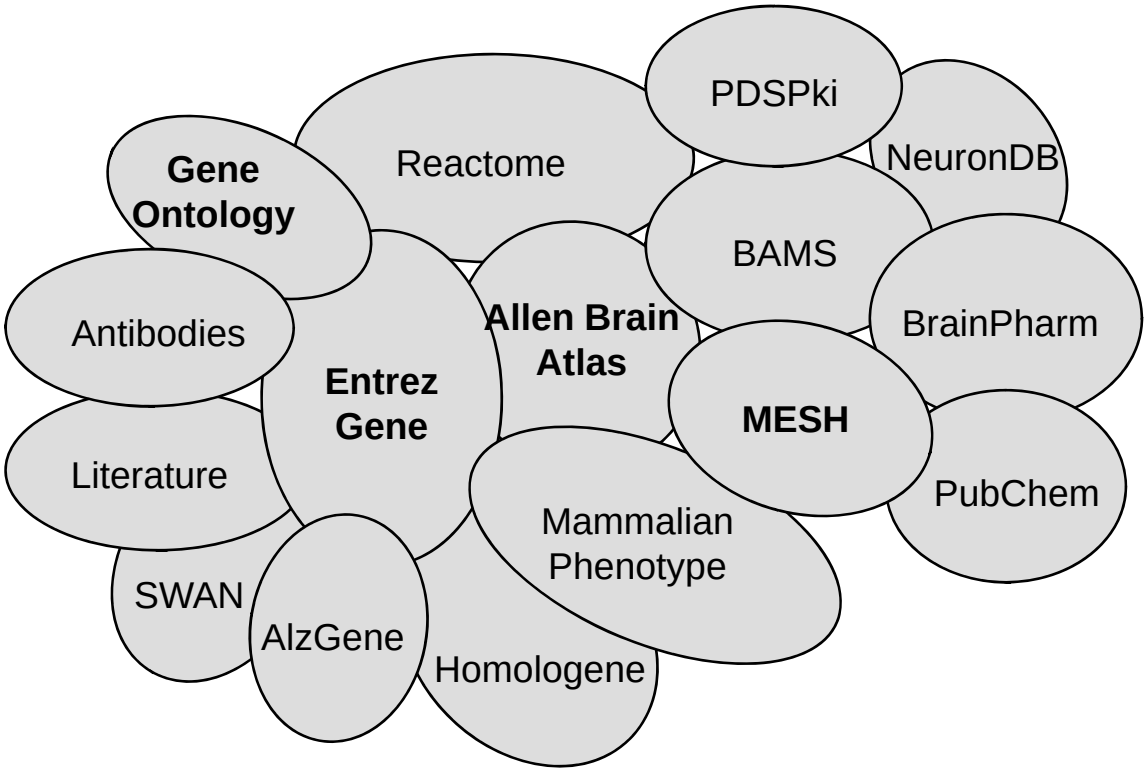
BioRDF: Looking for Targets for Alzheimer's

- **Signal transduction pathways are considered to be rich in "druggable" targets**
- **CA1 Pyramidal Neurons are known to be particularly damaged in Alzheimer's disease**
- **Casting a wide net, can we find candidate genes known to be involved in signal transduction and active in Pyramidal Neurons?**



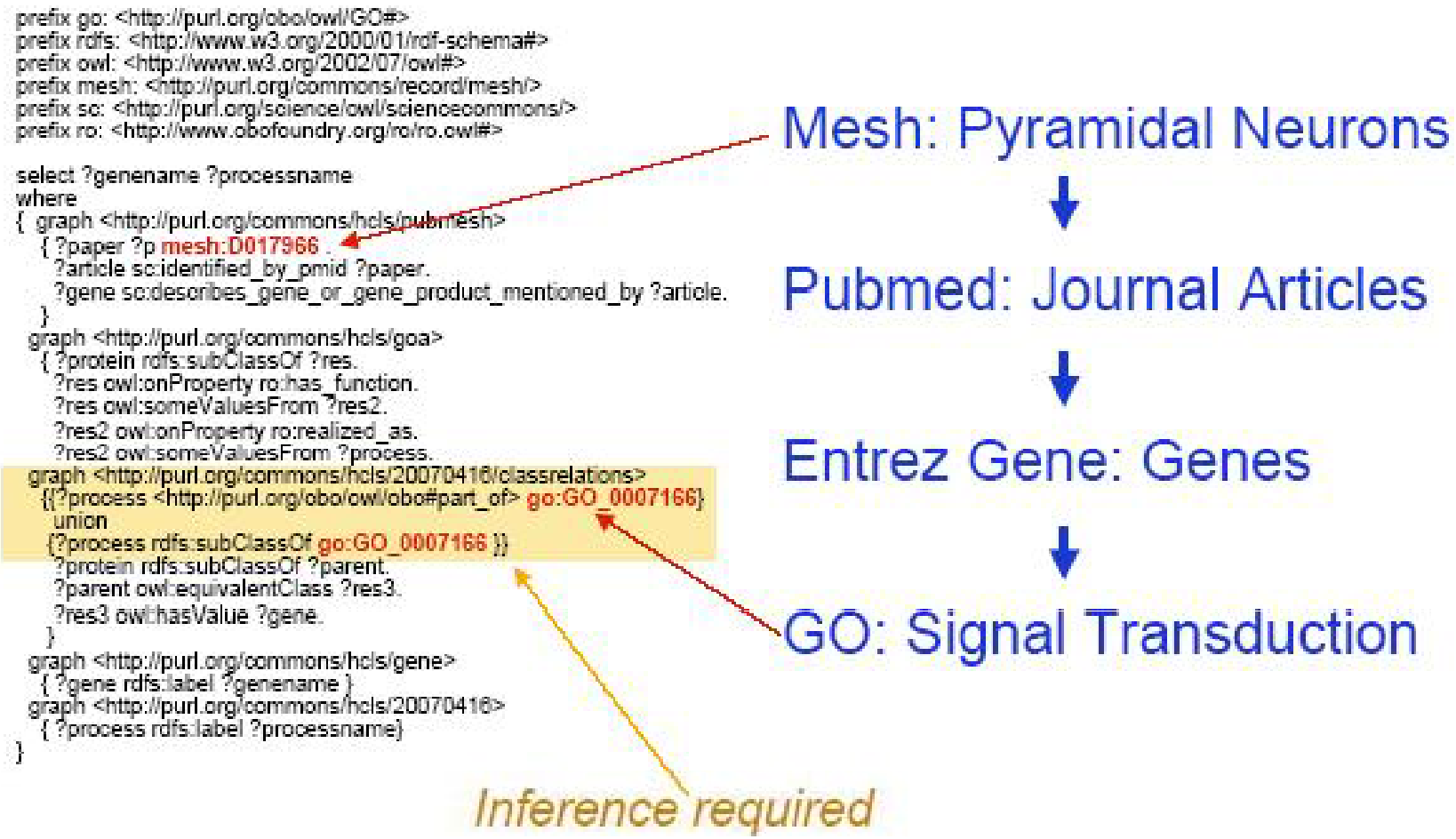
Source: Alan Ruttenberg

BioRDF: Integrating Heterogeneous Data



Source: Susie Stephens

BioRDF: SPARQL Query



Source: Alan Ruttenberg

BioRDF: Results: Genes, Processes

•DRD1, 1812	adenylate cyclase activation
•ADRB2, 154	adenylate cyclase activation
•ADRB2, 154	arrestin mediated desensitization of G-protein coupled receptor protein signaling pathway
•DRD1IP, 50632	dopamine receptor signaling pathway
•DRD1, 1812	dopamine receptor, adenylate cyclase activating pathway
•DRD2, 1813	dopamine receptor, adenylate cyclase inhibiting pathway
•GRM7, 2917	G-protein coupled receptor protein signaling pathway
•GNG3, 2785	G-protein coupled receptor protein signaling pathway
•GNG12, 55970	G-protein coupled receptor protein signaling pathway
•DRD2, 1813	G-protein coupled receptor protein signaling pathway
•ADRB2, 154	G-protein coupled receptor protein signaling pathway
•CALM3, 808	G-protein coupled receptor protein signaling pathway
•HTR2A, 3356	G-protein coupled receptor protein signaling pathway
•DRD1, 1812	G-protein signaling, coupled to cyclic nucleotide second messenger
•SSTR5, 6755	G-protein signaling, coupled to cyclic nucleotide second messenger
•MTNR1A, 4543	G-protein signaling, coupled to cyclic nucleotide second messenger
•CNR2, 1269	G-protein signaling, coupled to cyclic nucleotide second messenger
•HTR6, 3362	G-protein signaling, coupled to cyclic nucleotide second messenger
•GRIK2, 2898	glutamate signaling pathway
•GRIN1, 2902	glutamate signaling pathway
•GRIN2A, 2903	glutamate signaling pathway
•GRIN2B, 2904	glutamate signaling pathway
•ADAM10, 102	integrin-mediated signaling pathway
•GRM7, 2917	negative regulation of adenylate cyclase activity
•LRP1, 4035	negative regulation of Wnt receptor signaling pathway
•ADAM10, 102	Notch receptor processing
•ASCL1, 429	Notch signaling pathway
•HTR2A, 3356	serotonin receptor signaling pathway
•ADRB2, 154	transmembrane receptor protein tyrosine kinase activation (dimerization)
•PTPRG, 5793	ransmembrane receptor protein tyrosine kinase signaling pathway
•EPHA4, 2043	transmembrane receptor protein tyrosine kinase signaling pathway
•NRTN, 4902	transmembrane receptor protein tyrosine kinase signaling pathway
•CTNND1, 1500	Wnt receptor signaling pathway

Many of the genes are related to AD through gamma secretase (presenilin) activity

Source: Alan Ruttenberg

Current activities

- **HCLS KB's**
  - **DERI Galway and Freie Universitat Berlin**
- **Query federation and aTag**
- **Publication**
  - **Cheung KH, Frost HR, Marshall MS, Prud'hommeaux E, Samwald M, Zhao J, Paschke A. (2009). A Journey to Semantic Web Query Federation in Life Sciences. BMC Bioinformatics, 10(Suppl 10):S10.**

Source: Kei Cheung

Near future activities

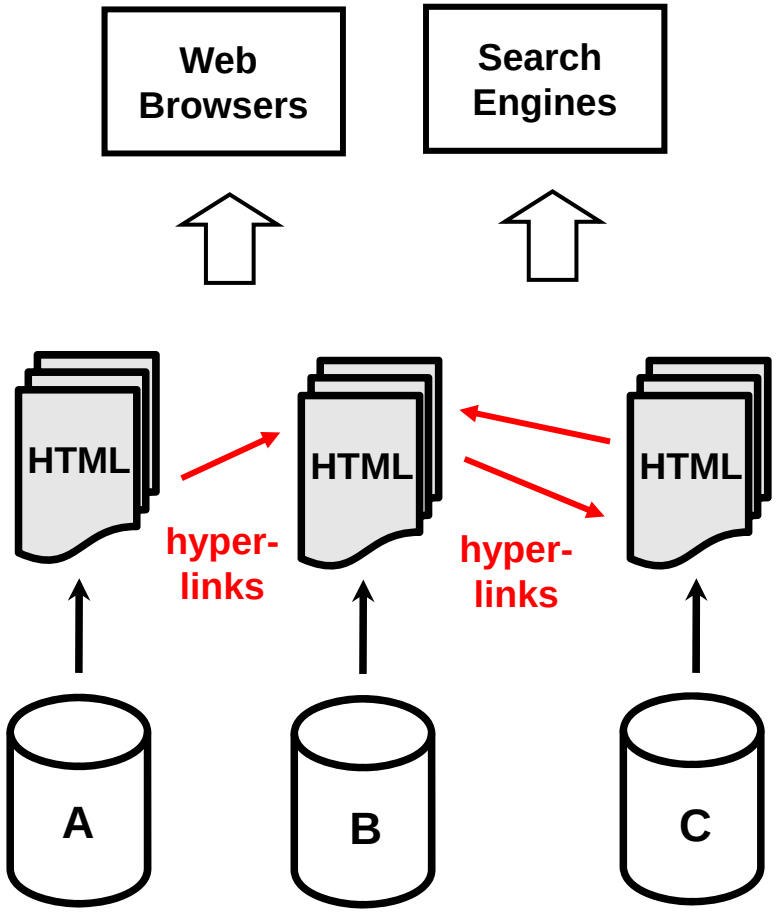
- **Expansion of query federation**
  - **Incorporation of new data types including neuroscience microarray data, image data and TCM data**
  - **Inter-community collaboration with NIF (NeuroLex) and MGED (EBI Expression Atlas)**

Source: Kei Cheung

Linking Open Drug Data

- HCLSIG task started October 1st, 2008
- Primary Objectives
  - Survey publicly available data sets about drugs
  - Explore interesting questions from pharma, physicians and patients that could be answered with Linked Data
  - Publish and interlink these data sets on the Web
- Participants: Bosse Andersson, Chris Bizer, Kei Cheung, Don Doherty, Oktie Hassanzadeh, Anja Jentzsch, Scott Marshall, Eric Prud'hommeaux, Matthias Samwald, Susie Stephens, Jun Zhao

The Classic Web

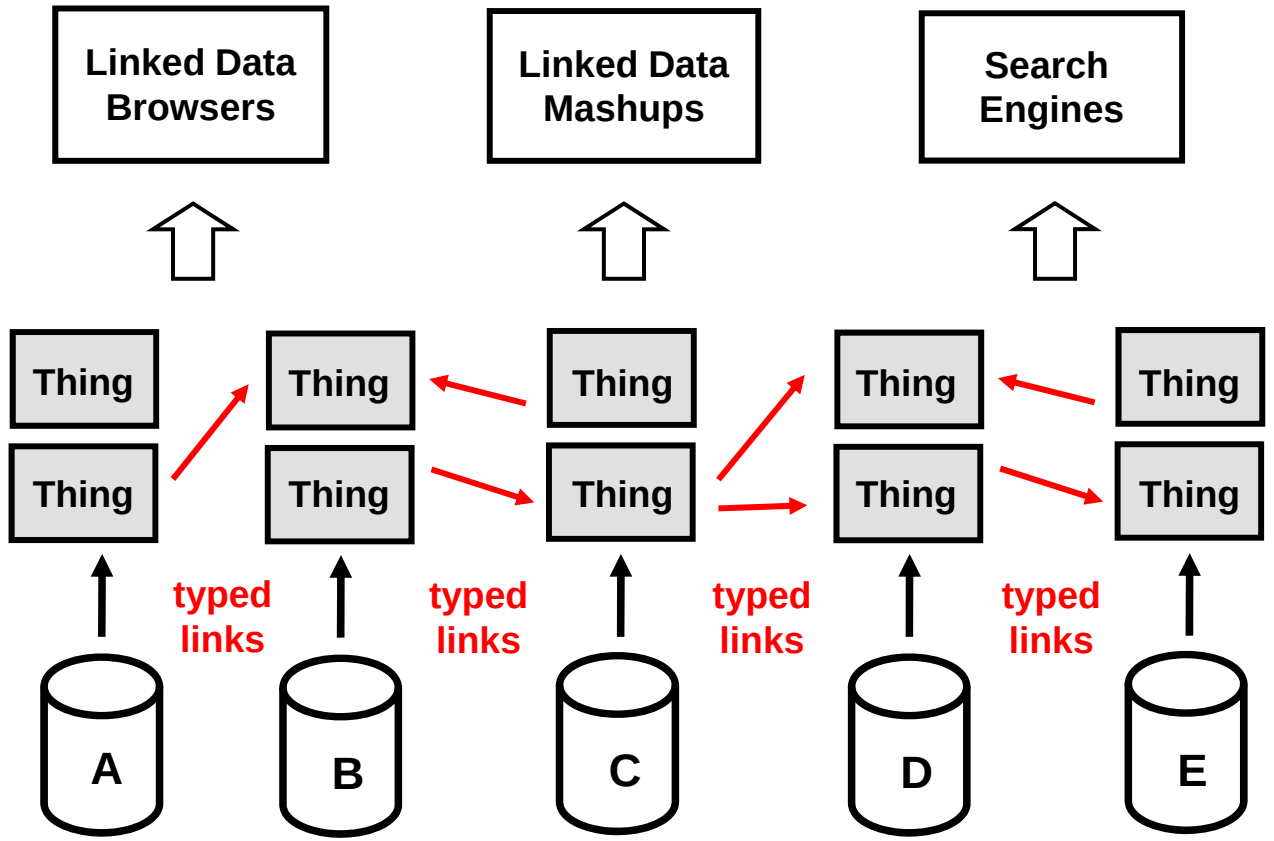


- Single information space
- Built on URIs
  - globally unique IDs
  - retrieval mechanism
- Built on Hyperlinks
  - are the glue that holds everything together

Source: Chris Bizer

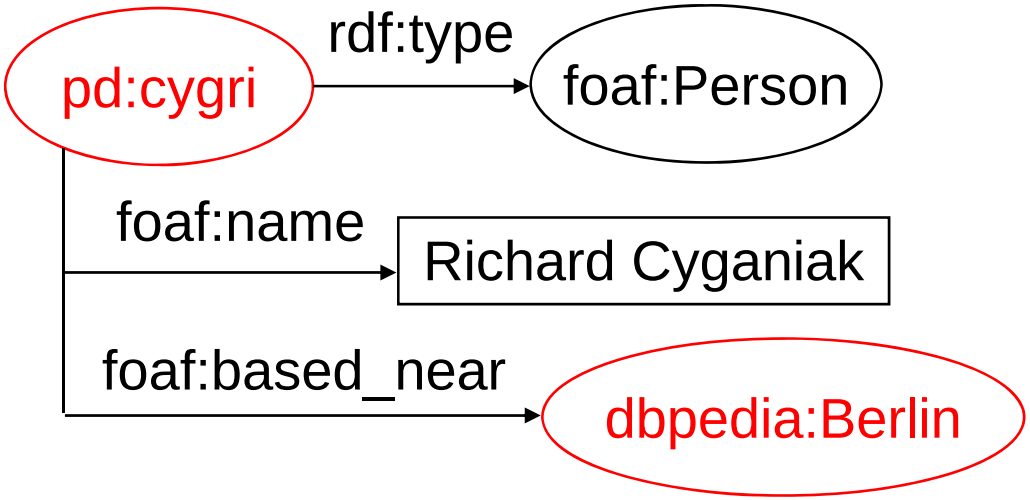
Linked Data

Use Semantic Web technologies to publish structured data on the Web and set links between data from one data source and data from another data sources



Source: Chris Bizer

Data Objects Identified with HTTP URIs



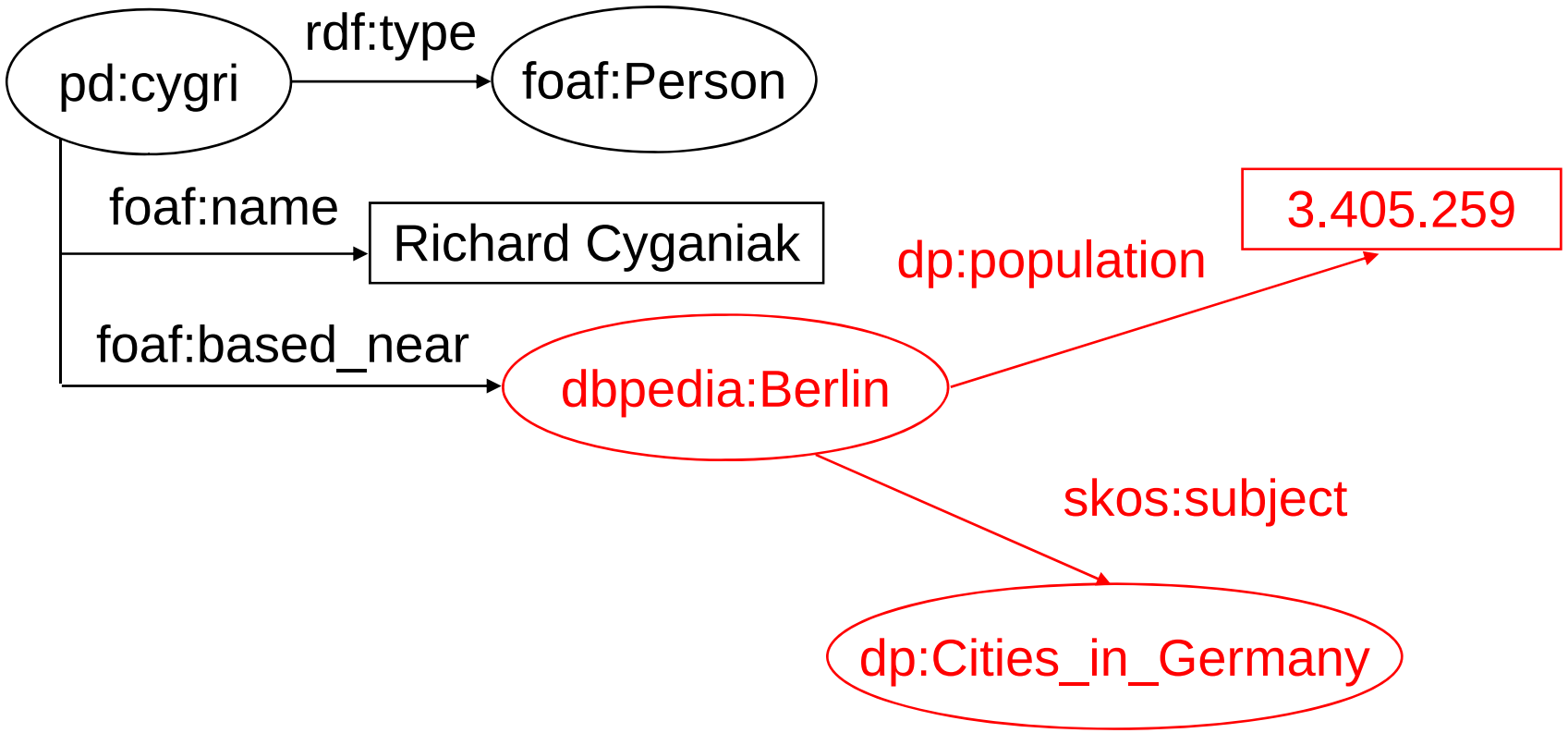
pd:cygri = http://richard.cyganiak.de/foaf.rdf#cygri

dbpedia:Berlin = http://dbpedia.org/resource/Berlin

Forms an RDF link between two data sources

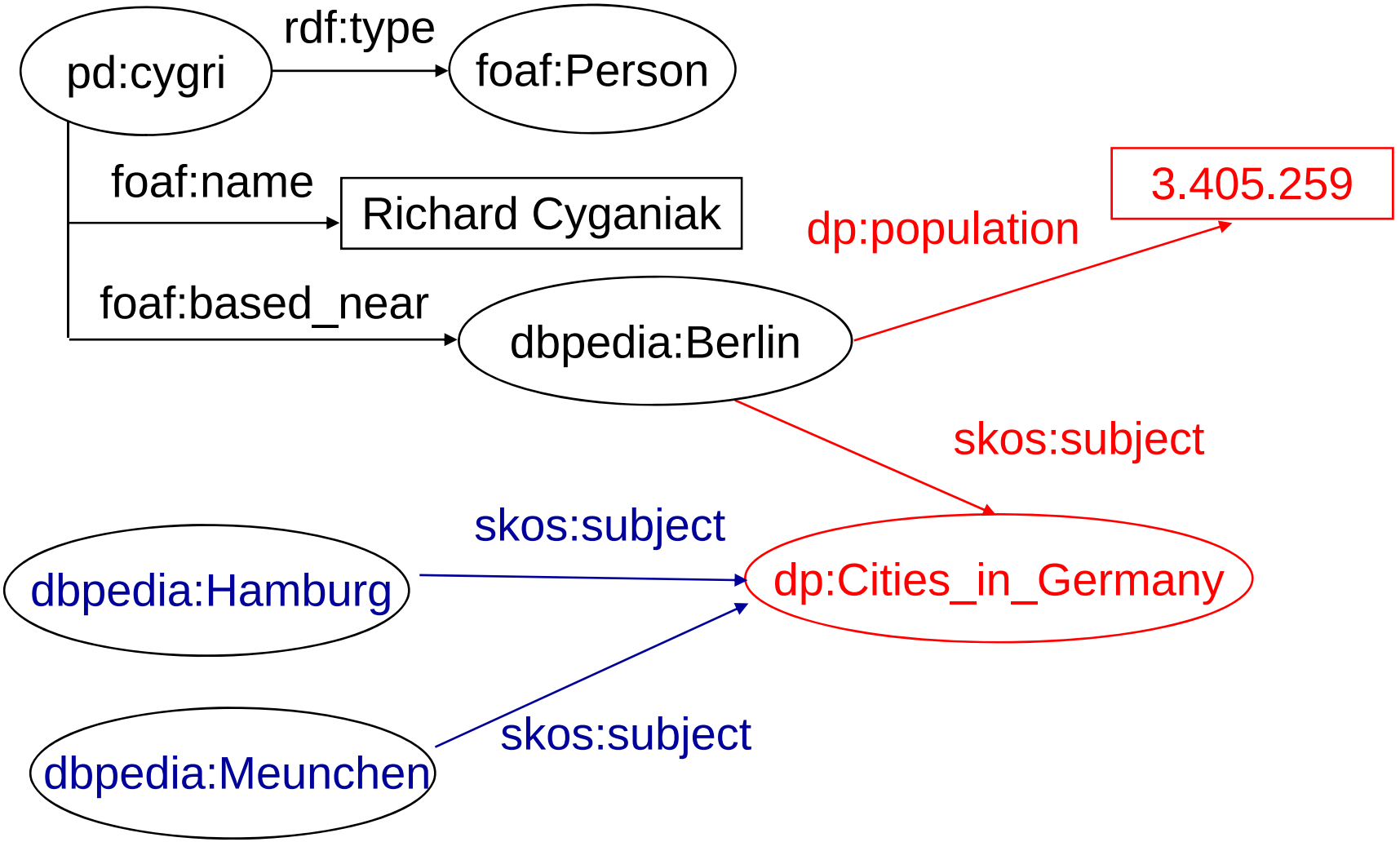
Source: Chris Bizer

Dereferencing URIs over the Web



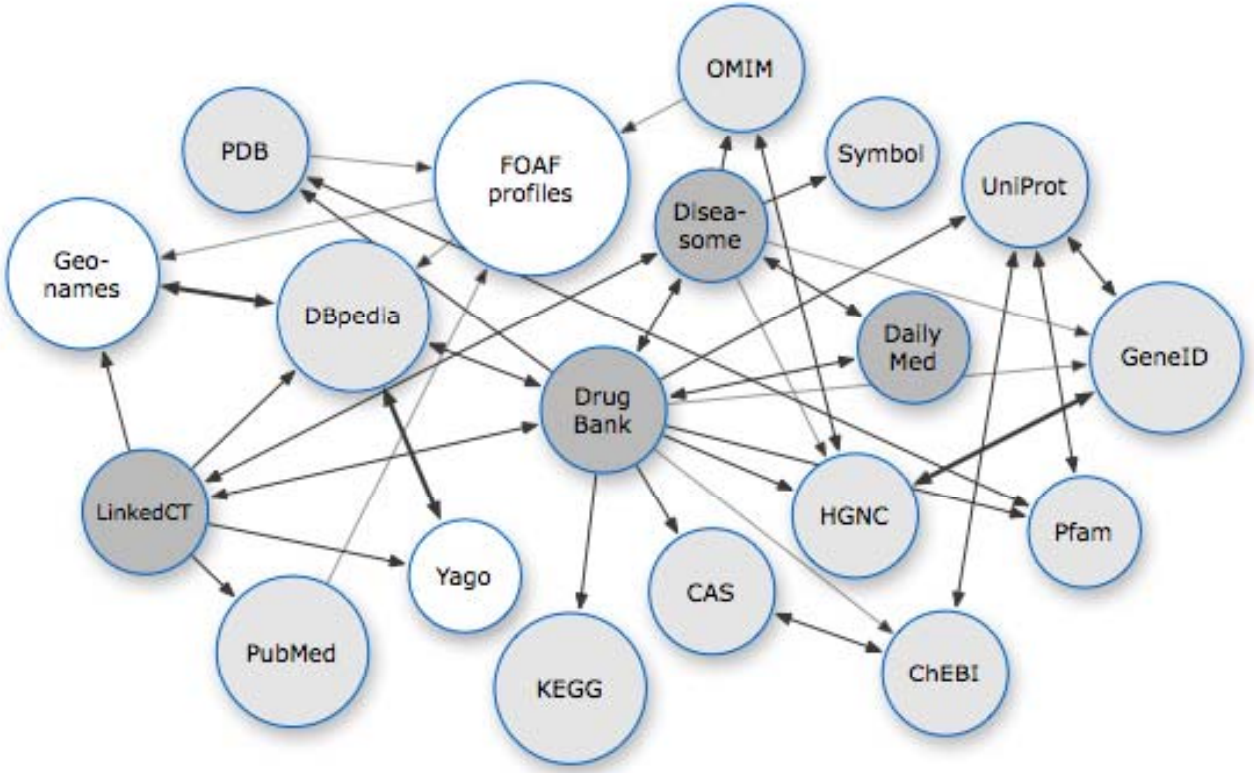
Source: Chris Bizer

Dereferencing URIs over the Web



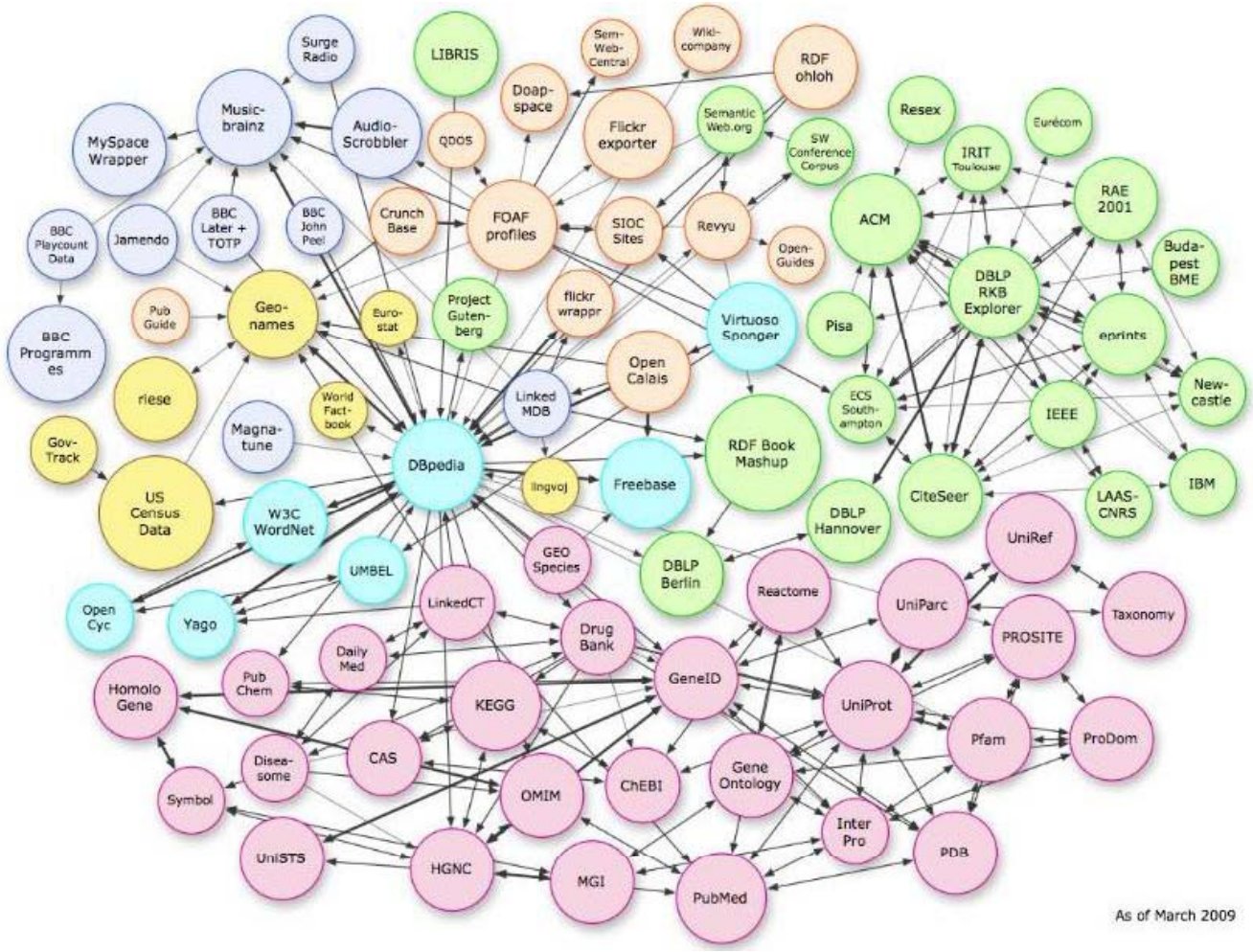
Source: Chris Bizer

LODD Data Sets



Source: Anja Jentzsch

The Linked Data Cloud



Source: Chris Bizer

COI Task Force

- **Task Lead: Vipul Kashap**
- **Participants: Eric Prud'hommeaux, Helen Chen, Jyotishman Pathak, Rachel Richesson, Holger Stenzhorn**

COI: Bridging Bench to Bedside

- How can existing Electronic Health Records (EHR) formats be reused for patient recruitment?
- Quasi standard formats for clinical data:
  - HL7/RIM/DCM – healthcare delivery systems
  - CDISC/SDTM – clinical trial systems
- How can we map across these formats?
  - Can we ask questions in one format when the data is represented in another format?

Source: Holger Stenzhorn

COI: Use Case

Pharmaceutical companies pay a lot to test drugs

Pharmaceutical companies express protocol in CDISC

-- precipitous gap –

Hospitals exchange information in HL7/RIM

Hospitals have relational databases

Source: Eric Prud'hommeaux

Inclusion Criteria

- Type 2 diabetes on diet and exercise therapy or
- monotherapy with metformin, insulin
- secretagogue, or alpha-glucosidase inhibitors, or
- a low-dose combination of these at 50%
- maximal dose. Dosing is stable for 8 weeks prior
- to randomization.
- …
- `?patient takes meformin .`

Source: Holger Stenzhorn

Exclusion Criteria

Use of warfarin (Coumadin), clopidogrel (Plavix) or other anticoagulants.

…

```
?patient doesNotTake anticoagulant .
```

Source: Holger Stenzhorn

Criteria in SPARQL

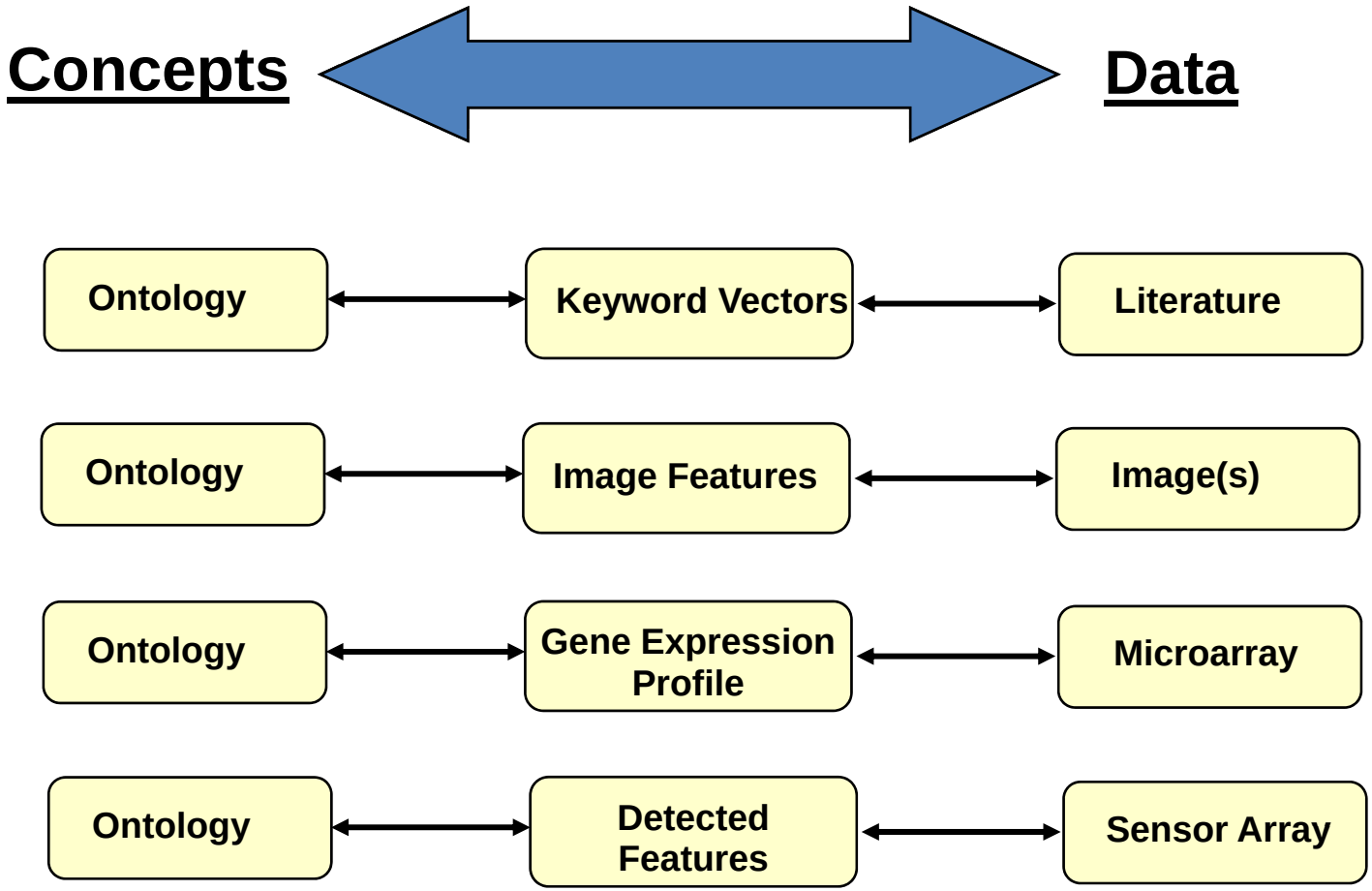
```
?medication1 sdtm:subject ?patient ;
   spl:activeIngredient ?ingredient1 .
?ingredient1 spl:classCode 6809 . #metformin

OPTIONAL {

  ?medication2 sdtm:subject ?patient ;
    spl:activeIngredient ?ingredient2 .
  ?ingredient2 spl:classCode 11289 .
                              #anticoagulant

} FILTER (!BOUND(?medication2))
```

Source: Holger Stenzhorn

Terminology Task Force

- **Task Lead: John Madden**
- **Participants: Chimezie Ogbuji, M. Scott Marshall, Helen Chen, Holger Stenzhorn, Mary Kennedy, Xiashu Wang, Rob Frost, Jonathan Borden, Guoqian Jiang**

Features: the “bridge” to meaning



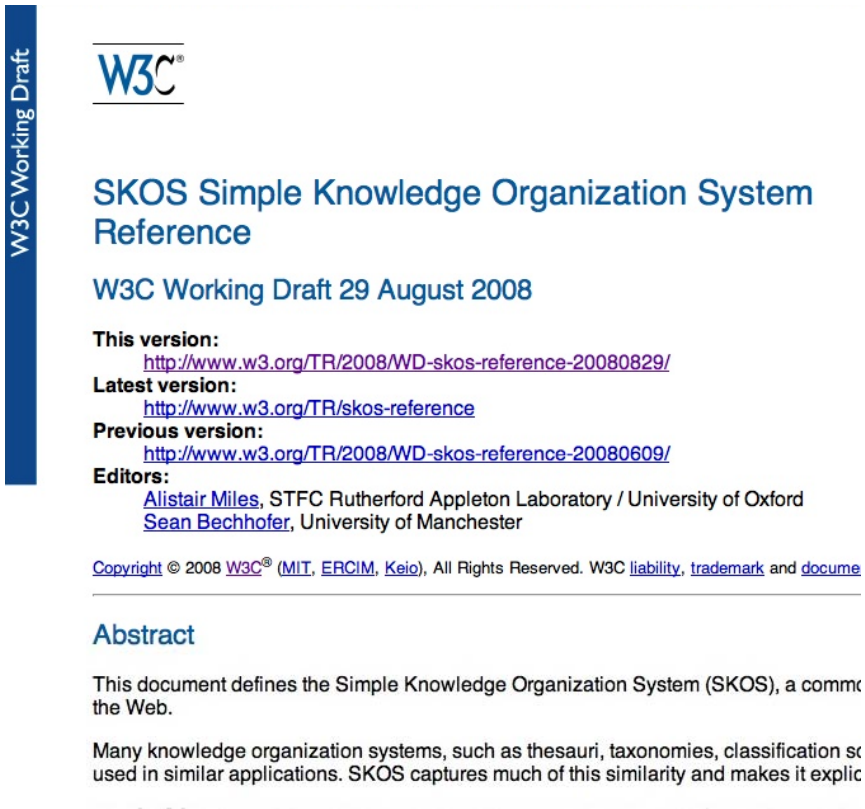
Terminology: Overview

- Goal is to identify use cases and methods for extracting Semantic Web representations from existing, standard medical record terminologies, e.g. UMLS
- Methods should be reproducible and, to the extent possible, not lossy
- Identify and document issues along the way related to identification schemes, expressiveness of the relevant languages
- Initial effort will start with SNOMED-CT and UMLS Semantic Networks and focus on a particular sub-domain (e.g. pharmacological classification)

Source: John Madden

SKOS & the 80/20 principle: map “down”

- Minimal assumptions about expressiveness of source terminology
- No assumed formal semantics (no model theory)
- Treat it as a knowledge “map”
- Extract 80% of the utility without risk of falsifying intent



W3C Working Draft

W3C

SKOS Simple Knowledge Organization System Reference

W3C Working Draft 29 August 2008

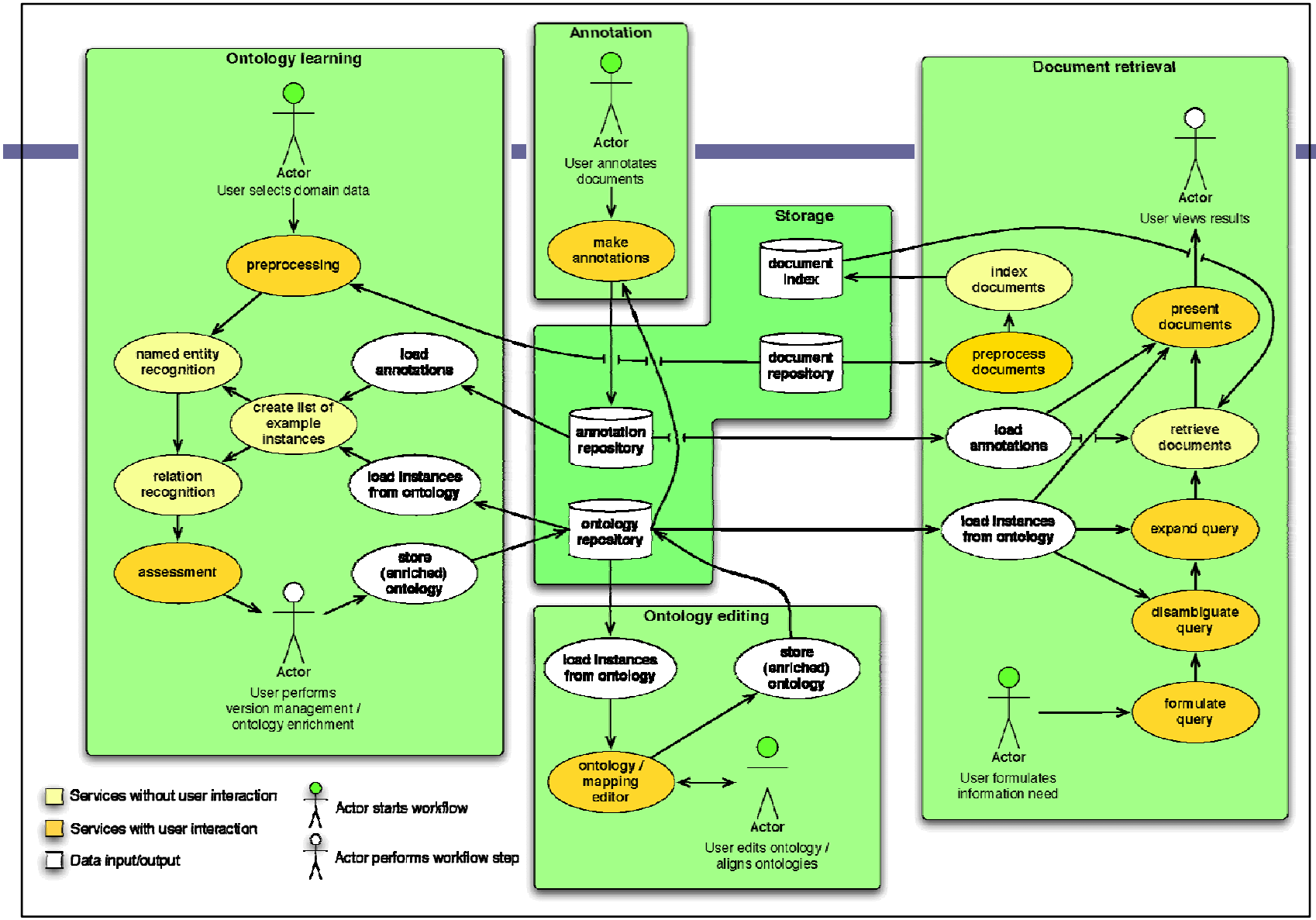
This version:
http://www.w3.org/TR/2008/WD-skos-reference-20080829/
Latest version:
http://www.w3.org/TR/skos-reference
Previous version:
http://www.w3.org/TR/2008/WD-skos-reference-20080609/
Editors:
Alistair Miles, STFC Rutherford Appleton Laboratory / University of Oxford
Sean Bechhofer, University of Manchester

Abstract

This document defines the Simple Knowledge Organization System (SKOS), a comm
the Web.

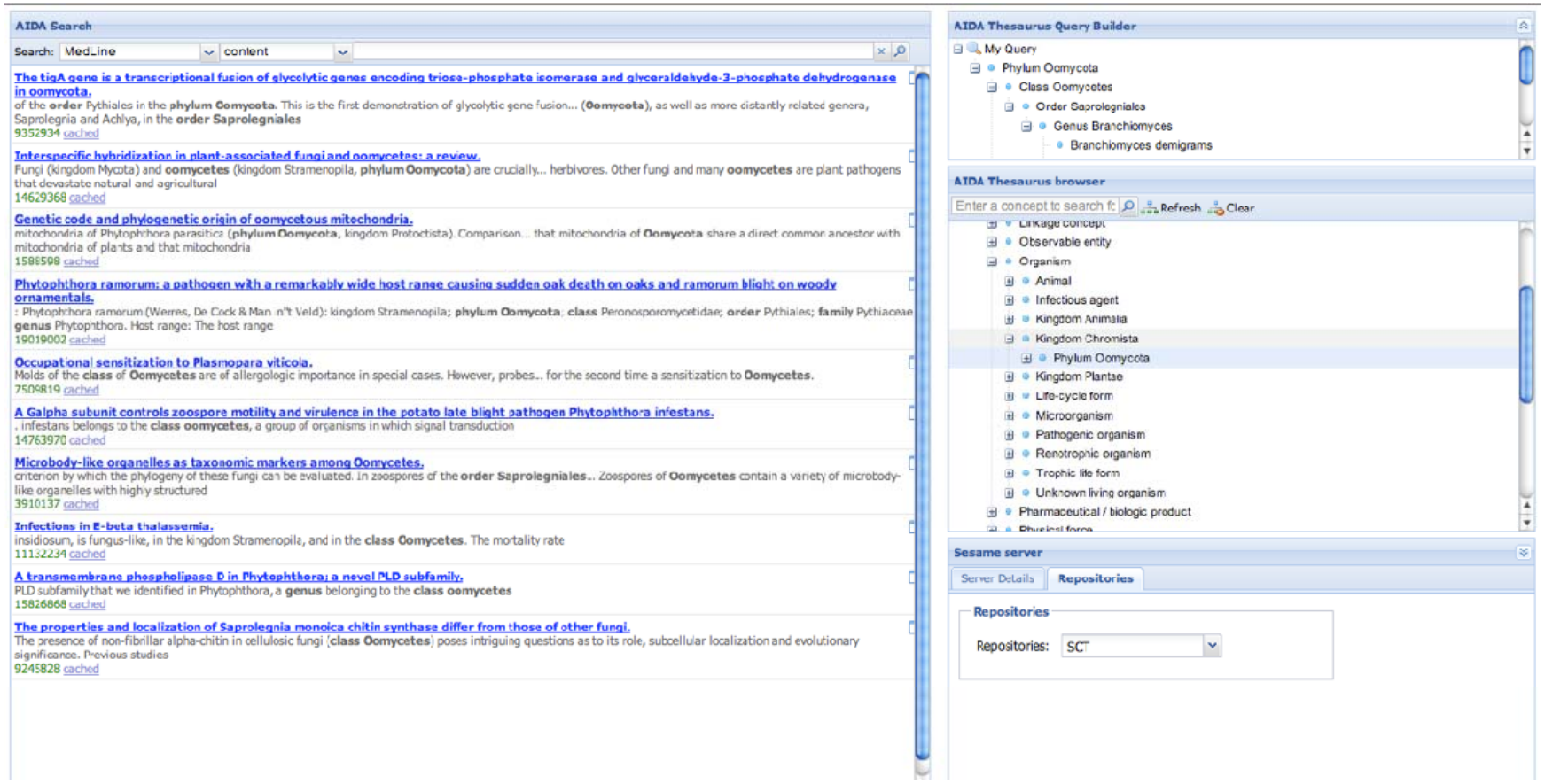
Many knowledge organization systems, such as thesauri, taxonomies, classification s
used in similar applications. SKOS captures much of this similarity and makes it explic

Source: John Madden



The **AIDA** toolbox
for knowledge extraction and knowledge management
in a Virtual Laboratory for e-Science

SNOMED CT/SKOS under AIDA: retrieve



AIDA Search

http://ws.adaptivedisclosure.org/search/

Inquisitor

AIDA Search

Search: huntington | content

Purisai.Neurobiol_Dis.2006.17166727.pdf
of **paraquat** with molecular oxygen. Besides **paraquat** and other bipyridyl **pesticides** (e.g., **diquat**.... Keywords: Parkinson?s disease; Substantia nigra; **Paraquat**; Pesticide; Microglia; Inflammation; NADPH
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Bove.NeuroRx.2005.16389312.pdf
, **rotenone**, **paraquat**. INTRODUCTION Parkinson?s disease (PD) is currently regarded as the most common...- tetrahydropyridine (MPTP), **rotenone**, and **paraquat**. The main goal is to provide an updated summary of the main
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hague-j_neurosurg_psychiatry-2005-16024878.pdf
. 10 Khan **N**, Graham E, Dixon **P**, et al. Parkinson?**s** disease is not associated with the combined **alpha**... DM, Lockhart **P**, et al. **Alpha**-synuclein gene haplotypes are associated with Parkinson?**s** disease. Hum
/scratch/emeij/huntington/Literature_Repository/hague-j_neurosurg_psychiatry-2005-16024878.pdf cached

McBride.J_Comp_Neurol.2004.15211462.pdf
JODI L. MCBRIDE, 1 SOSHANA **P**. BEHRSTOCK, 2 ER-YUN CHEN, **1** REBEKAH J. JAKEL, 2 IRWIN SIEGEL, 1 CLIVE **N**...: quinolinic **acid**; human neurospheres; xenograft; proliferation; migration; differentiation Huntir
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Janhumen.Naunyn_Schmiedebergs_Arch
fmol, **n**=10, saline: 72±23 fmol, **n**=6, means± endogenous dopaminergic transmission
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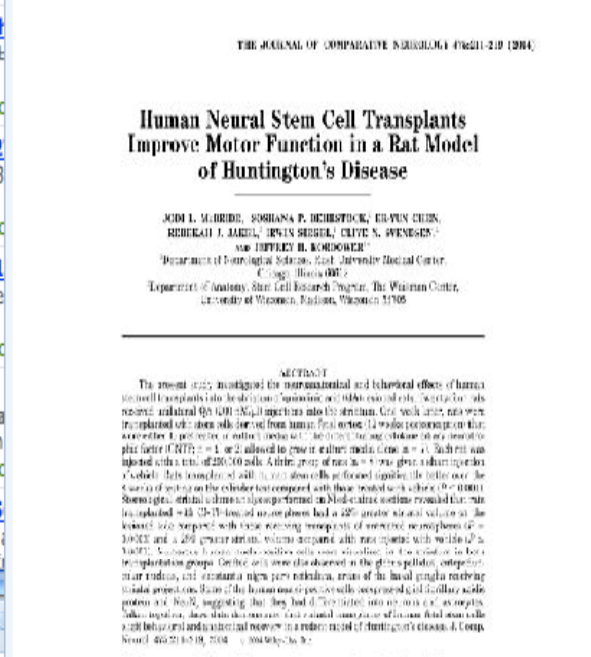
Janhunen.Eur_J_Pharmacol.2005.15792
receptor subtypes containing at least a4h2, a3 Janhunen et al. / European Journal144
/scratch/emeij/huntington/Literature_Reposito

OsakadaJ_Pharmacol_Exp_Ther.2004.1
with those of di- **methyl** sulfoxide (DMSO), be glutamate receptor, or 3-nitropropionic **acid**
/scratch/emeij/huntington/Literature_Reposito

perry-n_engl_j_med-1978-148007.pdf
- **acetate** is the most effective inhibitor of **ga acid**: drug- induced elevation in monkey brain
/scratch/emeij/huntington/Literature_Reposito

Mizuno.Neuropharmacology.2004.14975
et al., 1995; Giulian et al., 1995). Exposure to **methyl**-l-arginine (l-NMMA) were purchased f



THE JOURNAL OF COMPARATIVE NEUROLOGY 476:211–218 (2004)

Human Neural Stem Cell Transplants Improve Motor Function in a Rat Model of Huntington's Disease

JODI L. MCBRIDE, SOSHANA P. BEHRSTOCK, ER-YUN CHEN, REBEKAH J. JAKEL, IRWIN SIEGEL, CLIVE N. SVENDSEN AND JEFFREY H. KORDOWER

ABSTRACT

n To investigate **nicotine s** effects on

ed

urther enhanced the effects of **nicotine**, **S**.

N-**methyl**-D-aspartate sub- type of the

art **N**, Hansen **S**, et al: ,?-Aminobutyric

an). Lipopolysaccharide (LPS) and **N** G -

Page 1 of 20

and residues" "2-napthyloxyacetic aci...

AIDA Thesaurus Query Builder

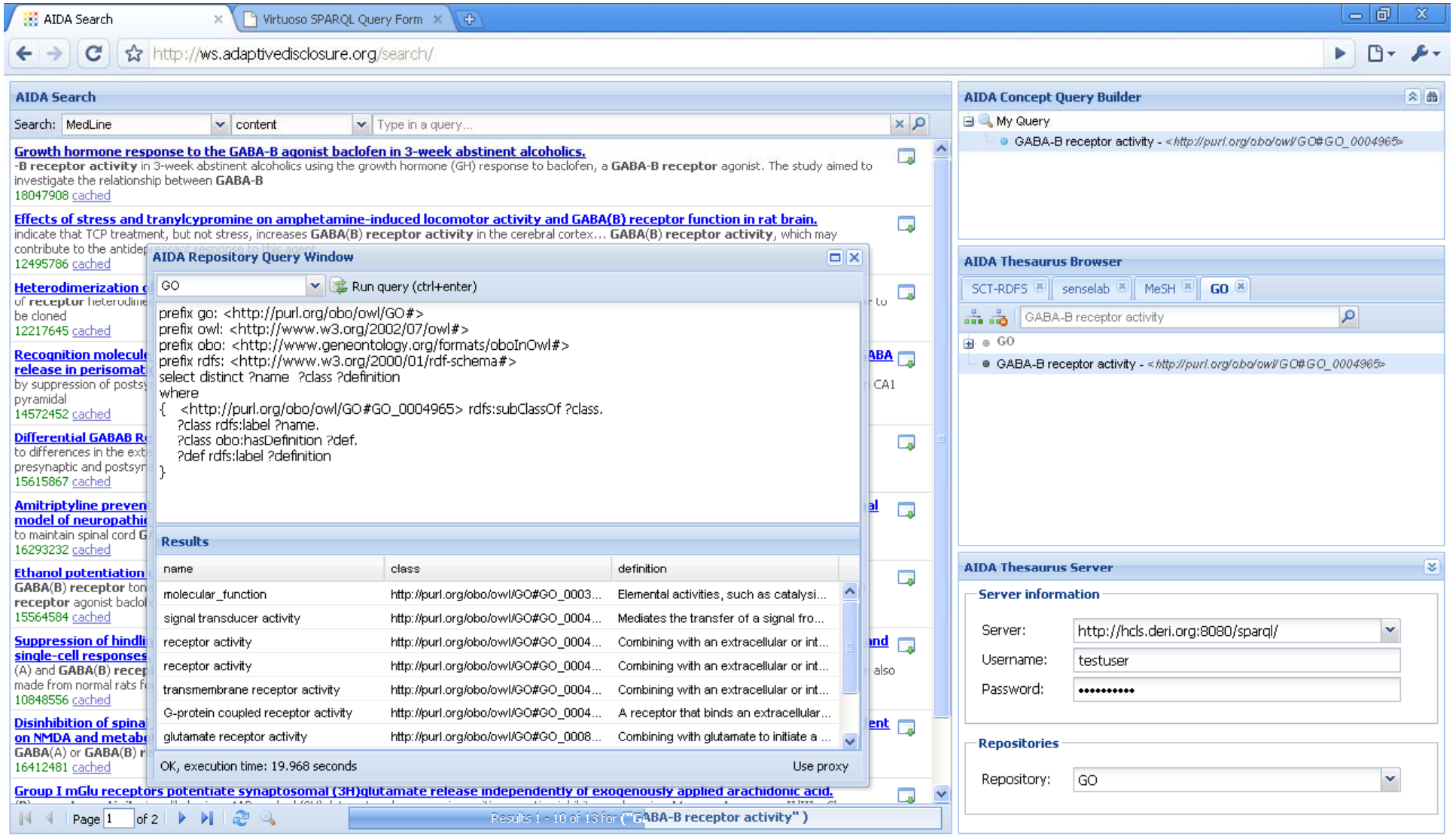
- My Query
  - pesticides and residues
    - 2-napthyloxyacetic acid
    - 3-chloro-1 2-propanediol
    - 4-cpa
    - acaricide

AIDA Thesaurus browser

Enter a concept to search fc | Refresh | Clear

- TNO
  - food and feed
  - hazards
    - hazards by effect
      - allergens
      - probable carcinogens
        - 1 1 1 2-tetrachloroethane
        - 1 1 1-trichloroethane
        - 1 1 2 2-tetrachloroethane
        - 1 1 2-trichloroethane
        - 1 1-dimethylhydrazine
        - 1 2 3-trichloropropane
        - 1 2 3-tris(chloromethoxy)propane
        - 1 2-bis(chloromethoxy)ethane
        - 1 2-diamino-4-nitrobenzene
        - 1 2-dibromo-3-chloropropane
        - 1 2-dichloroethane
        - 1 2-dichloropropane
        - 1 2-diethylhydrazine
        - 1 2-dimethylhydrazine
        - 1 2-epoxybutane

Open # on this page in a new tab


AIDA Search
Virtuoso SPARQL Query Form
http://ws.adaptivedisclosure.org/search/
AIDA Search
Search: MedLine content Type in a query...
Growth hormone response to the GABA-B agonist baclofen in 3-week abstinent alcoholics.
-B receptor activity in 3-week abstinent alcoholics using the growth hormone (GH) response to baclofen, a GABA-B receptor agonist. The study aimed to investigate the relationship between GABA-B
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Effects of stress and tranylcypromine on amphetamine-induced locomotor activity and GABA(B) receptor function in rat brain.
indicate that TCP treatment, but not stress, increases GABA(B) receptor activity in the cerebral cortex... GABA(B) receptor activity, which may contribute to the antide
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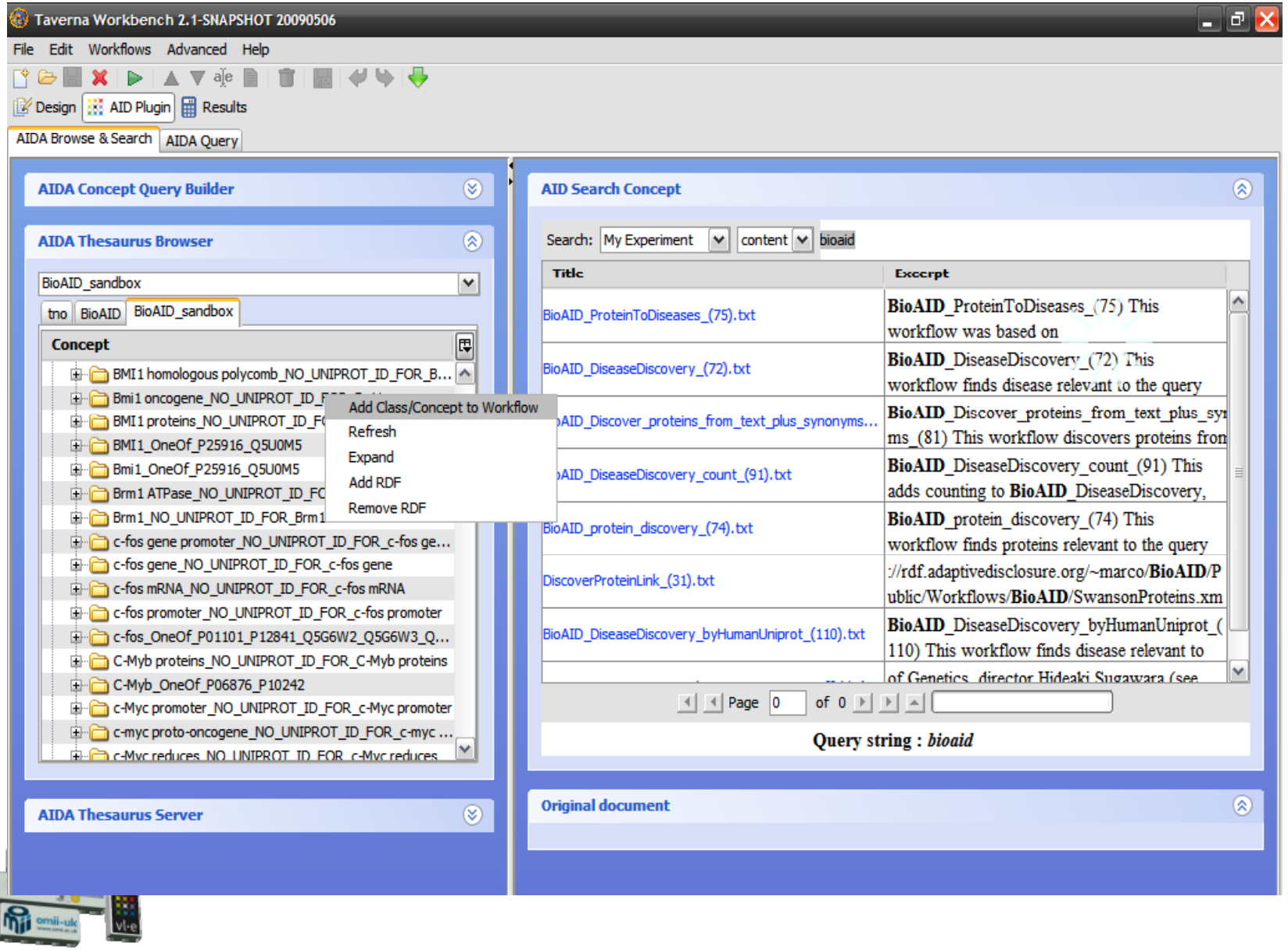
AIDA Repository Query Window
GO
Run query (ctrl+enter)
prefix go: <http://purl.org/obo/owl/GO#>
prefix owl: <http://www.w3.org/2002/07/owl#>
prefix obo: <http://www.geneontology.org/formats/oboInOwl#>
prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#>
select distinct ?name ?class ?definition
where
{ <http://purl.org/obo/owl/GO#GO_0004965> rdfs:subClassOf ?class.
?class rdfs:label ?name.
?class obo:hasDefinition ?def.
?def rdfs:label ?definition
}
Results
name class definition
molecular_function http://purl.org/obo/owl/GO#GO_0003... Elemental activities, such as catalysi...
signal transducer activity http://purl.org/obo/owl/GO#GO_0004... Mediates the transfer of a signal fro...
receptor activity http://purl.org/obo/owl/GO#GO_0004... Combining with an extracellular or int...
receptor activity http://purl.org/obo/owl/GO#GO_0004... Combining with an extracellular or int...
transmembrane receptor activity http://purl.org/obo/owl/GO#GO_0004... Combining with an extracellular or int...
G-protein coupled receptor activity http://purl.org/obo/owl/GO#GO_0004... A receptor that binds an extracellular...
glutamate receptor activity http://purl.org/obo/owl/GO#GO_0008... Combining with glutamate to initiate a ...
OK, execution time: 19.968 seconds
Use proxy
Group I mGlu receptors potentiate synaptosomal (3H)glutamate release independently of exogenously applied arachidonic acid.
Page 1 of 2
Results 1 - 10 of 13 for ("GABA-B receptor activity")
AIDA Concept Query Builder
My Query
GABA-B receptor activity - <http://purl.org/obo/owl/GO#GO_0004965>
AIDA Thesaurus Browser
SCT-RDFS senselab MeSH GO
GABA-B receptor activity
GO
GABA-B receptor activity - <http://purl.org/obo/owl/GO#GO_0004965>
AIDA Thesaurus Server
Server information
Server: http://hcls.deri.org:8080/sparql/
Username: testuser
Password: ••••••••••
Repositories
Repository: GO

Access to triples in Taverna via AIDA plugin



Source: Marco Roos

Accomplishments

Demonstrations:

- http://hcls.deri.org/hcls_demo.html
- Demonstrator of querying across heterogeneous EHR systems
  - http://hcls.deri.org/coi/demo/
- http://www.w3.org/2009/08/7tmdemo
- http://ws.adaptivedisclosure.org/search
- HCLS KB hosted at 2 institutes
- Linked Open Data contributions

Interest Group Notes:

- HCLS KB
- Integration of SWAN and SIOC ontologies for Scientific Discourse
  - SWAN
  - SIOC
  - SWAN-SIOC

Technologies: http://sourceforge.net/projects/swobjects/

Accomplishments II

- **Conference Presentations:**
  - **Bio-IT World, WWW, ISMB, AMIA, etc.**
- **(Co)Organized Workshops:**
  - **C-SHALS, SWASD, SWAT4LS 2009, IEEE Workshop**
- **Publications:**
  - **Proceedings of LOD Workshop at WWW 2009: Enabling Tailored Therapeutics with Linked Data**
  - **Proceedings of the ICBO: Pharma Ontology: Creating a Patient-Centric Ontology for Translational Medicine**
  - **AMIA Spring Symposium: Clinical Observations Interoperability: A Semantic Web Approach**
  - **BMC Bioinformatics. A Journey to Semantic Web Query Federation in Life Sciences**
  - **Briefings in Bioinformatics. Life sciences on the Semantic Web: The Neurocommons and Beyond**

We've come a long way

- Triplestores have gone from millions to billions
- Linked Open Data cloud
- http://lod.openlinksw.com/
- On demand Knowledge Bases: Amazon's EC2
- Terminologies: SNOMED-CT, MeSH, UMLS, ..
- Neurocommons, Flyweb, Biogateway, Bio2RDF, Linked Life Data, ..
- https://wiki.nbic.nl/index.php/BioWiseInformationManagement2009

Penetrance of ontology in biomedicine

- OBO Foundry - http://www.obofoundry.org
- BioPortal - http://bioportal.bioontology.org
- National Centers for Biomedical Computing http://www.ncbcs.org/
- Shared Names http://sharednames.org
- Concept Web Alliance http://conceptweblog.wordpress.com/conferences/
- Semantic Web Interest Group PRISM Forum http://www.prismforum.org/
- Work packages in ELIXIR http://www.elixir-europe.org/

HCLS operations: How does it scale?

How many tasks can we handle? Global reach?

Limiting factors:

Time

- **Time for HCLS work for participants**
- **Time slots for teleconferencing**
  - **Including participants in Asia is a challenge**
- **Organizational and communication overhead**

Money

- **Become a member**
- **Apply for a grant for HCLS work**

Translating across domains

- **Translational medicine – use cases that cross domains**
- **Link across domains and research:**
  - **What are the links?**
    - **gene – transcription factor – protein**
    - **pathway – molecular interaction – chemical compound**
    - **drug – drug side effect – chemical compound**

But also:

- **Link discourse to raw data**

Memes

- Joining forces – NCBO, CWA, NIF, EBI, ..
- Synergy through Services
  - SPARQL endpoints
- Data Stewardship

Synergy through Services

- AIDA – remote collaboration simplified [image]
- ISATools [image]
- NIF [image]
- HCLS with NCBO
- …

A SPARQL endpoint on every ‘table’

- Expose knowledge as OWL and RDF for all important data
- Example: SPARQL endpoint for
  - Uniprot (RDF)
  - SWAN (SWAN/SIOC RDF)
  - myExperiment (SWAN/SIOC RDF)
- Enables us to link workflows stored in myExperiment that are related by a common protein family to discussion forum postings (evidence)

Pooling resources - collaborative environments

- **Wiki is becoming something more than community edited web pages**
- **Semantic Wiki has the potential to become both:**
  1. **An interface to knowledge bases**
     - **Templates that generate a view for a particular record – See Wiki Professional**
  2. **A source of information to be added to knowledge bases – SWAN/SIOC endpoints**
     - **On such a Semantic Wiki, each resource can be cited as a form of support for an assertion**

Use case scenario – Semantic Wiki

1. User has posted about Drug A side effect
2. Side effect similarity with Drug B theory is boosted by 1
3. Additional pathway for Drug A theory is boosted by 2

What do we need?

- New attitudes towards data – Data Stewardship
- Identifiers – people (authors, patients), diseases, drugs, compounds - preferably SharedNames
- Scalable triplestores
- Lightweight and ‘incomplete’ reasoning
- Coordination and cooperation across groups