The NanoParticle Ontology for Nanoinformatics

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Overview

- Introduction to vocabulary in nanoinformatics
- NanoParticle Ontology design
- NanoParticle Ontology applications
- Future growth and development

What is an ontology?

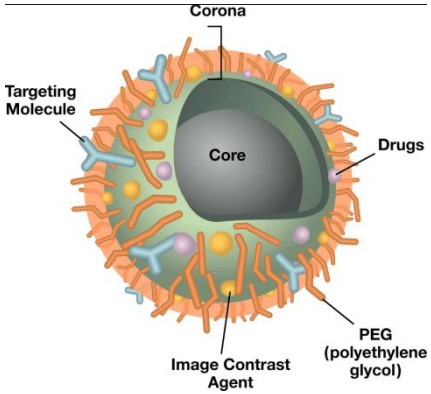
- Not a disease!
- Specification of logical relationships between concepts
- Also usually includes definitions, synonyms, properties, etc.

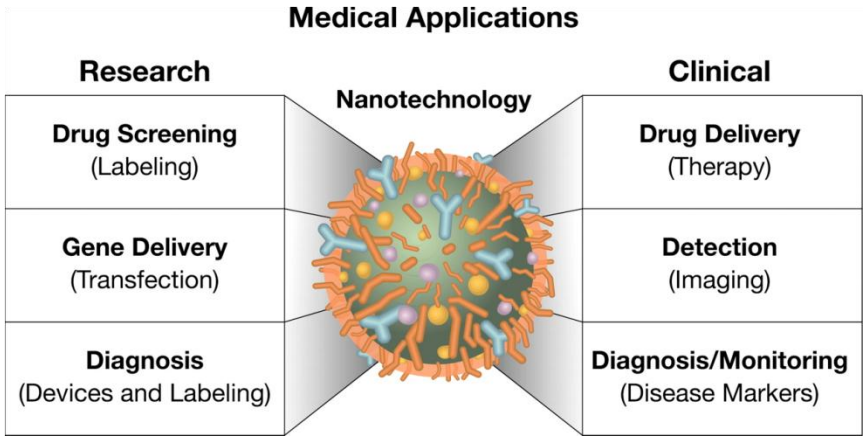
Other popular vocabularies:

Gene ontology
MeSH
ChEBI
UMLS
SNOMED
Omega
NCI Thesaurus
RadLex
Foundational Model of Anatomy
MGED Ontology

Nanotechnology: promise and problems

- Nanomaterials are small and diverse
- The promise:
  - High density
  - Improved biodistribution
  - Multi-modal applications
- The problems:
  - Combinatorial diversity
  - Difficult characterization
- ***An important informatics challenge!***





McNeil SE. *J Leukoc Biol*, 2005. **78**(3): p. 585-94. doi:10.1189/jlb.0205074

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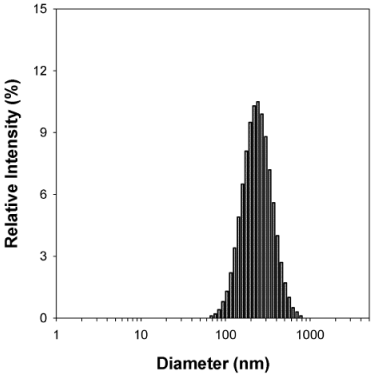
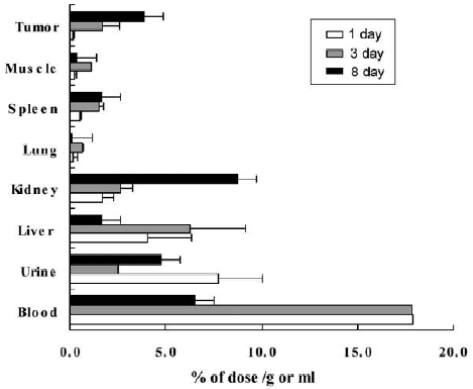
Why are Nanoparticles "Different"? *Diversity of Data!*

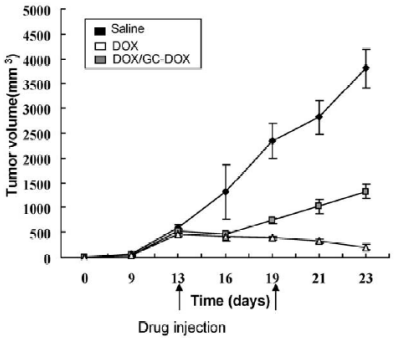
Size distribution data

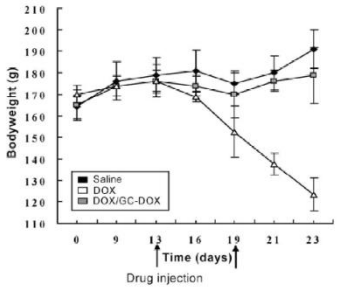


Tissue biodistribution

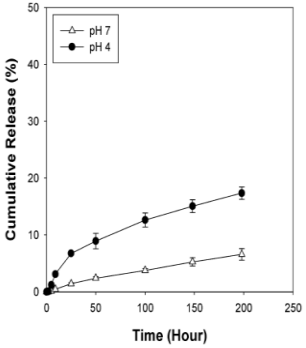


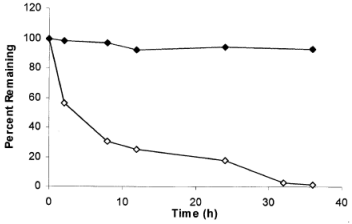
Anti-tumor activity

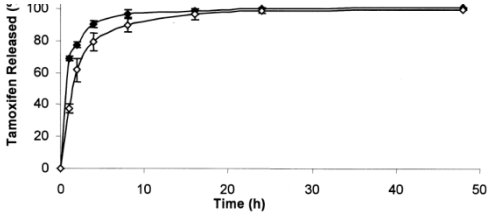




In vitro drug release







Zeta Potential

Table 1
Zeta potential values of control and tamoxifen loaded nanoparticles[a]

Nanoparticle formulations	Zeta potential (mV)
Control nanoparticles	6.7±1.2[b]
Tamoxifen-loaded nanoparticles	25.4±1.4

[a] Zeta potentials of the nanoparticle suspension in deionized distilled water were measured using the Brookhaven's Zeta PALS instrument.
[b] Mean ±S.D ($n = 8$).

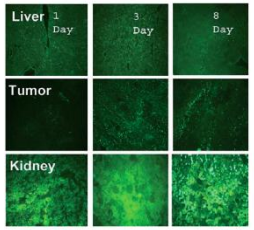
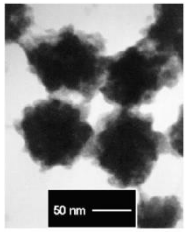
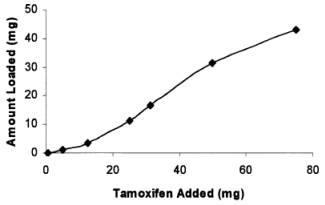


Fig. 8. Tissue accumulation of FITC-conjugated glycol-chitosan (FTC-GC) nanoaggregates for 8 days after i.v. injection in tumor-bearing rats at a dose of 10 mg/kg. Tissue accumulation measured by fluorescence microscopy.

Surface morphology data

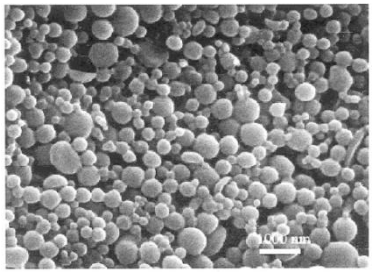


Drug loading data



Preparation

Chemical composition of nanoparticle formulation



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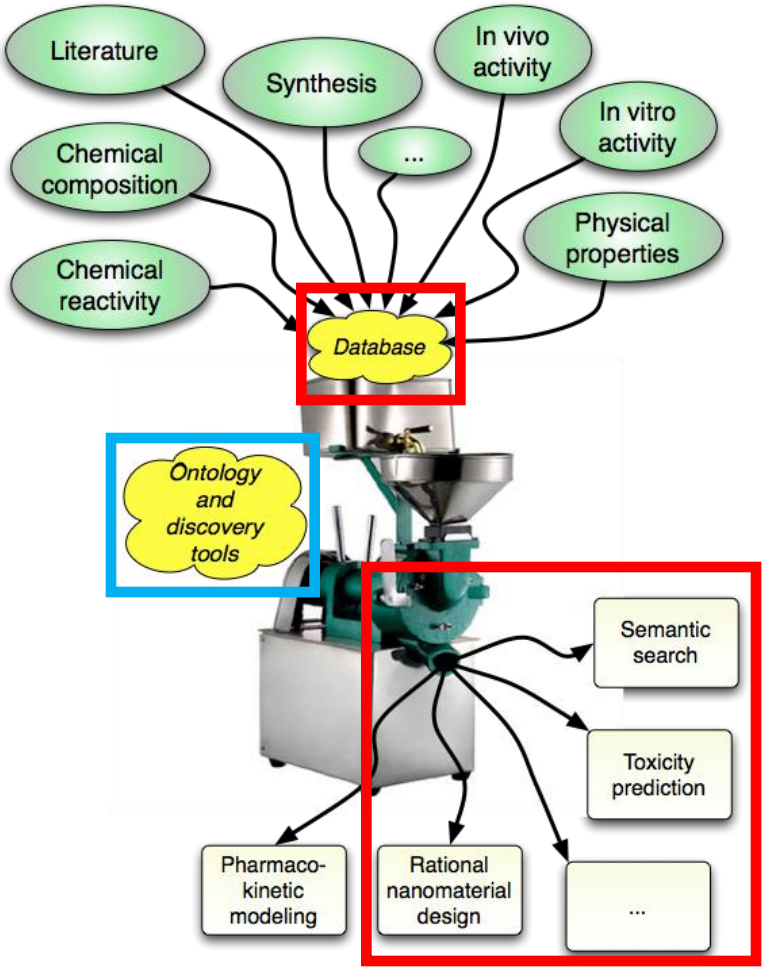
Source: Chawla JS et al, *Int J Pharm*, **249**, 127-38 (2002), Son YJ et al, *J Control Release*, **91**, 135-145 (2003)

Nanomedicine community needs and response

- The nanomedicine community has an immediate need for nanomaterial informatics:
  - Understand nanomaterial toxicity and other biological properties
  - Search for existing data on nanoparticle synthesis and properties
  - Design nanoparticles, and other materials with custom properties for specific biological applications
- The community has responded with resources *including*
  - caBIG® Nanotechnology Working Group (http://goo.gl/mi2D)
  - NanoParticle Ontology (http://www.nano-ontology.org/)
  - caNanoLab (http://goo.gl/XkBt)
  - nano-TAB (http://goo.gl/Wozi)



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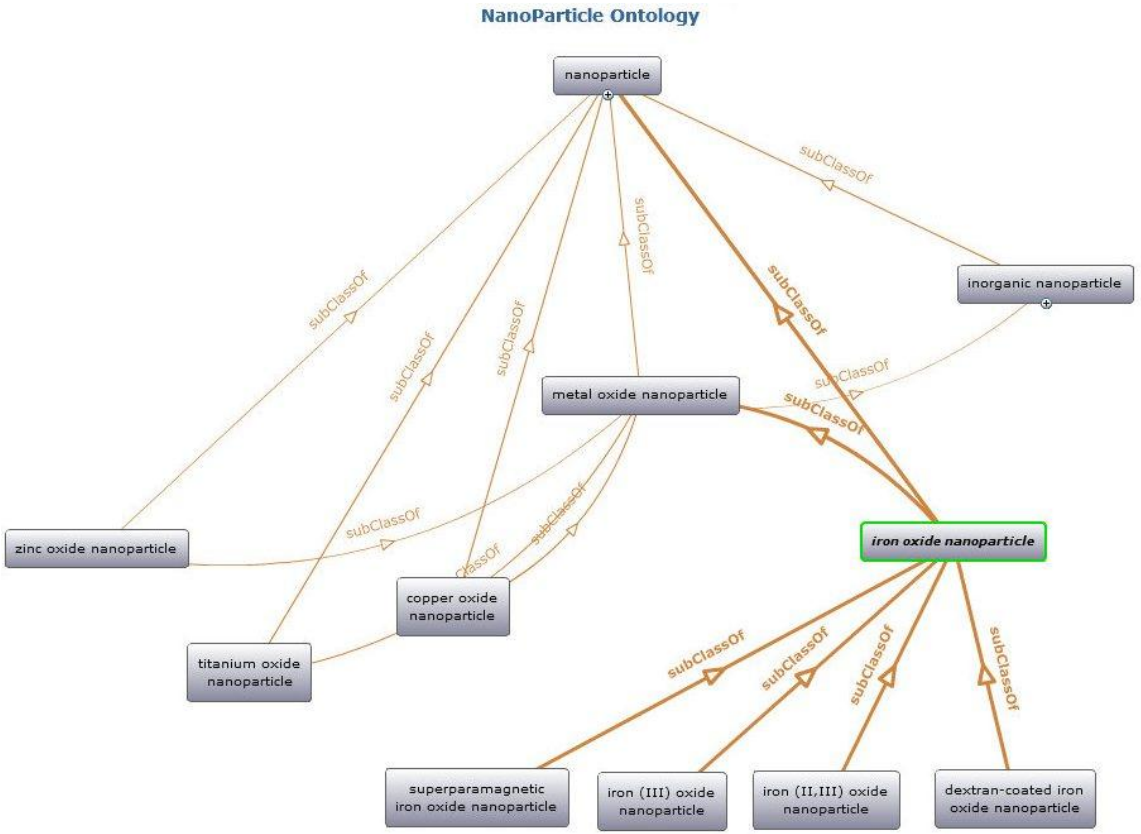
The need for nanomedicine vocabularies and ontologies

- Standard terminology
  - Interdisciplinary discourse
  - Data sharing
  - Semantic interoperability
- Logical relationships between concepts
  - Data and knowledge management
  - Semantic search
  - Inference and association
- Classifiers for computer-aided materials design



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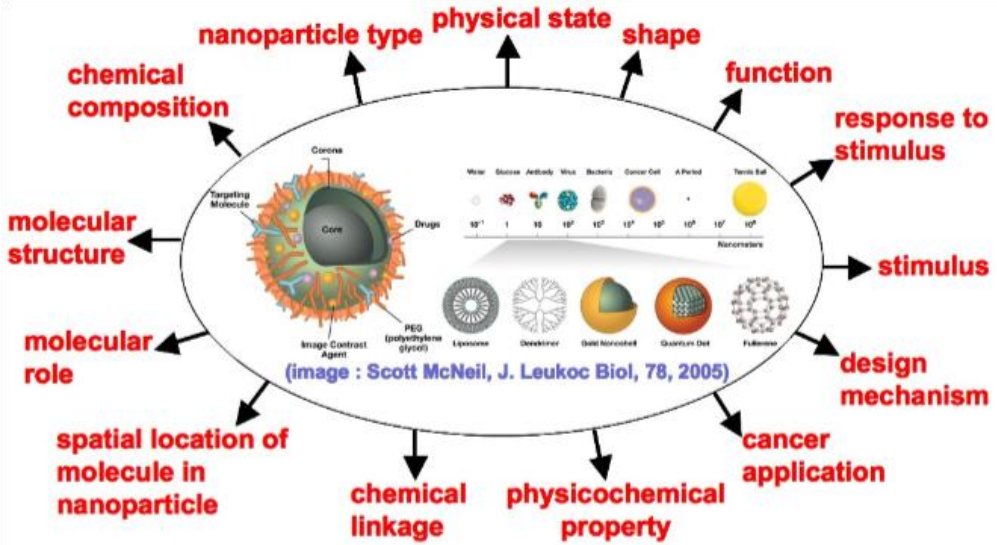
NanoParticle Ontology (NPO) initial scope

- Capture knowledge underlying nanomaterial
  - Preparation
  - Chemical composition
  - Physiochemical characterization
  - Biological function/behavior
- Initial focus on cancer diagnosis and therapy
- Current growth to include a broader range of nanotechnology concepts



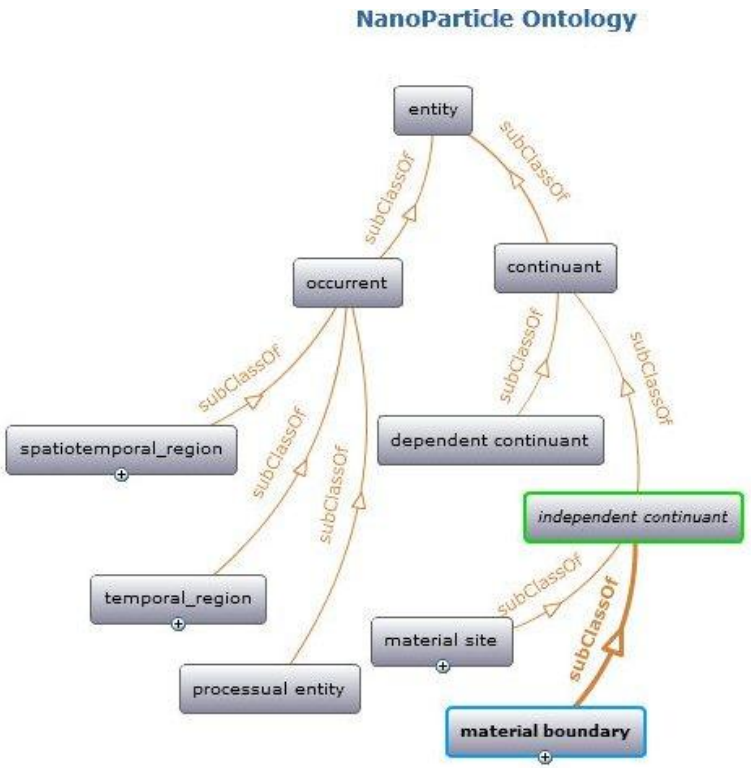
Thomas DG, Pappu RV, Baker NA. NanoParticle Ontology for Cancer Nanotechnology Research. *J Biomed Inform*, in press. doi:10.1016/j.jbi.2010.03.001

NPO initial goals

1. To provide terms for ***annotating data*** generated from research in cancer nanotechnology.
2. To provide the ***knowledge framework*** required for developing data sharing models and standards in nanomedicine.
3. To enable ***semantic integration*** of the data by providing the terms and relationships for data annotation.
4. To enable ***unambiguous interpretation*** of data pertaining to the description and characterization of nanomaterials.
5. To enable ***knowledge-based searching*** of the data for accessing and retrieving relevant information that facilitates ***comparison of nanomaterials*** and characterization results, leading towards knowledge enhancement and discovery.

NPO design principles

- Follows Basic Formal Ontology (BFO) design principles:
  - Provides a formal structure for classification of terms
  - Provides a set of well-defined principles known for best ontology practices in the biomedical arena
  - Helps make the NPO interoperable with other ontologies that have the formal structure of BFO
  - Information represented in the ontology will remain clear, rigorous and unambiguous
- Provides clear development/expansion path



NCBO BioPortal visualization of top-level structure: http://goo.gl/Wuxt

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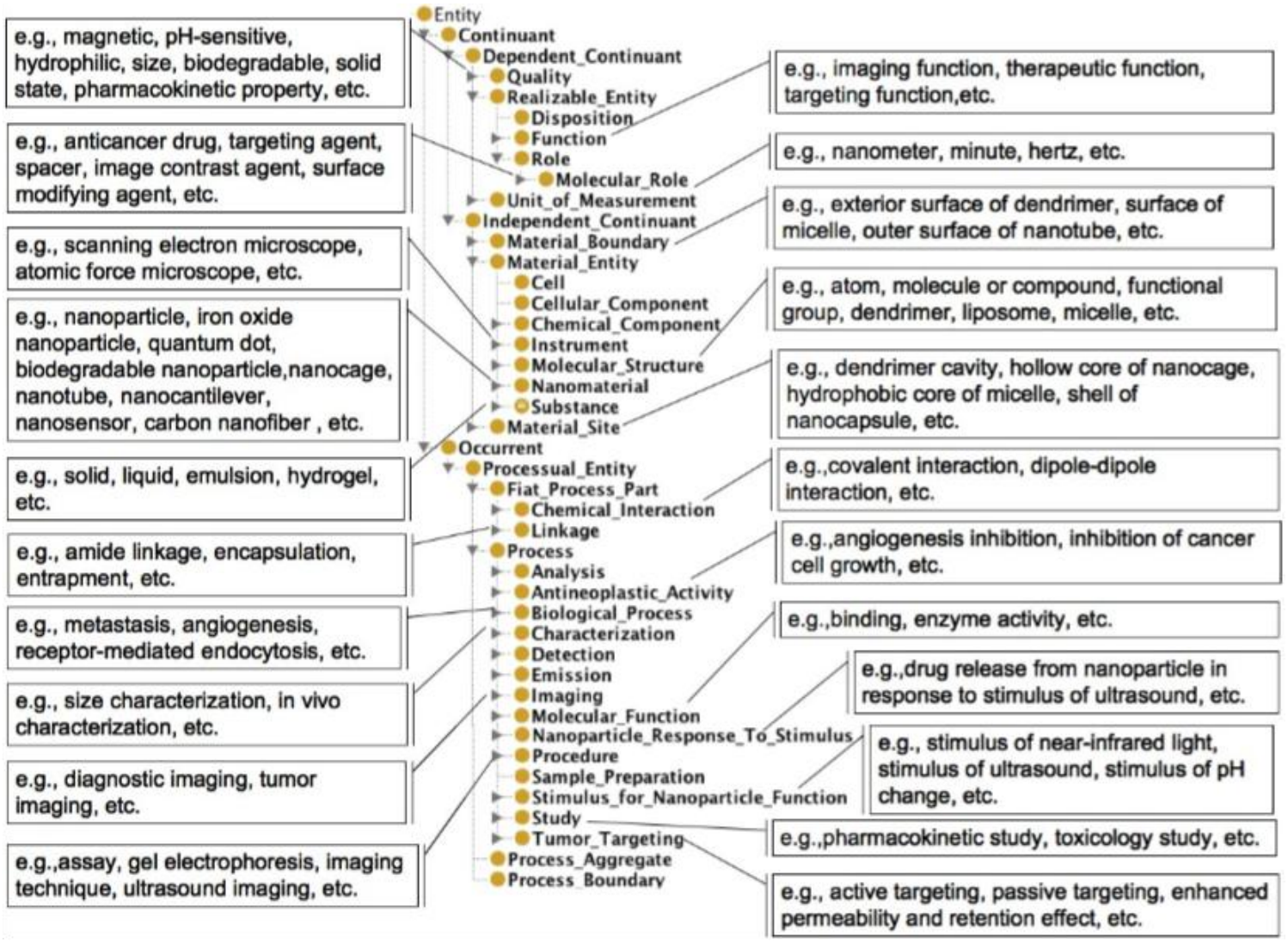
NPO example classes



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Using the NPO for sharing nanotechnology data

- caNanoLab and nano-TAB
  - Object structure
  - Concept definitions
  - Defined types and allowable values
- Semantic interoperability in data exchange

SAMPLE MATERIAL
Sample Material Source Name
Sample Material Name
Sample Material Type
Sample Material Type Term Accession Number
Sample Material Type Term Source REF
Sample Material Description
Sample Material Synthesis
Sample Material Design Rationale
Sample Material Design RationaleTerm Accession Number
Sample Material Design Rationale Term Source REF
Sample Material Characteristic
Sample Material Characteristic Term Accession Number
Sample Material Characteristic Term Source REF
Sample Material Characteristic Value
Sample Material Characteristic Value Term Accession Number
Sample Material Characteristic Value Term Source REF
Sample Material Characteristic Statistic
Sample Material Characteristic Statistic Term Accession Number
Sample Material Characteristic Statistic Term Source REF
Sample Material Characteristic Unit
Sample Material Characteristic Unit Term Accession Number
Sample Material Characteristic Unit Term Source REF
Sample Material Intended Application
Sample Material Intended Application Term Accession Number
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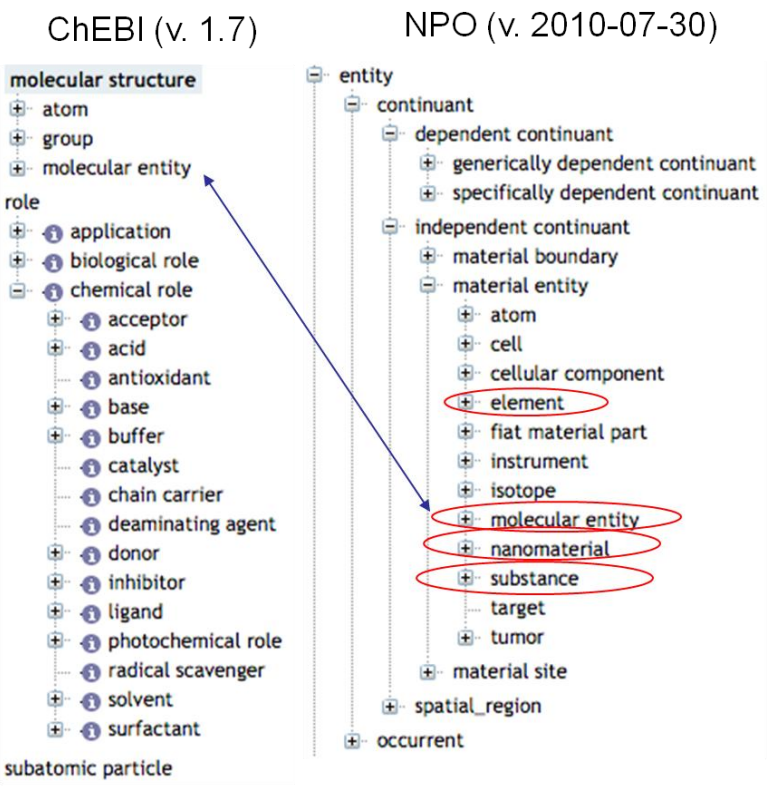
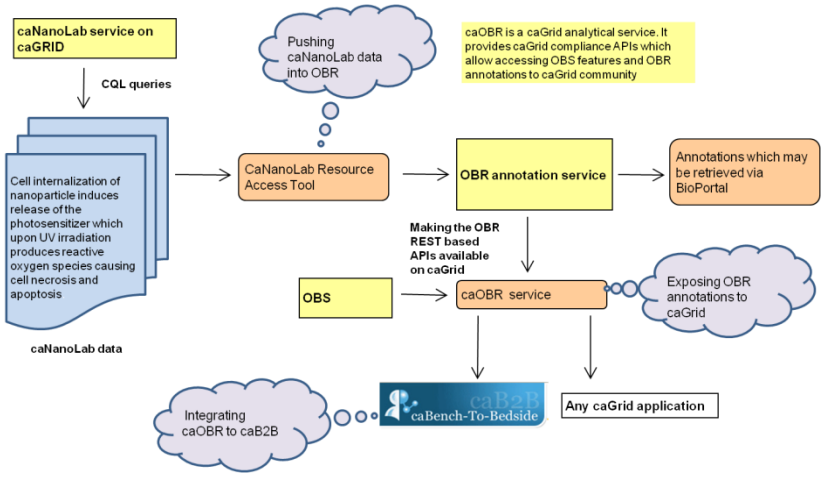
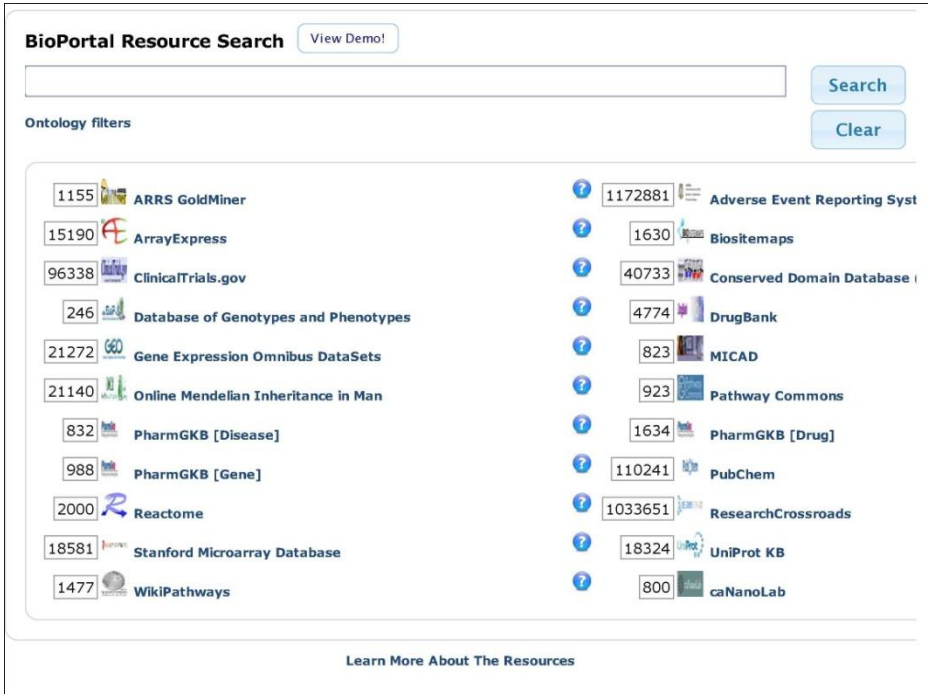
Sample Material File Name
Sampe Material File Type
Sample Material File Type Term Accession Number
Sample Material File Type Term Source REF
Sample Material File Version
Sampe Material File Description

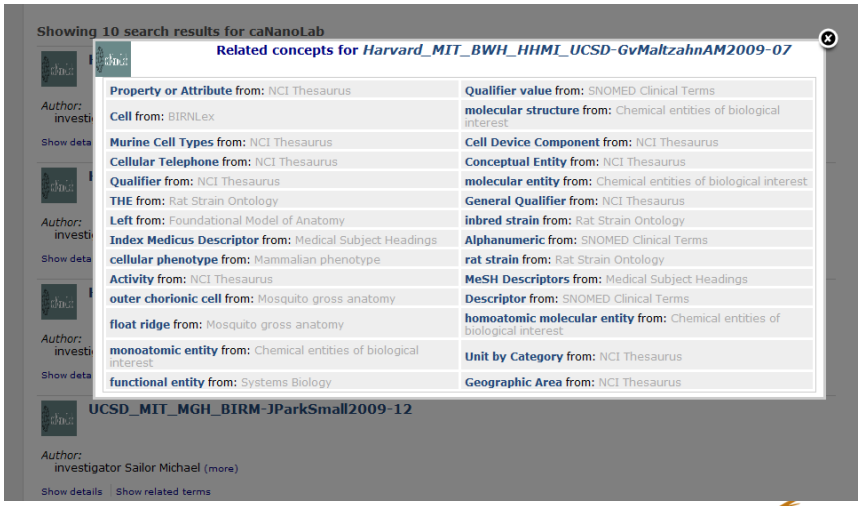


Using the NPO for searching biomedical and nanotechnology databases

- Collaboration with the National Center for Biomedical Ontology
- Uses the NPO and other ontologies for *semantic* search
- NCBO BioPortal indexes several major biomedical resources, including caNanoLab



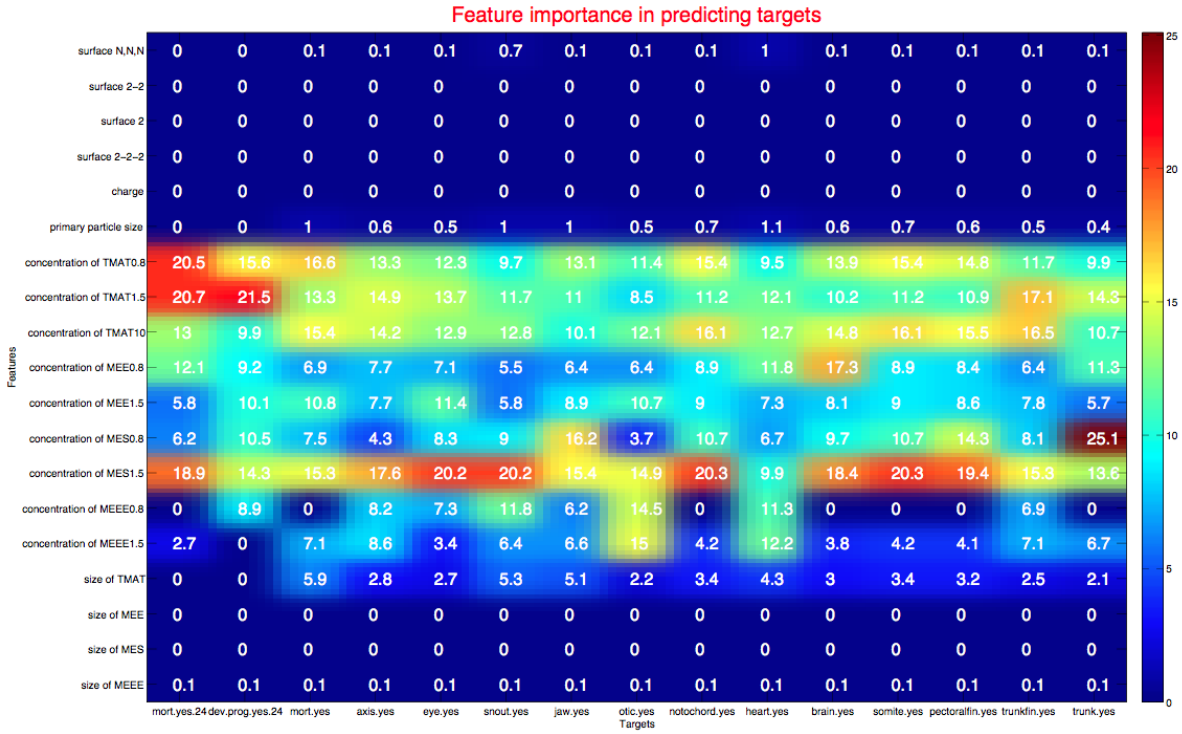




NCBO BioPortal: http://bioportal.bioontology.org/

Using the NPO for classification and modeling

- SAR-based approaches
  - Machine learning for best descriptors
  - Simple regression and regression tree approaches
  - Ontology-based categorization and inference
- Embryonic zebrafish models
- Gold nanoparticles
- Collaboration
  - Stacey Harper, ONAMI
  - Kilian Weinberger and Eddie Zhang, WUStL



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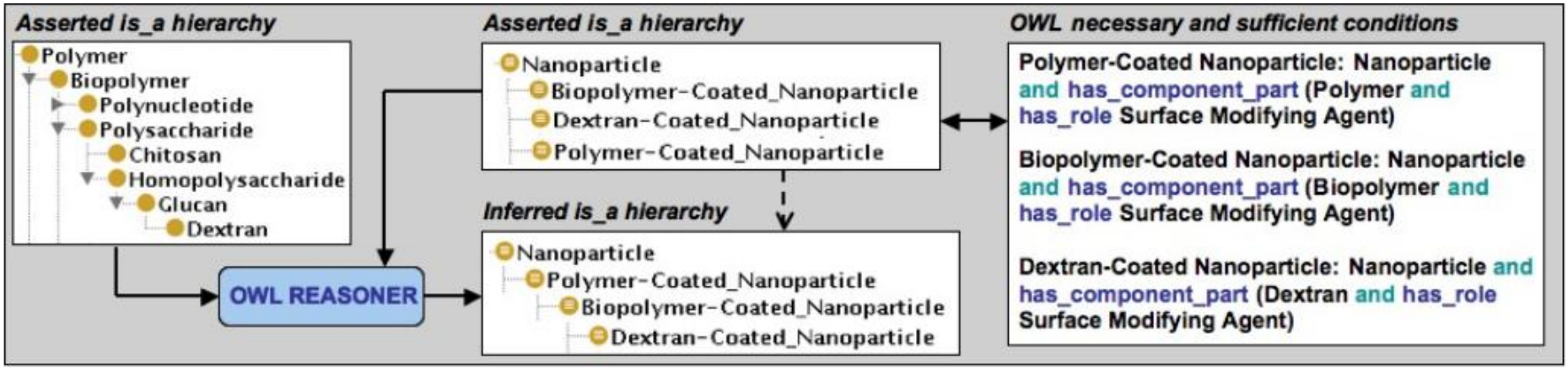
Using the NPO for inference



- Why?
  - Searching
  - Model generalization and interpretability
  - Linking observations
- How?
  - Ontology structure
  - Pellet reasoner

Example shows how an OWL reasoner infers parent-child relationships among ***Polymer-Coated Nanoparticle***, ***Biopolymer-Coated Nanoparticle***, and ***Dextran-Coated Nanoparticle*** based on their asserted associations to and based on the asserted hierarchy of ***Polymer***, ***Biopolymer***, and ***Dextran*** respectively.

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NPO is a community project

- Governed and developed by the caBIG® Nanotechnology Working Group (http://goo.gl/mi2D)
- Freely available through
  - NPO website: http://www.nano-ontology.org/
  - ***NCBO BioPortal***: http://purl.bioontology.org/ontology/NPO
  - NCI Meta-Thesaurus: http://ncimeta.nci.nih.gov/
- Community involvement welcomed ***and needed!***
  - New concepts and growth
  - Harmonization and mapping
  - Additional applications

Funding sources

- U54 CA119342
- U54 CA119367
- U54 HG004028
- NCI caBIG®

Further reading

Thomas DG, Pappu RV, Baker NA. NanoParticle Ontology for Cancer Nanotechnology Research. *J Biomed Inform*, in press doi:10.1016/j.jbi.2010.03.001

Collaborators

caBIG® ICR Workspace, Raul Cachau, Gilbert Fragoso, Elaine Freund, Marty Fritts, Sharon Gaheen, Liz Hahn-Dantona Stacey Harper, Mark Hoover, Fred Klaessig, Juli Klemm, Michal Lijowski, David Paik, Sue Pan, Rohit Pappu, Persistent Systems Ltd, Stan Shaw, Eddie Xu, Kilian Weinberger, Trish Whetzel