Building an OBO Foundry Ontology using Semantic Web Technologies

Mélanie Courtot and Alan Ruttenberg
mcourtot@gmail.com
alanruttenberg@gmail.com

ICBO 2012

Goals of this section of tutorial

- Give a brief introduction to semantic web technologies for those who are unfamiliar with them
- Expose why these technologies are important for the OBO Foundry, and how we help the effort
- Detail specific practices used by Foundry developers
  - Registering a namespace
  - Authoring using Protege 4.2, saving as RDF/XML
  - Reusing other ontologies either by import or MIREOT
    - Initial imports: BFO, RO, ontology-metadata
  - ID/URI Policy (How to set up Protege to help)
  - Use of common metadata from ontology-metadata.owl
  - Use of existing relations, creating new (shortcut) relations
  - Use of axioms to constrain meaning of terms
  - Use of reasoner to check ontology
  - Having your ontology made accessible via Ontobee

The semantic web in a nutshell

Adds to Web standards and practices (currently only for documents and services) encouraging

- Unambiguous names for things, classes, and relationships
- Well organized and documented in ontologies
- With data expressed using uniform knowledge representation languages
  - Logic-based: RDF, OWL, RIF (a number of syntaxes available)
- To enable computationally assisted exploitation of information
  - Information for machines to work with, not only people
  - Allows consistency checking, precise query, inference
- That can be easily integrated from different sources
  - Both within and across public and organizational boundaries

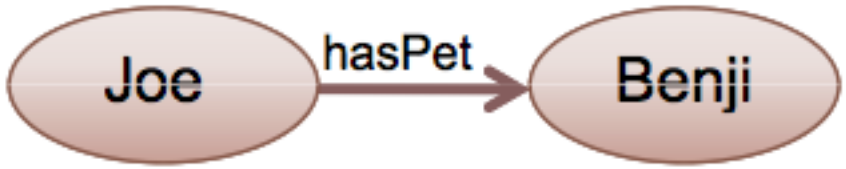
How semantic web technologies help us achieve our goals (1)

The project of enabling effective communication and discovery in the biological and life sciences is complex

Some pieces of this effort are handled by these technologies

- We need tools for logical languages that have effective implementations. We get OWL, HerMIT, Pellet, FaCT++
- In contrast to RDBs, tools work on combined schema (ontology) and data.
  - Both are expressed logically
  - Both are queryable together at once
- We get a free data model: RDF without any more effort beyond building the ontology
  - Saves us the trouble of designing a "data model" unless there is some good reason to do so.
  - Building "data models" is a common source of non-integrable data - everyone wants their own

Resource Description Framework



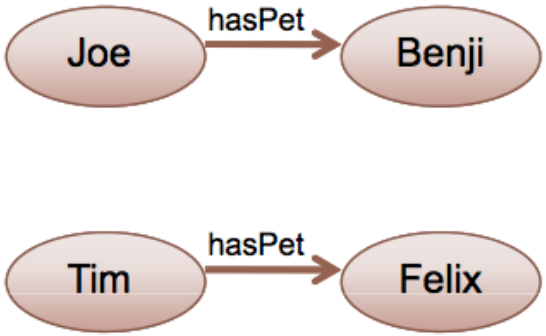
- Resources (= nodes)
  - Identified by Unique Resource Identifier (URI)
- Properties (= edges)
  - Identified by Unique Resource Identifier (URI)
  - Binary relations between 2 resources

Courtesy Natalia Villanueva- Rosales

One dataset

Source 1

Owner	Pet
Joe	Benji
Tim	Felix
...	...



I can query about owners and the name of their pets.

Courtesy Natalia Villanueva- Rosales

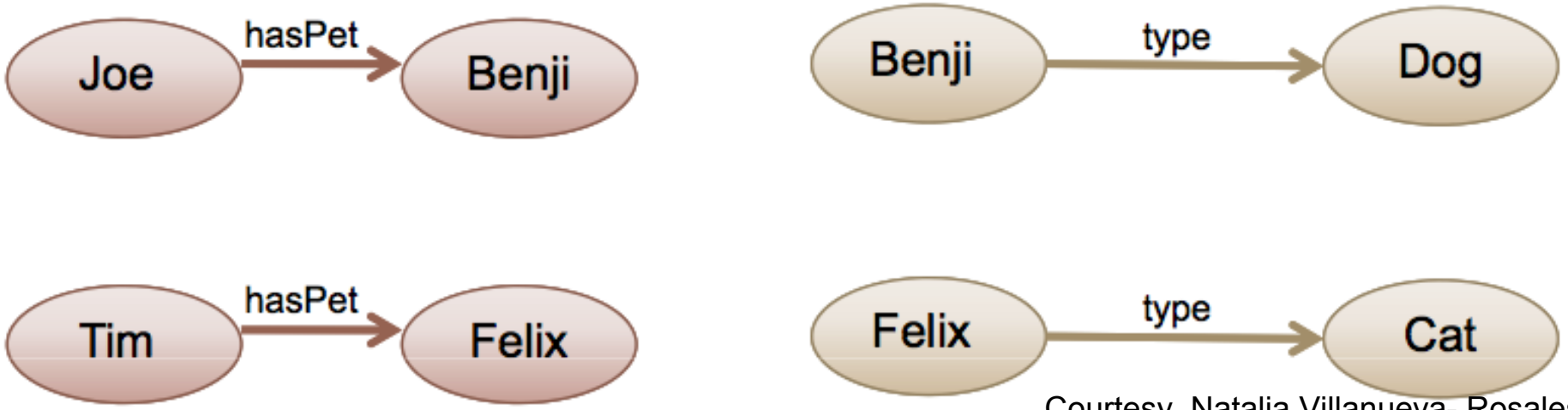
Two datasets

Source 1

Owner	Pet
Joe	Benji
Tim	Felix
...	...

Source 2

Pet	Species
Benji	Dog
Felix	Cat
...	...



Courtesy Natalia Villanueva- Rosales

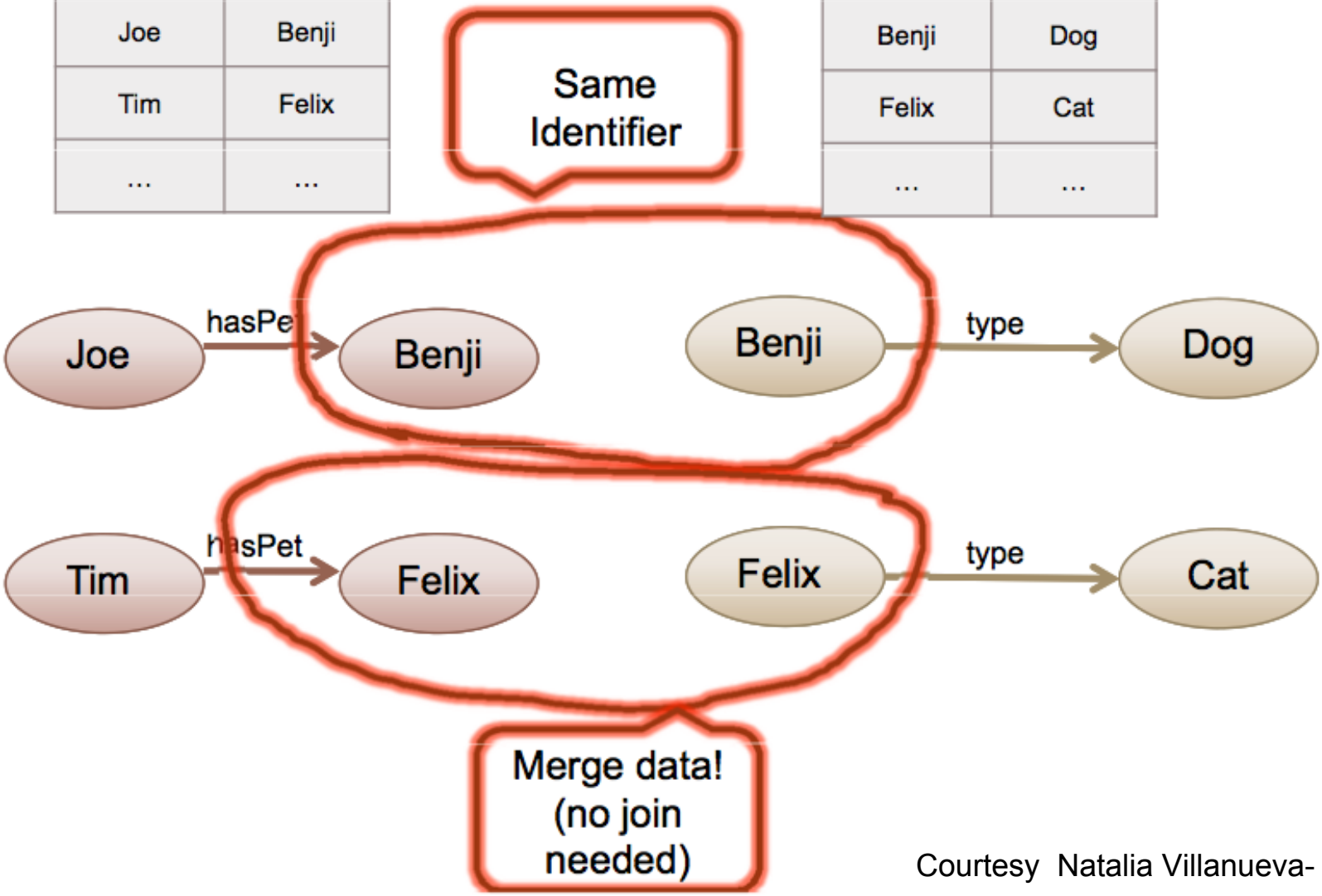
Data merge

Source 1

Owner	Pet
Joe	Benji
Tim	Felix
...	...

Source 2

Pet	Species
Benji	Dog
Felix	Cat
...	...



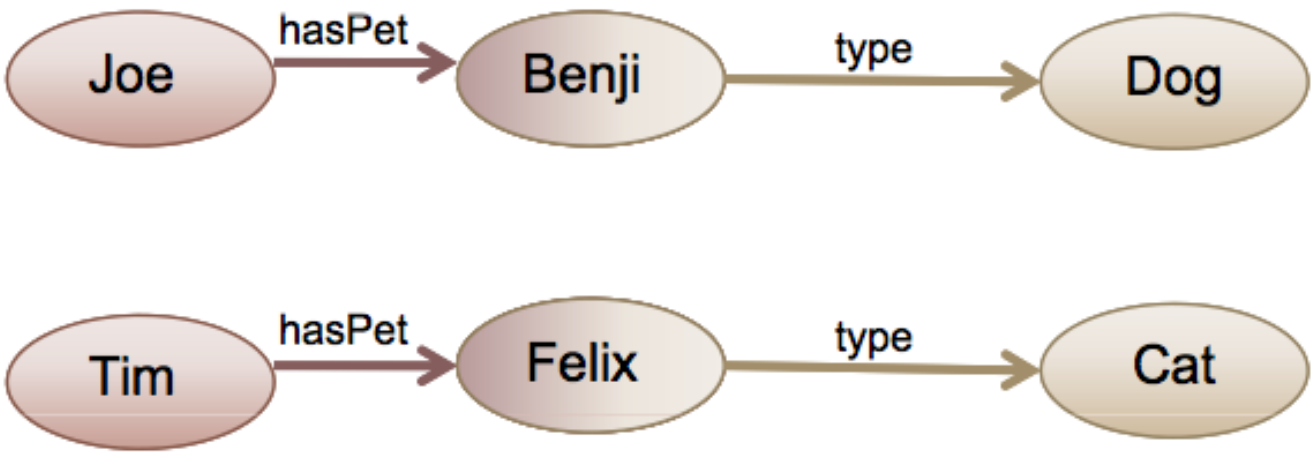
Courtesy Natalia Villanueva- Rosales

Source 1

Owner	Pet
Joe	Benji
Tim	Felix
...	...

Source 2

Pet	Species
Benji	Dog
Felix	Cat
...	...



I can query about owners of pets of a certain species, which is not in Source 1 or source 2, but in the **union** of both.

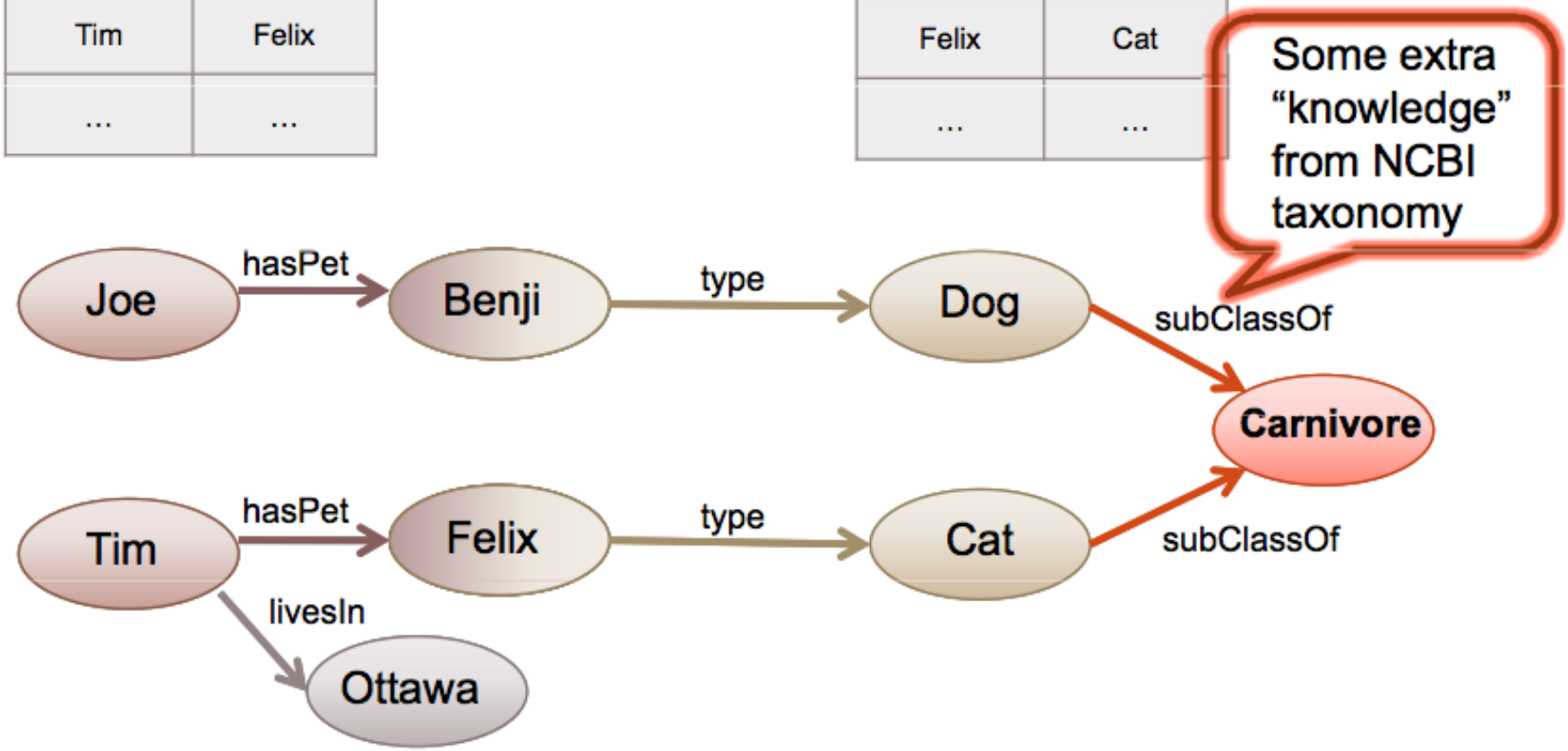
Courtesy Natalia Villanueva- Rosales

Source 1

Owner	Pet
Joe	Benji
Tim	Felix
...	...

Source 2

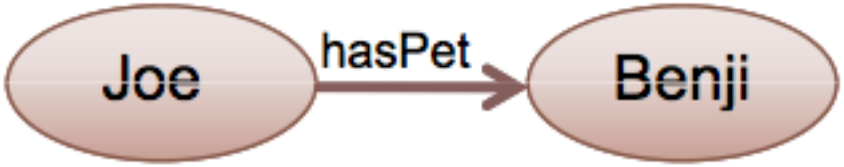
Pet	Species
Benji	Dog
Felix	Cat
...	...



Now I can ask about possible customers of a new brand of pet meat: owners of carnivore pets.

Courtesy Natalia Villanueva- Rosales

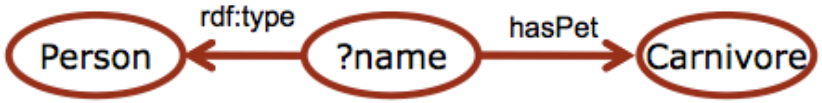
RDF statement



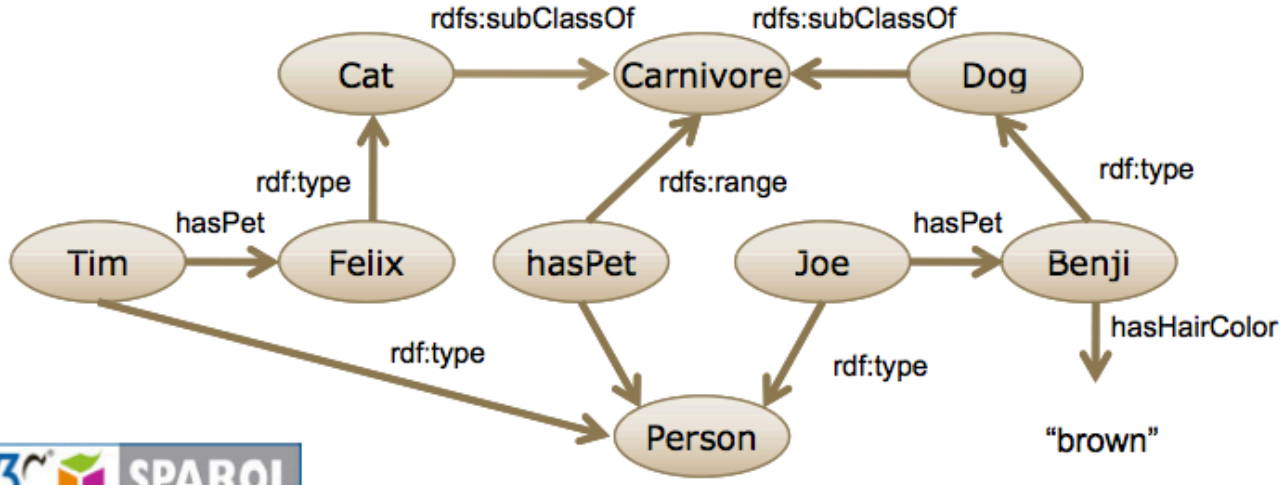
- Triple subject, object, property
- SPARQL query by graph matching

Courtesy Natalia Villanueva- Rosales

SPARQL QUERY




```
PREFIX example:
http://semanticscience.org/resource/ws_example#
SELECT ?name
WHERE {
?name rdf:type example:Person.
?name example:hasPet ?pet.
?pet rdf:type example:Carnivore.
}
```



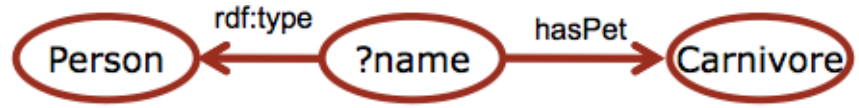
RDF Graph

Courtesy Natalia Villanueva- Rosales

Inference rule

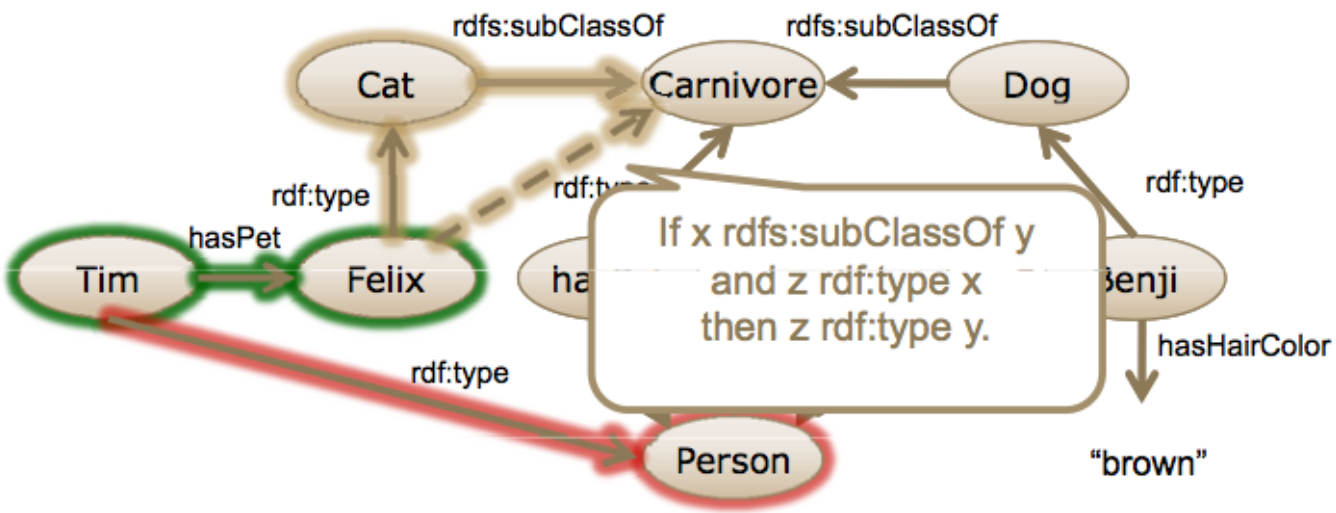
SPARQL

```
PREFIX example:
http://semanticscience.org/resource/ws_example#
SELECT ?name
WHERE {
?name rdf:type example:Person.
?name example:hasPet ?pet.
?pet rdf:type example:Carnivore.
}
```



?name=Tim

?pet=Felix



RDF Graph

Courtesy Natalia Villanueva- Rosales

How semantic web technologies help us achieve our goals (2)

- We get databases that support those data models
  - Triple stores: Virtuoso, Stardog, OWLIM, more...
- Tools are standardized and there is a growing workforce we can tap.
  - This scales better than making our own tools, training people
- Our goal of universal easy access is shared with semweb efforts. The web is good at supporting this.
  - We need tools for logical languages that have effective implementations. We get OWL, HerMIT, Pellet, FaCT++
  - By using these tools early we get to help guide their future

How we help the semweb effort

These standards and tools are still young

Ontology building is hard. Too many semantic web efforts suffer from poor ontology design and the consequences of that - failure to integrated, confused messages.

We help that by

- Providing and teach how to build high quality ontologies
- Provide a positive example of how a coordinated effort can develop good practices using the tools
- Provide feedback to standards efforts and tool developers that help improve successive versions
- Documenting our approaches so that others can benefit from them

The semantic web needs us!

Step by step: Building a foundry ontology for semantic web deployment

1. Register a namespace

If you plan to build an orthogonal ontology, you do this step once you are clear what your domain is and that id does not overlap another:

- Read http://obofoundry.org/id-policy.shtml
- Send mail to obo-discuss@obofoundry.org asking for your namespace (a short string of letters used as part of your identifier)
- Provide a description of your (planned) work, email for a point of contact, and location of your ontology
  - We recommend google code for setting up new projects
- Use the "New entities" preference in Protege to have protege create ids like:

  http://purl.obolibrary.org/obo/ XXX_0000000

2. Use Protégé to author your ontology

- Download the most recent version of protege - currently 4.2 beta
- After setting preferences create a new ontology
- Answer http://purl.obolibrary.org/obo/xxx.owl for the ontology IRI (xxx is lower case of your namespace)
- Save. When it asks format accept the default RDF/XML

If something doesn't seem to work in Protégé don't assume that you are doing something wrong. Ask for help on the discussion lists

3. ID/URI policy

- OBO Foundry aims at building orthogonal interoperating resources

- Reuse is successfully achieved by using the identifier from the source ontology in your own ontology.
- See http://obofoundry.org/id-policy.owl

The case for http: URIs

- A global namespace promotes generic tools
  - Query, inference, cross-reference, data integration
- URIs coordinate with web standards
  - Created with and for the Web
  - IETF and W3C recommended for naming
  - HTTP, HTML, RDF, OWL, SPARQL
- http: URIs are universally understood
  - Most people will know what to do with an http: URI
- http: URIs can identify anything
  - Not only a web page, but any kind of entity
- http: URIs are as reliable as anything else
  - Durability doesn't depend on protocol
  - http: URIs are not tied to the HTTP protocol

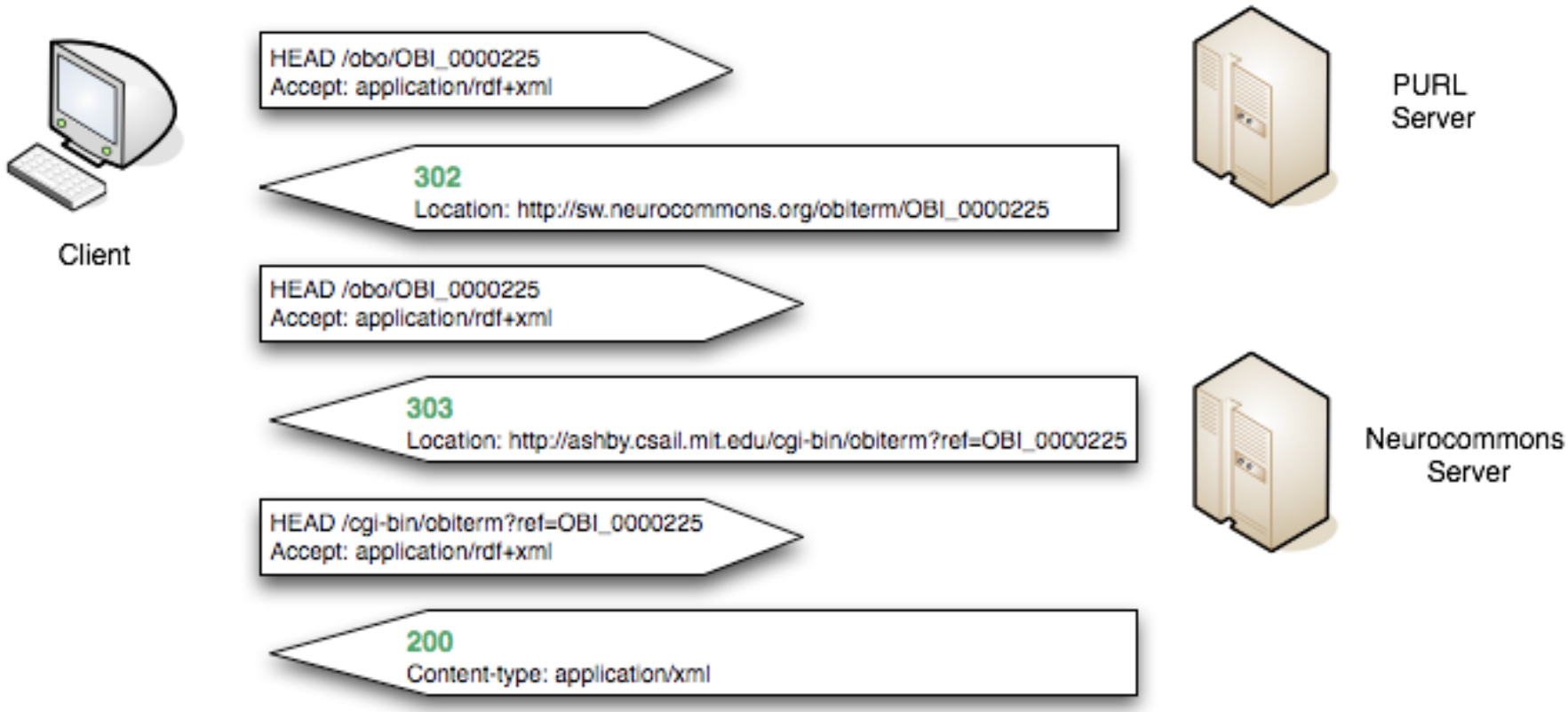
OBO Foundry URIs

- Unique resource identifier: denotes each entity
- OBO Foundry ID policy: http://obofoundry.org/id-policy.shtml
- **FOUNDRY_OBO_URI ::= "http://purl.obolibrary.org/obo/" IDSPACE "_" LOCALID**
- Current ontology document:
  - Current OWL: http://purl.obolibrary.org/obo/IDSPACE.owl
  - Current OBO: http://purl.obolibrary.org/obo/IDSPACE.obo
- Versions of ontology:
  - OWL: http://purl.obolibrary.org/obo/<idspace>/YYYY-MM-DD/<idspace>.owl
  - OBO: http://purl.obolibrary.org/obo/<idspace>/YYYY-MM-DD/<idspace>.obo

Additional stable links

- Home page
  - http://purl.obolibrary.org/obo/IDSPACE
- Issue tracker
  - http://purl.obolibrary.org/obo/IDSPACE/tracker
- Ontology browsing
  - http://purl.obolibrary.org/obo/IDSPACE/browse
- Wiki
  - http://purl.obolibrary.org/obo/IDSPACE/wiki

URI dereferencing



Ontobee

Home | Introduction | Tutorial | FAQs | References | Links | Contact | Acknowledge

Ontology for biomedical investigations

Keywords: Search terms

Class: cell culture

- Term IRI: http://purl.obolibrary.org/obo/OBI_0100060
- definition: a cell culture is a material entity consisting of a population of cells that is maintained in vitro

Annotations

- definition editor: Bjoern Peters
- has curation status: ready for release
- example of usage: Jurkat cell line in RPMI w/ 10% FCS. PBMCs were purified from blood sample and put into tissue culture media. Purification of recombinant human growth hormone from CHO cell culture supernatant by Gradiflow preparative electrophoresis technology. Protein Expr Purif. 2003 Nov;32(1):126-34. PMID: 14680949
- definition source: GROUP: OBI Biomaterial Branch

Class Hierarchy

Thing
+ entity
  + continuant
    + independent continuant
      + material entity
        + processed material
          + device
          - polyacrylamide gel
          - xenograft
          - precipitate
          + amplified DNA
          + extract
          + cloning vector

HTML for human, RDF for machines


```
<rdf:Description rdf:about="&obo;IAO_0000119"><rdf:type rdf:resource="&owl;AnnotationProperty"/></rdf:Description>
<rdf:Description rdf:about="&obo;IAO_0000122"><rdf:type rdf:resource="&obo;IAO_0000078"/></rdf:Description>
<rdf:Description rdf:about="http://code.google.com/p/information-artifact-ontology/"><rdf:type rdf:resource="&owl;Thing"/></rdf:Description>
<rdf:Description rdf:about="http://protege.stanford.edu/plugins/owl/protege#defaultLanguage"><rdf:type rdf:resource="&owl;AnnotationProperty"/></rdf:Description>
<rdf:Description rdf:about="&obo;OBI_0000312"><rdf:type rdf:resource="&owl;ObjectProperty"/></rdf:Description>
<rdf:Description rdf:about="&obo;OBI_0600036"><rdf:type rdf:resource="&owl;Class"/></rdf:Description>
<rdf:Description rdf:about="&obo;OBI_0000047"><rdf:type rdf:resource="&owl;Class"/></rdf:Description>
<rdf:Description rdf:about="&obo;IAO_0000122"><rdf:type rdf:resource="&owl;NamedIndividual"/></rdf:Description>
<rdf:Description rdf:about="&obo;CL_0000000"><rdf:type rdf:resource="&owl;Class"/></rdf:Description>
<rdf:Description rdf:about="&obo;IAO_0000115"><rdf:type rdf:resource="&owl;AnnotationProperty"/></rdf:Description>
<rdf:Description rdf:about="&obo;OBI_1000036"><rdf:type rdf:resource="&owl;Class"/></rdf:Description>
<rdf:Description rdf:about="&obo;IAO_0000117"><rdf:type rdf:resource="&owl;AnnotationProperty"/></rdf:Description>
<rdf:Description rdf:about="&obo;IAO_0000122"><rdf:type rdf:resource="&owl;Thing"/></rdf:Description>
<rdf:Description rdf:about="&obo;obi/2012-07-01/obi.owl"><rdf:type rdf:resource="&owl;NamedIndividual"/></rdf:Description>
<rdf:Description rdf:about="&obo;OBI_1000042"><rdf:type rdf:resource="&owl;Class"/></rdf:Description>
<rdf:Description rdf:about="&obo;OBI_1000023"><rdf:type rdf:resource="&owl;Class"/></rdf:Description>
<rdf:Description rdf:about="&obo;OBI_1000024"><rdf:type rdf:resource="&owl;Class"/></rdf:Description>
<rdf:Description rdf:about="&obo;obi/2012-07-01/obi.owl"><rdf:type rdf:resource="&owl;Thing"/></rdf:Description>
<rdf:Description rdf:about="&obo;OBI_1000029"><rdf:type rdf:resource="&owl;Class"/></rdf:Description>
<rdf:Description rdf:about="&obo;OBI_0100067"><rdf:type rdf:resource="&owl;Class"/></rdf:Description>
<rdf:Description rdf:about="&obo;IAO_0000114"><rdf:type rdf:resource="&owl;AnnotationProperty"/></rdf:Description>
<rdf:Description rdf:about="&obo;IAO_0000111"><rdf:type rdf:resource="&owl;AnnotationProperty"/></rdf:Description>
<rdf:Description rdf:about="&obo;OBI_0100086"><rdf:type rdf:resource="&owl;Class"/></rdf:Description>
<rdf:Description rdf:about="http://code.google.com/p/information-artifact-ontology/"><rdf:type rdf:resource="&owl;NamedIndividual"/></rdf:Description>
<rdf:Description rdf:about="&obo;OBI_0000643"><rdf:type rdf:resource="&owl;ObjectProperty"/></rdf:Description>
<rdf:Description rdf:about="&obo;CL_0000000"><rdfs:label xml:lang="en">cell</rdfs:label></rdf:Description>
<rdf:Description rdf:about="&obo;IAO_0000114"><rdfs:label xml:lang="en">has curation status</rdfs:label></rdf:Description>
<rdf:Description rdf:about="&obo;OBI_0100067"><rdfs:label xml:lang="en">bronchial alveolar lavage</rdfs:label></rdf:Description>
<rdf:Description rdf:about="&obo;OBI_0000643"><rdfs:label rdf:datatype="http://www.w3.org/2001/XMLSchema#string">has grain</rdfs:label></rdf:Description>
<rdf:Description rdf:about="&obo;OBI_1000023"><rdfs:label xml:lang="en">cell culture supernatant</rdfs:label></rdf:Description>
<rdf:Description rdf:about="&obo;OBI_1000029"><rdfs:label xml:lang="en">phage display library</rdfs:label></rdf:Description>
<rdf:Description rdf:about="&obo;IAO_0000111"><rdfs:label xml:lang="en">editor preferred term</rdfs:label></rdf:Description>
<rdf:Description rdf:about="&obo;OBI_1000024"><rdfs:label xml:lang="en">cell pellet</rdfs:label></rdf:Description>
<rdf:Description rdf:about="&obo;OBI_0100086"><rdfs:label rdf:datatype="http://www.w3.org/2001/XMLSchema#string">glucose in solution</rdfs:label></rdf:Description>
<rdf:Description rdf:about="&obo;IAO_0000115"><rdfs:label xml:lang="en">definition</rdfs:label></rdf:Description>
<rdf:Description rdf:about="&obo;IAO_0000122"><rdfs:label xml:lang="en">ready for release</rdfs:label></rdf:Description>
<rdf:Description rdf:about="&obo;IAO_0000117"><rdfs:label xml:lang="en">term editor</rdfs:label></rdf:Description>
<rdf:Description rdf:about="&obo;OBI_0000312"><rdfs:label xml:lang="en">is_specified_output_of</rdfs:label></rdf:Description>
<rdf:Description rdf:about="&obo;IAO_0000119"><rdfs:label xml:lang="en">definition source</rdfs:label></rdf:Description>
```

4. Reuse other ontologies

There are two ways of using other ontologies.

- Using the OWL import mechanism
  - We recommend importing
    - A version of BFO
      - BFO 1, stable: http://ifomis.org/bfo/1.1
      - BFO 2, under development: http://purl.obolibrary.org/obo/bfo.owl
    - A version of the relation ontology
      - For BFO 1, http://www.obofoundry.org/ro/ro.owl
      - For BFO 2, http://purl.obolibrary.org/obo/ro.owl
    - The ontology metadata annotation properties
      - http://purl.obolibrary.org/obo/ontology-metadata.owl
  - If you will try BFO 2, attend wednesday's tutorial and engineer to be able to make changes as it evolves.
- Import selected terms only, using MIREOT

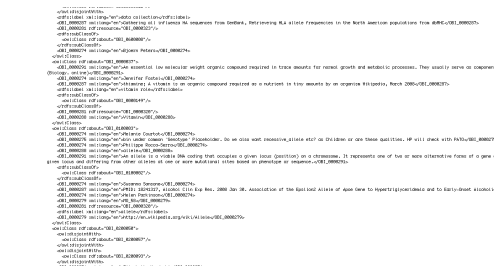
MIREOT

- Minimimum Information to Reference an External ontology term
- ~ copy/paste of terms into your own ontology
- Terms in OBO Foundry ontologies stand on their own
- If their meaning changes, they are deprecated

=> *denotation* of individual terms remain stable

=> they can be seen as ***individual units*** of meaning

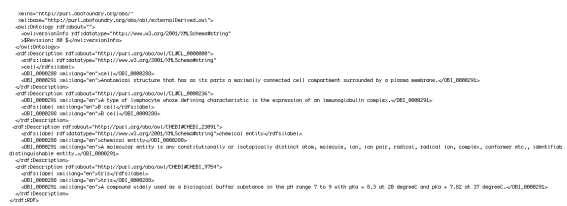
MIREOT in practice



xxx.owl
Main ontology file, imports external and externalDerived.owl files.

IMPORTS

SCRIPT

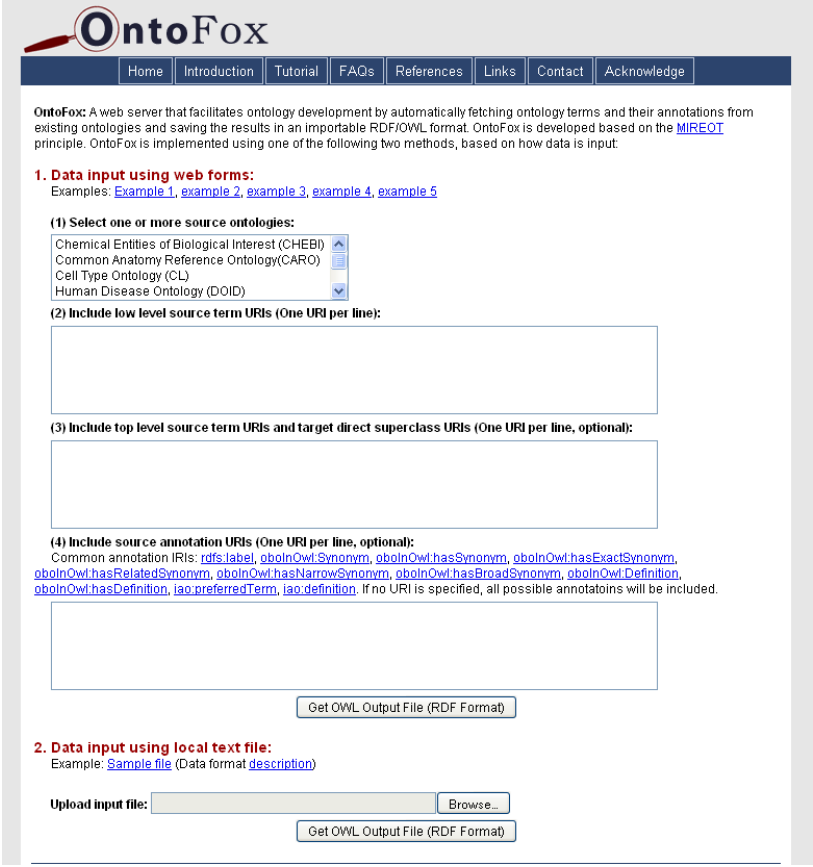


external.owl
Contains minimal information
about mapped classes

externalDerived.owl
Contains additional information
about mapped classes

OntoFox: a Web Server for MIREOTing

- Based on the MIREOT principle
- Web-based data input and output
- Output OWL file can be directly imported in your ontology
- Easy to use
- No programming needed for users



http://ontofox.hegroup.org

MIREOT - extras

- Common metadata set for the OBO Foundry resources
- Developed within the Information Artifact Ontology (IAO)
  - IAO working session tonight
- MIREOT can be used to import anything you want
  - For example, we currently import superclasses (parents) from NCBITaxon

- Other ways to use MIREOT
  - Lisp scripts (OBI)
  - Protégé plugin (in progress, EBI)

5. Use of common metadata

By ontology metadata, we mean assertions about the ontology representational units (terms) rather than assertions about what they mean

E.g. A label, who defined the term, who edited the term, what is an english definition of the term, etc.

Common metadata supports common tools such as MIREOT as well as browsing tools such as Ontobee. Protégé now supports numeric IDs for label display.

6. Using / sharing relations

- Relations ontology
  http://code.google.com/p/obo-relations/
- BFO2 contains “core” relations
- RO will include biology specific relations
- RO includes *macro* or *shortcut* relations

ObjectProperty: capable of

- Term IRI: http://purl.obolibrary.org/obo/RO_0002215
- definition: A relation between a material entity (such as a cell) and a process. This is a shortcut relation, translation rule for which is: capable_of P <-> bearer_of (some realized_by only P). Example: osteoclast capable of bone resorption.

Annotations

- definition editor: Chris Mungall
- alternative term: has function realized in
- has curation status: pending final vetting
- example of usage: osteoclast SubClassOf 'capable of' some 'bone resorption'
- expand expression to: BFO_0000053 some (BFO_0000054 only ?Y)
- definition source: PMID:21208450, PMID:20123131

7. Axioms constrain meaning of your terms

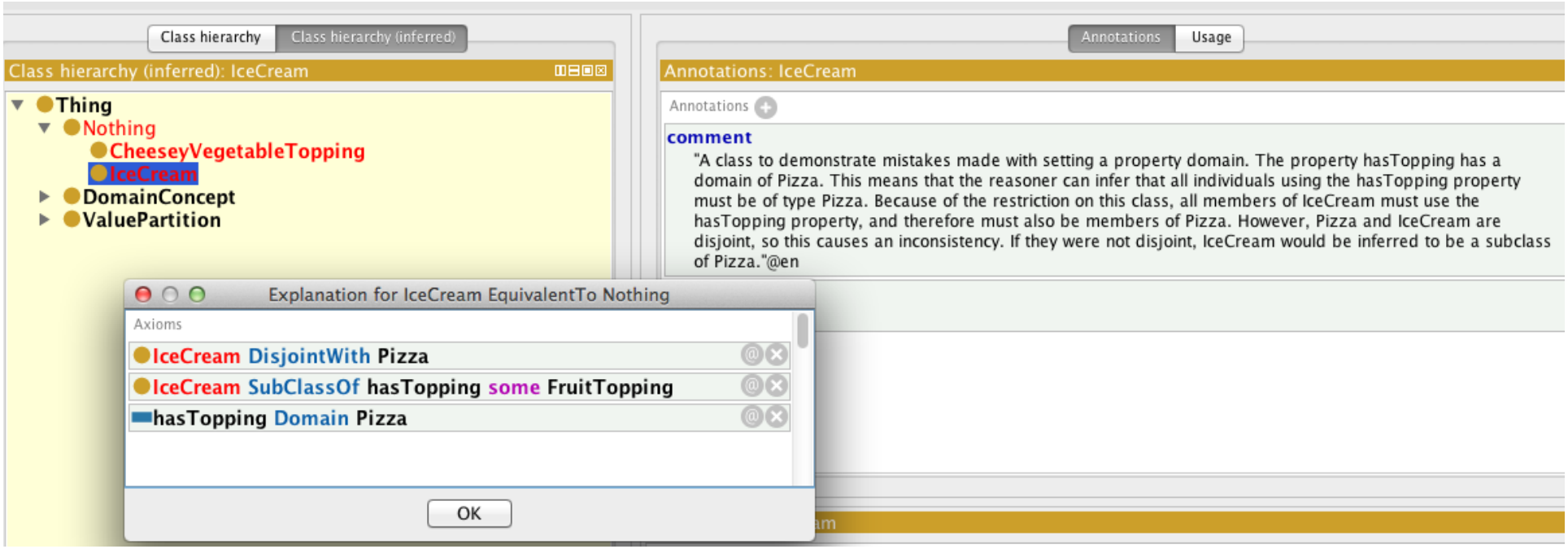
BFO and RO provide a taxonomy under which to put your terms. However, unless you add further axioms they won't be able to help you make a quality ontology

Here are some examples that should consider adding

- If every instance of an entity type E has certain types of parts P1, P2 make E subclass of (has part some P1) and (has part some P2)
- If you define a role type, say what kind of entity it inheres in and define and relate it to its realization process type. e.g. 'traffic guard role': 'inheres in' some 'homo sapiens' and 'is realized by only 'escorting person across road'

During reasoning these axioms interact with the ones from BFO and RO the reasoner will be able to detect some mistakes

Reasoning - consistency checking



http://www.co-ode.org/ontologies/pizza/2007/02/12/

8. Have a deliberate release process

The goal of a deliberate release process is to prepare a version that is aimed at users (which might be other developers or biologists) rather than the developers of this ontology

Typical activities

- Creation of dated release directory in repository
- Copy project files to release directory
- Update of MIREOT related files
- Merge in one release file for ease of use
- Run reasoner to add inferred axioms
- OWL and OBO format
- Quality checks
- Create dated and "latest" PURLs as stable URIs for your ontology

OORT – release tool

- An application to help manage ontologies and manage the ontology release process.
- Takes as input an *editors* version of an ontology and creates a number of *release* versions in both obo and owl format.
- These versions currently include:
  - The *main* version, with additional non-redundant links added via an OWL reasoner (i.e. *classified* in advance).
  - A *simple* version, which corresponds to the main version with any imported or "mireoted" classes removed
  - A version that has not had been reasoned over - the *non-classified* version

BFO2

- All OBO ontologies built under Basic Formal Ontology
- New version as draft release for ICBO

Pyramidal neuron relevant genes and processes

```
prefix go: <http://purl.org/obo/owl/GO#>
prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#>
prefix owl: <http://www.w3.org/2002/07/owl#>
prefix mesh: <http://purl.org/commons/record/mesh/>
prefix sc: <http://purl.org/science/owl/sciencecommons/>
prefix ro: <http://www.obofoundry.org/ro/ro.owl#>

select ?genename ?processname
where
{ graph <http://purl.org/commons/hcls/pubmesh>
  { ?paper ?p mesh:D017966 .
    ?article sc:identified_by_pmid ?paper.
    ?gene sc:describes_gene_or_gene_product_mentioned_by ?article.
  }
 graph <http://purl.org/commons/hcls/goa>
  { ?protein rdfs:subClassOf ?res.
    ?res owl:onProperty ro:has_function.
    ?res owl:someValuesFrom ?res2.
    ?res2 owl:onProperty ro:realized_as.
    ?res2 owl:someValuesFrom ?process.
 graph <http://purl.org/commons/hcls/20070416/classrelations>
  {{?process <http://purl.org/obo/owl/obo#part_of> go:GO_0007165}
    union
   {?process rdfs:subClassOf go:GO_0007165 }}
    ?protein rdfs:subClassOf ?parent.
    ?parent owl:equivalentClass ?res3.
    ?res3 owl:hasValue ?gene.
   }
 graph <http://purl.org/commons/hcls/gene>
  { ?gene rdfs:label ?genename }
 graph <http://purl.org/commons/hcls/20070416>
  { ?process rdfs:label ?processname}
}
```

Mesh: Pyramidal Neurons

↓

Pubmed: Journal Articles

↓

Entrez Gene: Genes

↓

GO: Signal Transduction

Inference required

Results

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	transmembrane 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 indeed related to Alzheimer's Disease through gamma secretase (presenilin) activity

Links

- ID policy http://obofoundry.org/id-policy.shtml
- Obo-discuss mailing-list: https://lists.sourceforge.net/lists/listinfo/obo-discuss
- BFO1: http://ifomis.org/bfo/1.1, RO: http://www.obofoundry.org/ro/ro.owl
- BFO2: http://purl.obolibrary.org/obo/bfo.owl, RO: http://purl.obolibrary.org/obo/ro.owl
- Ontology metadata: http://purl.obolibrary.org/obo/ontology-metadata.owl
- MIREOT: http://obi-ontology.org/page/MIREOT, OntoFox: http://ontofox.hegroup.org/
- Ontobee: http://www.ontobee.org/
- OORT (release tool): http://code.google.com/p/owltools/wiki/Oort
- Neurocommons SPARQL endpoint
    - http://sparql.neurocommons.org/
    - http://sparql.obo.neurocommons.org/: OBO specific instance