

Semantics and Ontologies

A Brief Introduction

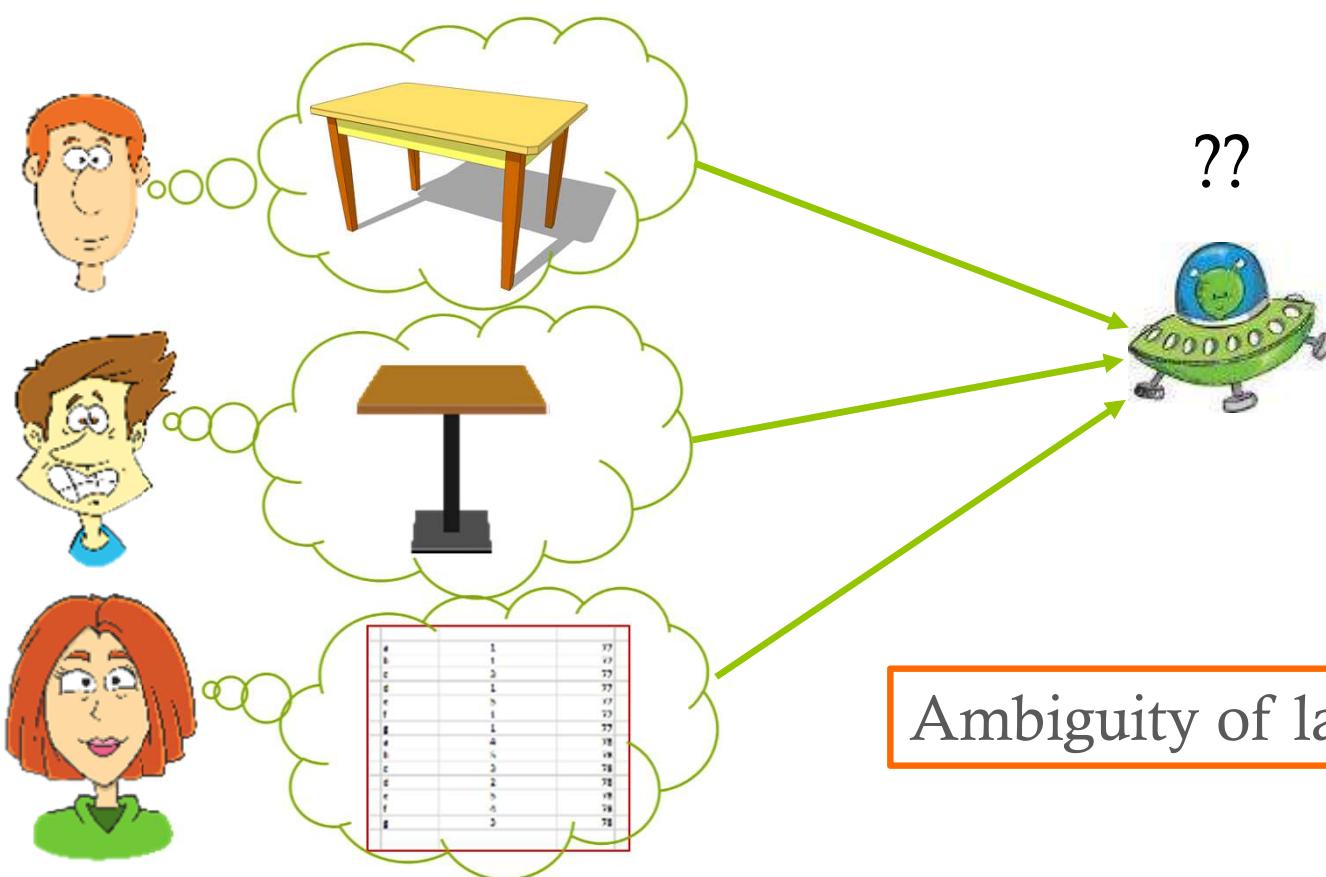
TACC, March 2018

Daniel Garijo, Yolanda Gil
Information Sciences Institute
and Department of Computer Science
University of Southern California
<http://w3id.org/people/dgarijo>
dgarijo@isi.edu
[@dgarijov](https://www.twitter.com/dgarijov)

http://

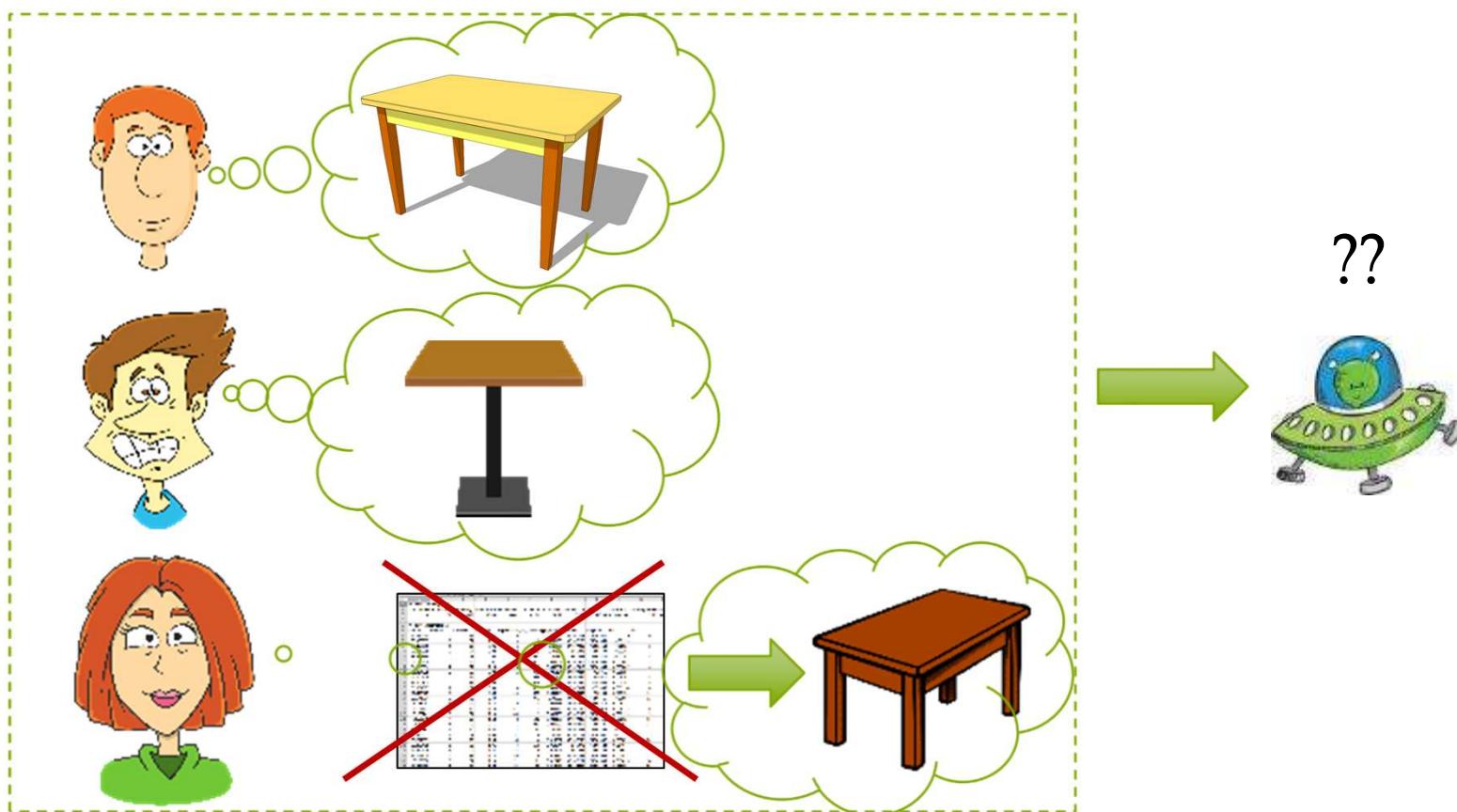
The problem: Defining a concept

- ◆ Imagine if three people explained the concept of “table” to someone that has never seen one



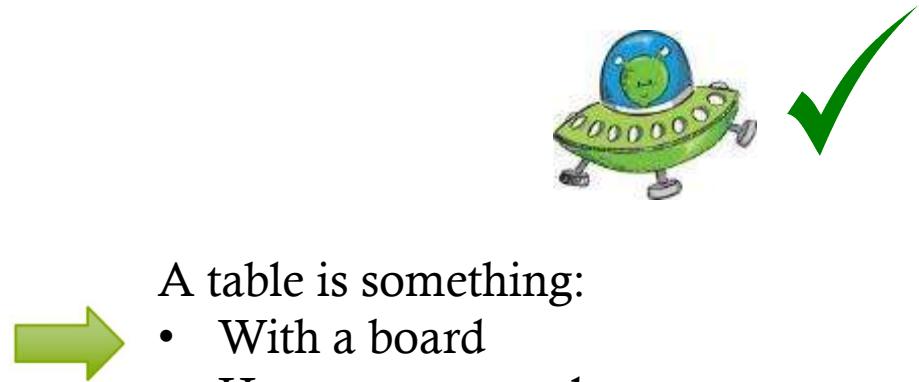
The problem: Defining a concept

- ◆ Reaching consensus can be difficult



The problem: Defining a concept

- ◆ After discussion, a shared conceptualization of a table is defined

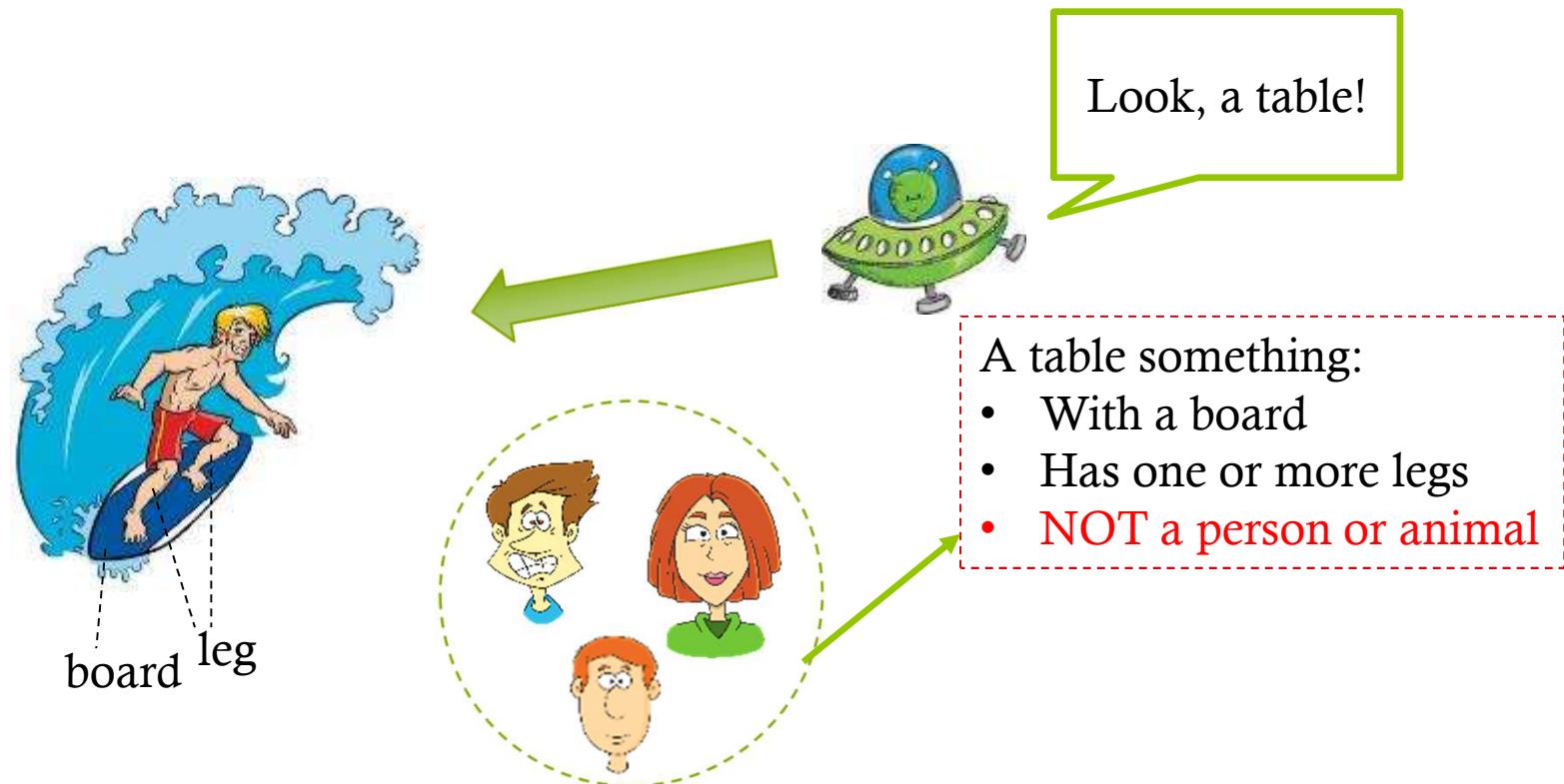


A table is something:

- With a board
- Has one or more legs

The problem: Defining a concept

- ◆ But, is it enough?



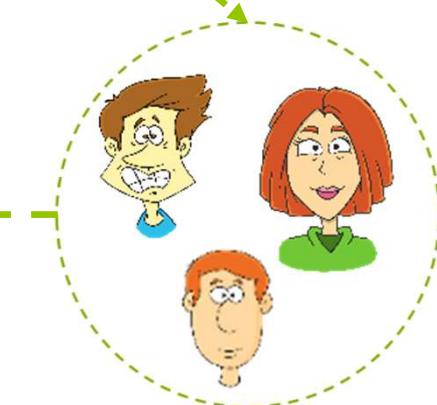
The solution: Ontologies

- ◆ Formal specification of a shared conceptualization [1]
- ◆ Designed for machines (machine readable)



A table is something:

- With a board
- Has one or more legs
- **NOT a person or animal**



Outline

- ◆ Background:
 - ◆ Biomedical data and the Gene Ontology
- ◆ How do ontologies work?
 - ◆ Structuring information: Ontology basics
 - ◆ The Semantic Web
- ◆ Ontologies and data on the Web
 - ◆ Linked Open Data
- ◆ Hands on: Pizza time!

Background: Biomedical Knowledge and The Gene Ontology

In the Beginning (circa 1998)



GenBank



The Gene Ontology (GO)

<http://www.geneontology.org/>

Three Organisms



Three Focus Areas

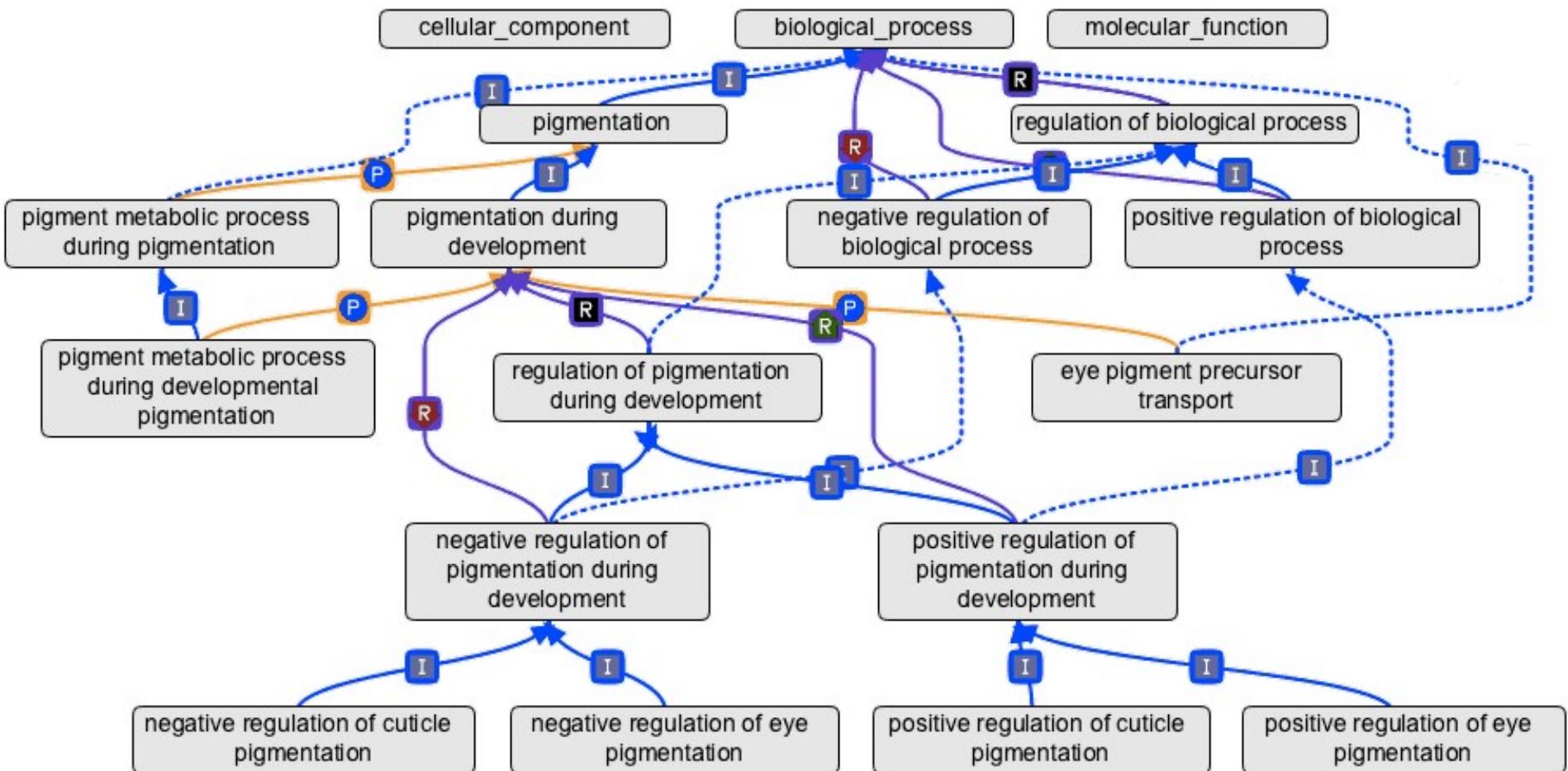
Cellular component

Biological process

Molecular function



Concepts and the Relationships Among Them



Sample GO Term

<http://geneontology.org/page/ontology-documentation>

Sample GO Term

The following is a GO term taken from the OBO format file.

- id: GO:0016049
- name: cell growth
- namespace: biological_process
- def: "The process in which a cell irreversibly increases in size over time by accretion and biosynthetic
- subset: goslim_generic
- subset: goslim_plant
- subset: gosubset_prok
- synonym: "cell expansion" RELATED []
- synonym: "cellular growth" EXACT []
- synonym: "growth of cell" EXACT []
- is_a: GO:0009987 ! cellular process
- is_a: GO:0040007 ! growth
- relationship: part_of GO:0008361 ! regulation of cell size

Found entities

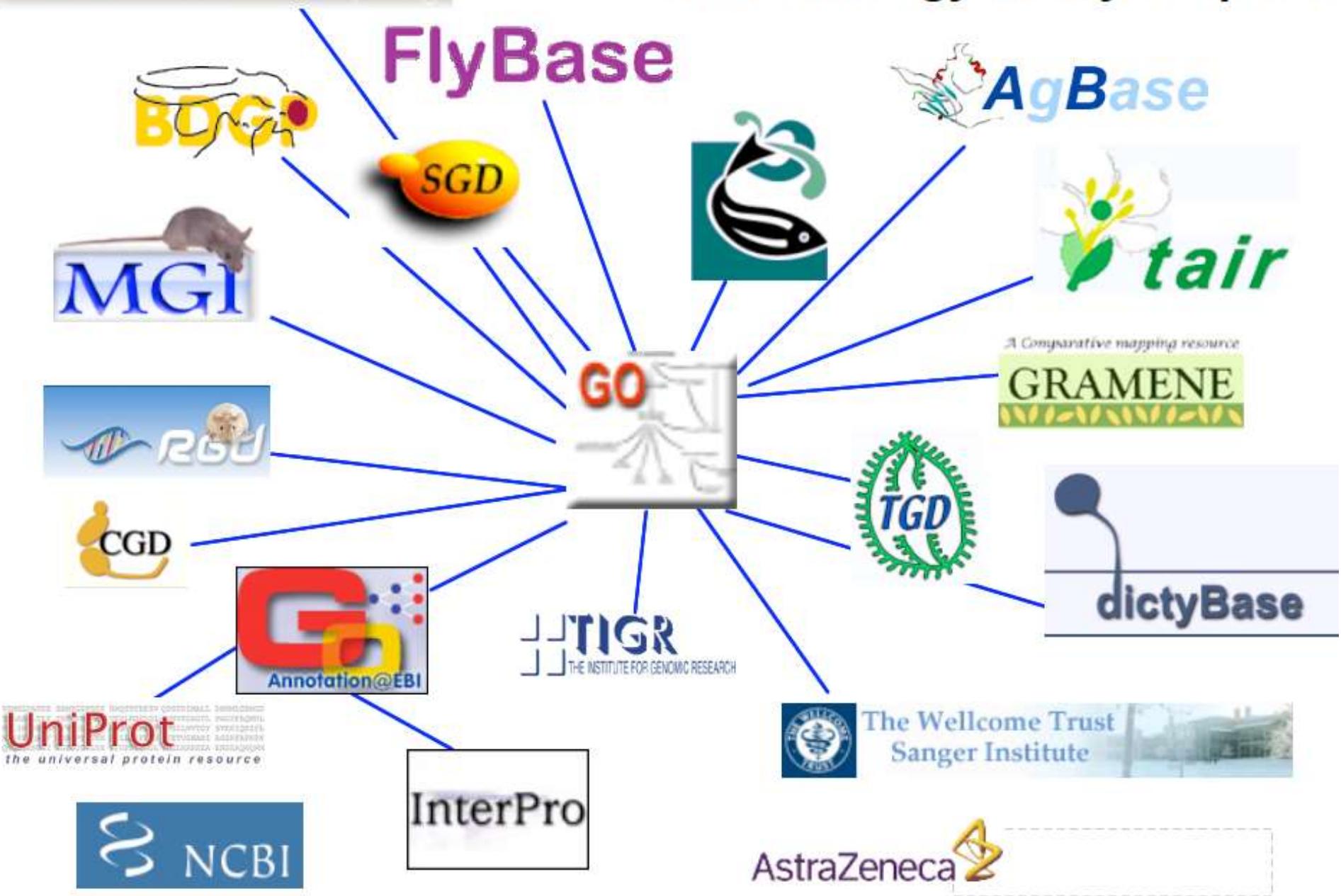
Total: 282; showing 1-10

Results count 10

<input type="checkbox"/>	Acc	Name	Taxon	PANTHER family	Type	Source	Synonyms	
<input type="checkbox"/>	BRCA1	AT4G21070	Arabidopsis thaliana		protein	TAIR	AT4G21070 ATBRCA1	
<input type="checkbox"/>	Brca1	breast cancer 1, early onset	Mus musculus	breast cancer type 1 susceptibility protein brca1 pthr13763	protein	MGI	Brca1 brca1	Breast cancer type 1 susceptibility protein Felis catus
<input type="checkbox"/>	Brca1	breast cancer 1	Rattus norvegicus	breast cancer type 1 susceptibility protein brca1 pthr13763	gene	RGD	BRCA1 Brca1 brca1	Breast cancer type 1 susceptibility protein Homo sapiens
<input type="checkbox"/>	Brca1	Breast cancer type 1 susceptibility protein homolog	Rattus norvegicus		protein	UniProtKB	BRCA1_RAT	Canis lupus familiaris
<input type="checkbox"/>	BRCA1	Breast and ovarian cancer susceptibility-like protein	Gallus gallus		protein	UniProtKB	Q90Z51_CHICK	Equus caballus
<input type="checkbox"/>	BRCA1	Uncharacterized protein	Takifugu rubripes	breast cancer type 1 susceptibility protein brca1 pthr13763	protein	UniProtKB	H2TDW1_TAKRU	Xenopus tropicalis



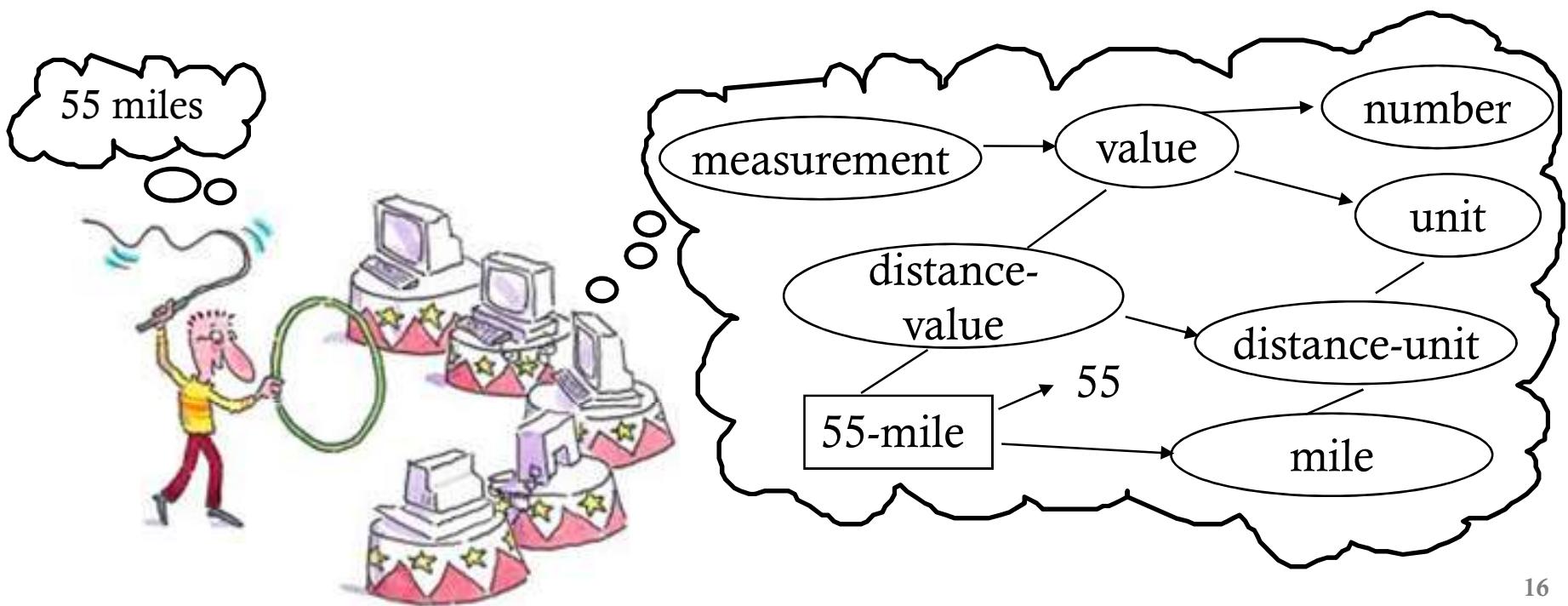
Gene Ontology widely adopted



Ontology Basics

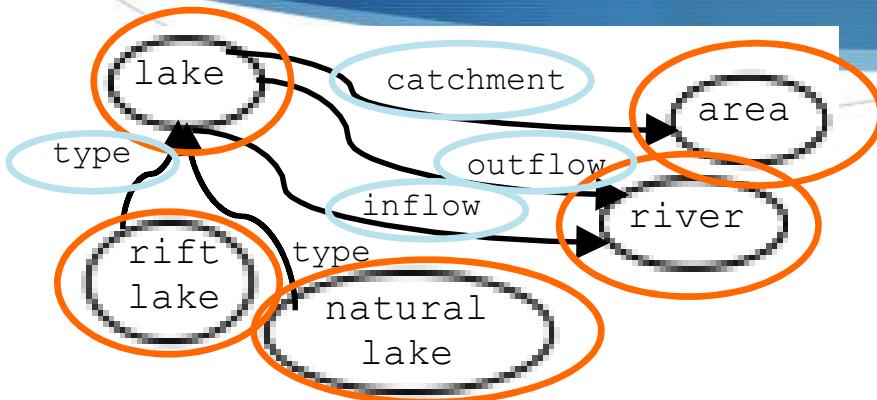
Knowledge Representation

- ◆ A subfield of artificial intelligence concerned with capturing formal (machine readable) information about the world
- ◆ Ontologies are one approach to knowledge representation
 - ◆ Focused on descriptions of objects
 - ◆ Based on mathematical logic

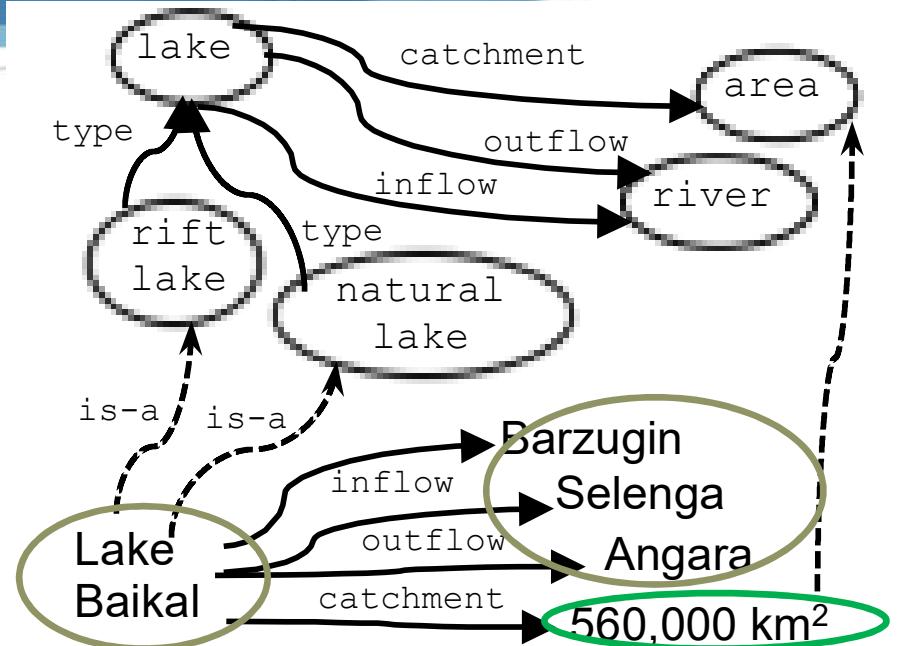


Ontology Basics

Ontology



Assertions (Data)



- ◆ Concepts (or classes)
- ◆ Properties
 - ◆ Domain -- applicability
 - ◆ Range – possible values

- ◆ Instances
- ◆ Property values

Ontologies vs Taxonomies vs Vocabularies

- ◆ **Vocabularies:** a set of terms
- ◆ **Taxonomies:** a hierarchical organization of terms
- ◆ **Ontologies:** formal taxonomies with logic constraints
 1. Mathematical logic provides formal semantics for what the hierarchies mean
 - ◆ Subclasses imply containment of instances
 - ◆ Instances of a class have all the properties of the class
 2. Logic constraints
 - ◆ Example: all humans have **exactly one** biological mother

Benefits – Take 1

1. Provide standards for data integration
 - ◆ eg the Gene Ontology
2. Data validation
 - ◆ Ensure that the data represent what was intended
3. Programmatic access to data
 - ◆ Enable structured queries

The Semantic Web

The Semantic Web

Ontology about
core samples

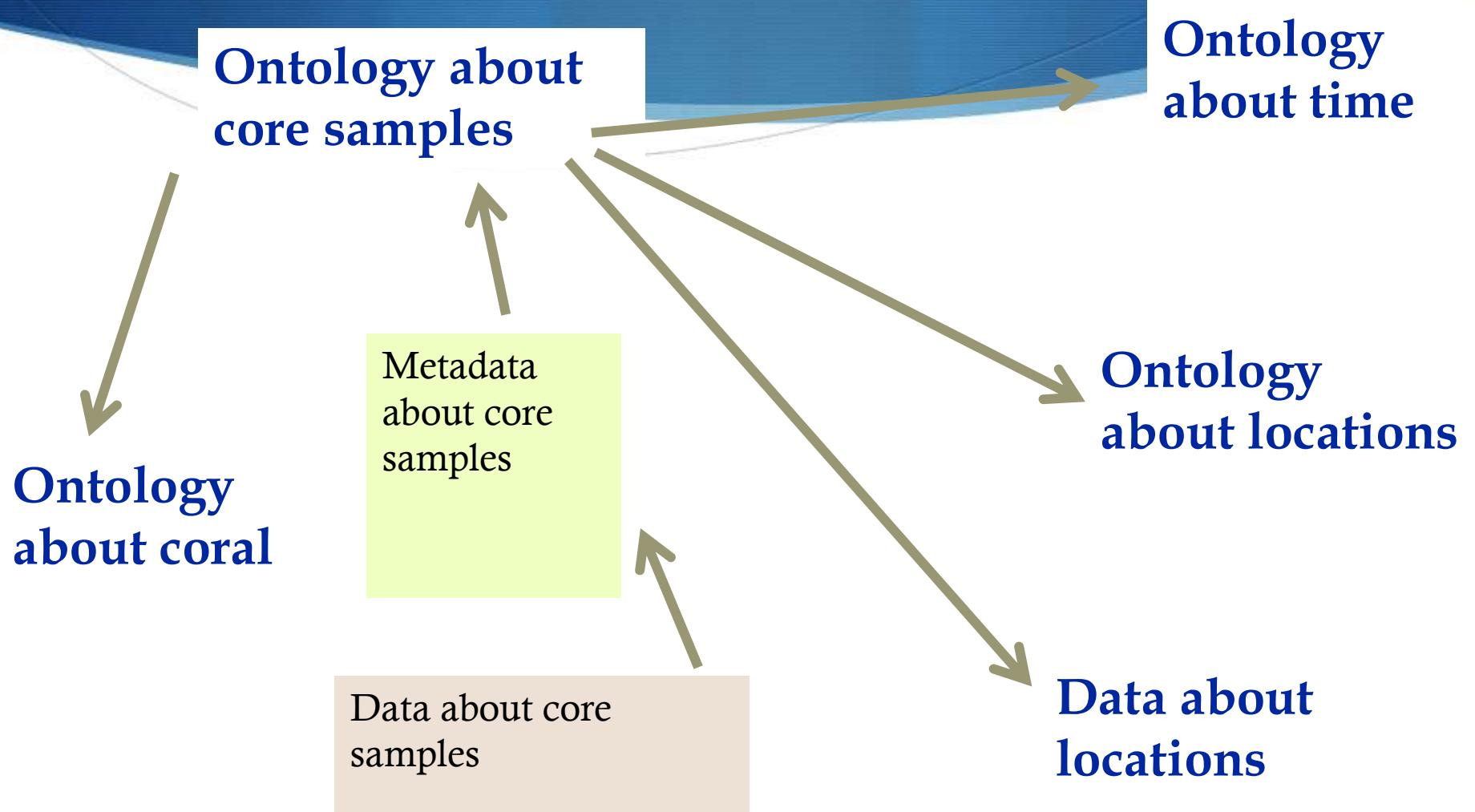


Metadata
about core
samples

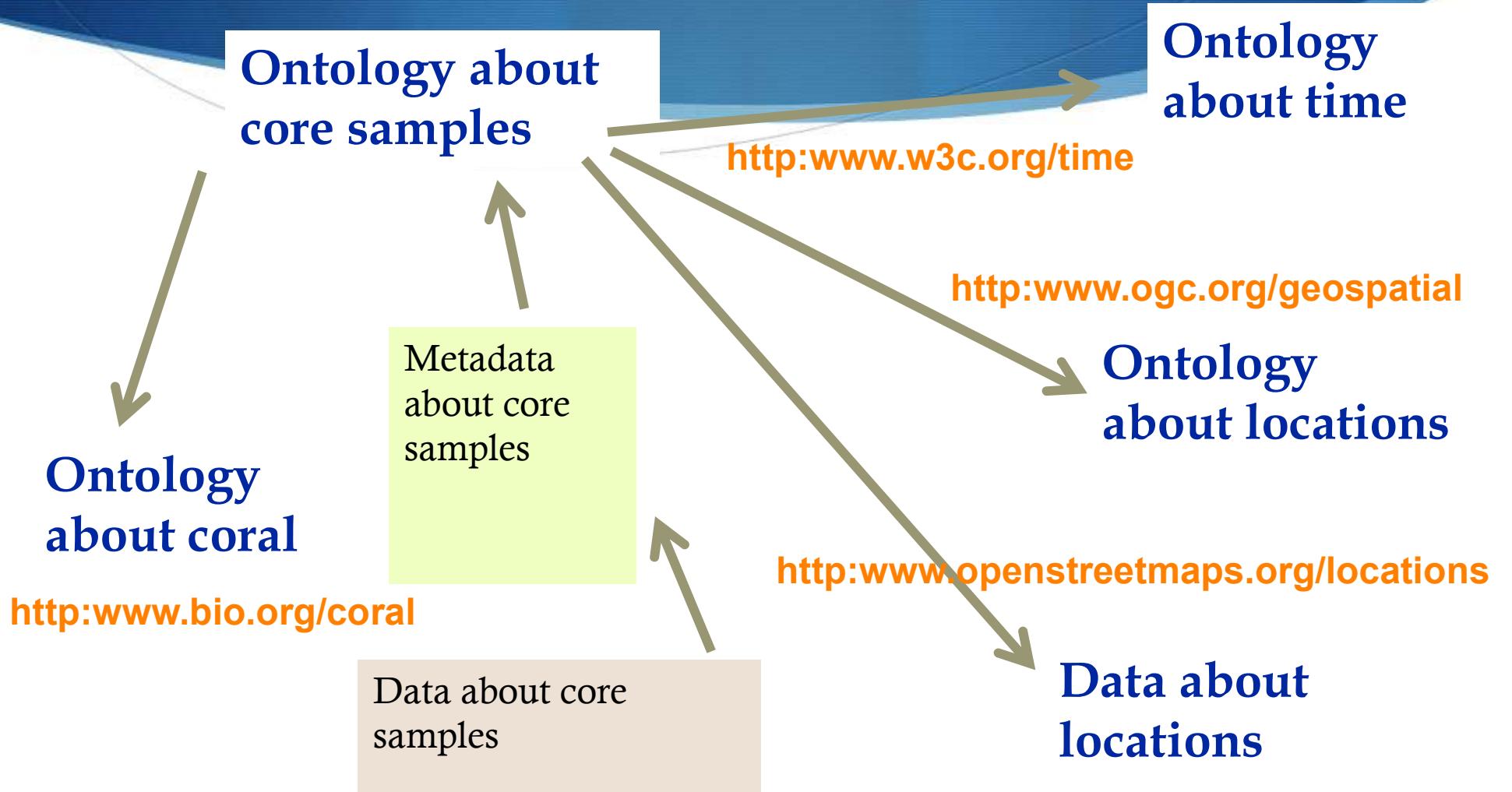


Data about core
samples

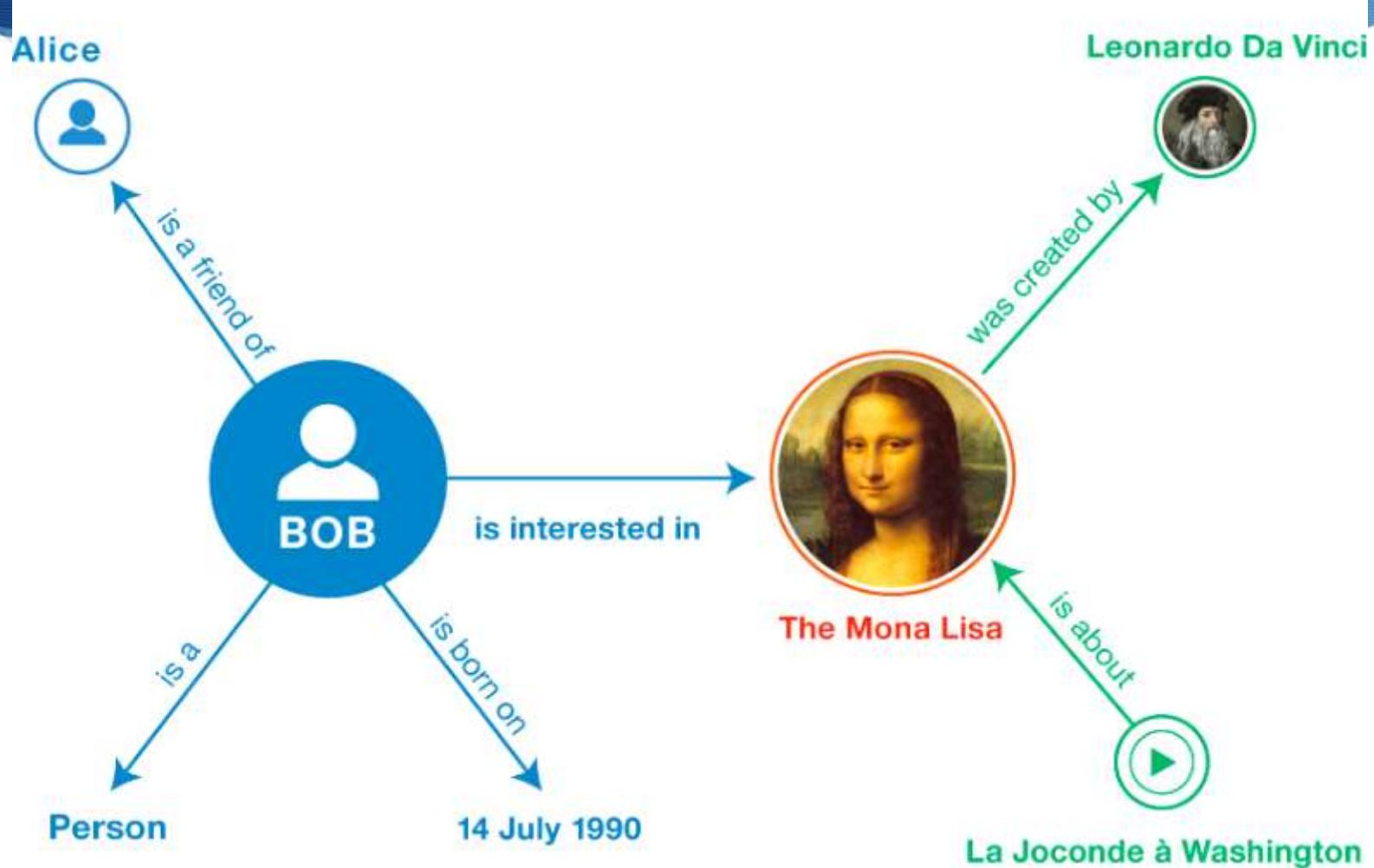
The Semantic Web



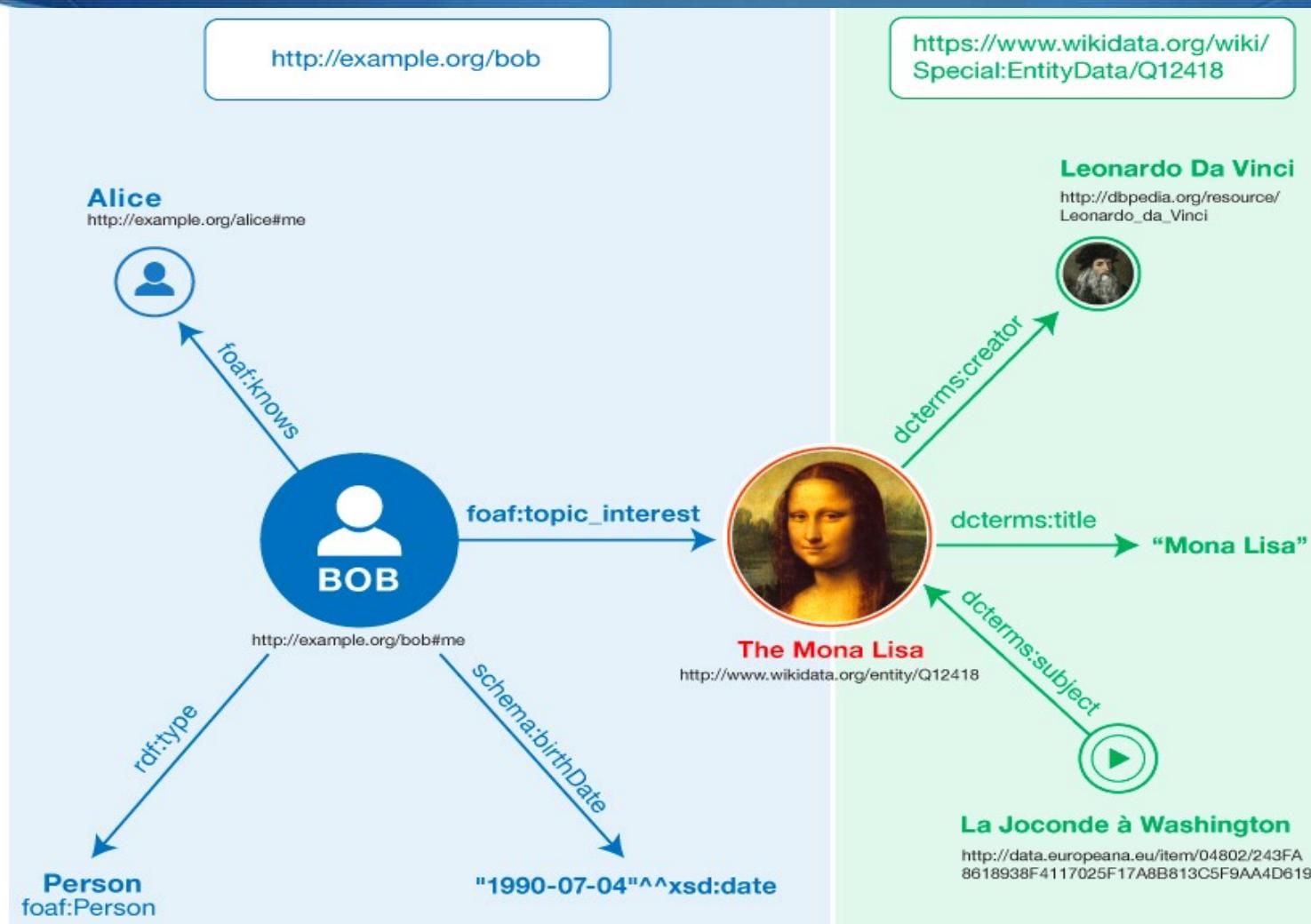
The Semantic Web



RDF: The Resource Description Framework



Giving Meanings to Hyperlinks on the Web



<http://www.w3.org/TR/2014/NOTE-rdf11-primer-20140624/>



Connecting to Other Ontologies/Data

WIKIDATA

Palmyra Atoll

[edit]

Structured Properties

main type (GND)	geographical feature	[edit]
is in the administrative unit	United States Minor Outlying Islands	[edit]

Linked Earth Wiki

Palmyra coral 20C

Data

- DOWNLOAD

From: <http://www.ncdc.noaa.gov/paleo/metadata/noaa-coral-1865.html>

Structured Properties

[x] SiteName	Palmyra	(By Julien)
[x] Archive	Coral	(By Julien)
[x] Domain(s)	Climate,geochemistry	(By Julien)
[x] Forward model	10.1029/2011GL048224	(By Julien)
[x] Genus	Porites	(By Julien)
[x] Interpretation	SST,SSS	(By Nick)
[x] Measurement	Delta18O	(By Julien)
[x] MeasurementMaterial	Skeletal aragonite	(By Julien)
[x] MeasurementStandard	VPDB	(By Nick)
[x] MeasurementUnits	Permil	(By Julien)
[x] Reference	Cobb et al, 2001	(By Julien)
[x] Species	Lutea	(By Julien)

Credits

Users who have contributed to this Page:

- Julien (43 Edits)
- Nick (34 Edits)

RDF

◆ NCBITaxon ontology:
porites <http://bioportal.bioontology.org/ontologies/NCBITAXON?p=classes&conceptid=http%3A%2F%2Fpurl.bioontology.org%2Fontology%2FNNCBITAXON%2F46719>

Porites

Structured Properties

[add/edit] [x] Property Name Topic Finger Coral [edit]
[x] <http://dbpedia.org/resource/Porites>
[x] [edit source]

Wikipedia Entry [go to original Wikipedia article](#)

Porites is a genus of stony coral; they are SPS (Small Polyp Stony) corals. They are characterised by a finger-like morphology. Members of this genus have widely spaced

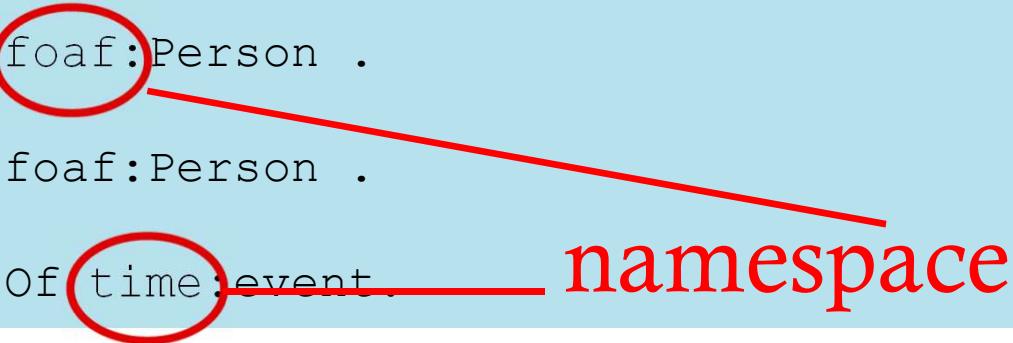
Finger Coral

Web of Data RDF

Porites	Topic
db	Topic
class	Coral
classes	Coral
domain	Porites
family	Polyzoa
genus	Porites
kingdom	Animalia
name	Finger Coral
name	Fungia
name	Leptastrea
order	Scleractinia
phylum	Cnidaria

Reusing Ontologies Through URLs/URIs

```
@prefix : <http://www.usc.edu/people#> .  
@prefix foaf: <http://www.w3.org/2012/foaf#> .  
@prefix time: <http://www.w3.org/2009/time#> .  
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .  
@prefix owl: <http://www.w3.org/2002/07/owl#> .  
  
:faculty rdfs:subClassOf foaf:Person .  
  
:student rdfs:subClassOf foaf:Person .  
  
:graduation rdfs:subClassOf time:event .
```



namespace

Semantic Search Engines

<http://watson.kmi.open.ac.uk/WatsonWUI/>



[What is it?](#) - [Submit URI](#) - [Website](#) - [APIs](#)

person

[Search Watson](#)

[Search Options](#)

<http://www.w3.org/2000/10/swap/pim/contact.rdf> +

- ◆ <http://www.w3.org/2000/10/swap/pim/contact#Person>
- © <http://www.w3.org/2000/10/swap/pim/contact#ContactLocation>
- ¶ <http://www.w3.org/2000/10/swap/pim/contact#knownAs>
- © <http://www.w3.org/2000/10/swap/pim/contact#SocialEntity>

<http://sw.cyc.com/2006/07/27/P/e/Person.owl> +

- © <http://sw.cyc.com/2006/07/27/cyc/#Person>

<http://www.xml.com/2004/09/01/examples/Politics.rdf> +

- © <http://hackingcongress.org/ns/Politics#Person>
- ¶ <http://hackingcongress.org/ns/Politics#Gender>
- ¶ <http://hackingcongress.org/ns/Politics#BirthPlace>
- ¶ <http://hackingcongress.org/ns/Politics#HomeTown>
- ¶ <http://hackingcongress.org/ns/Politics#Birthday>
- ¶ <http://hackingcongress.org/ns/Politics#FullName>

schema.org

schema.org

Review

Thing > CreativeWork > Review

A review of an item – for example, of a restaurant, n

Usage: Between 250,000 and 500,000 domains

Property	On Types
<code>resultReview</code>	ReviewAction
<code>review</code>	Organization or Place or Event or Service or CreativeWork or Product or Brand or Offer

The screenshot shows a search results page for "cannon rebel" on a search engine interface featuring Bing, Yahoo!, Google, and Yandex. The results are filtered under the "All" tab. The first result is for EOS DSLR Cameras | EOS Rebel T5 18-55 IS II Kit | Canon, with a green arrow pointing to it. The second result is for Canon EOS Rebel T5 DSLR Camera 2 Lens Bundle - Costco, also with a green arrow. The third result is for Canon T5 EOS Rebel DSLR Camera with EF-S 18-55mm IS, with another green arrow. The fourth result is for Canon EOS Rebel T5 DSLR Camera with 18-55mm and 75-300mm Lenses Bundle, with a final green arrow.

Bing YAHOO! Yandex

cannon rebel

All Shopping Images Videos News More Search tools

About 16,400,000 results (1.08 seconds)

Showing results for **canon rebel**
Search instead for [cannon rebel](#)

EOS DSLR Cameras | EOS Rebel T5 18-55 IS II Kit | Canon ...
<https://www.usa.canon.com/.../eos-rebel-t5-ef-s-18-55-is-ii-kit> ▾ Canon Inc. ▾
★★★★★ Rating: 4.5 - 34 reviews
Perfect for families, budding photo enthusiasts and first-time SLR users alike, the EOS Rebel T5 makes it easy to capture movies and photos that are nothing ...

Canon EOS Rebel T5 DSLR Camera 2 Lens Bundle - Costco
www.costco.com/Canon-EOS-Rebel-T5-DSLR-Camera-2-Lens-Bu... ▾ Costco ▾
★★★★★ Rating: 4.8 - 10 reviews
Canon EOS Rebel T5 DSLR Camera 2 Lens Bundle EF-S 18-55mm f/3.5-5.6 IS II and EF75/300 III Lens, 16GB SD Card, Camera Bag, EOS Digital Solution Disc ...

Canon T5 EOS Rebel DSLR Camera with EF-S 18-55mm IS ...
www.bhphotovideo.com/.../DSLR-Cameras ▾ B & H Photo Video ▾
★★★★★ Rating: 4.5 - 117 reviews - \$399.00 - In stock
Canon EOS T5 Rebel DSLR Camera with EF-S 18-55mm IS II Lens, Canon EOS 1200D features 18MP APS-C CMOS Sensor, EF-S 18-55mm IS II Lens ...

Canon EOS Rebel T5 DSLR Camera with 18-55mm and ...
www.bhphotovideo.com/.../DSLR-Cameras ▾ B & H Photo Video ▾
★★★★★ Rating: 5 - 74 reviews - \$499.00 - In stock
Buy Canon EOS Rebel T5 DSLR Camera with 18-55mm and 75-300mm Lenses Bundle features 18MP APS-C CMOS Sensor, DIGIC 4 Image Processor.

Microdata

- ◆ Microdata is markup added to HTML files that search engines use

```
<section> Hello, my name is John Doe, I am a graduate research assistant at  
the University of Dreams.  
My friends call me Johnny.  
You can visit my homepage at <a href="http://www.JohnnyD.com">www.JohnnyD.com</a>.  
I live at 1234 Peach Drive, Warner Robins, Georgia.</section>
```

```
<section itemscope itemtype="http://schema.org/Person">  
Hello, my name is  
<span itemprop="name">John Doe</span>,  
I am a  
<span itemprop="jobTitle">graduate research assistant</span>  
at the  
<span itemprop="affiliation">University of Dreams</span>.  
My friends call me  
<span itemprop="additionalName">Johnny</span>.  
You can visit my homepage at  
<a href="http://www.JohnnyD.com" itemprop="url">www.JohnnyD.com</a>.  
<section itemprop="address" itemscope itemtype="http://schema.org/PostalAddress">  
I live at  
<span itemprop="streetAddress">1234 Peach Drive</span>,  
<span itemprop="addressLocality">Warner Robins</span>,  
<span itemprop="addressRegion">Georgia</span>.  
</section>  
</section>
```

JSON-LD snippets

- ◆ Markup added to HTML files that search engines use (alternative to microdata)

The screenshot illustrates the JSON-LD snippet process. On the left, the browser's developer tools show the raw HTML code with a red box highlighting the JSON-LD script block. This block contains a `<script type="application/ld+json">` tag with a JSON-LD object describing a dataset. On the right, a JSON viewer titled "What engines see..." shows the parsed JSON-LD structure, listing properties like @type, url, version, keywords, name, contributor, and spatialCoverage, along with their corresponding values.

What users mark...

```
43 <a href="#p-search">search</a>
44 </div>
45 <div id="mw-content-te
46 ltr"><div class='subheader'> Dataset
47 <script type="application/ld+json">{"@context": "http://
48 /schema.org", "@type": "Dataset", "url": "http://wiki.linked.earth
49 /A7.Oppo.2005", "Name": ["A7.Oppo.2005"], "contributor": [{"@type": "Person", "name": "Y.
50 Sun"}, {"@type": "Person", "name": "D.W. Oppo"}, {"@type": "Person", "name": "R. Xiang"}, {"@type": "Person", "name": "W. Liu"}, {"@type": "Person", "name": "S.
51 Gao."}], "spatialCoverage": [{"@type": "Place", "geo":
52 {"@type": "GeoCoordinates", "latitude": "28.02", "longitude": "127.02", "elevation": "-
53 1264"}]}, {"citation": [{"@type": "CreativeWork", "identifier": "10.1029/2004PA001061", "name": "Last deglaciation
54 in the Okinawa Trough: Subtropical northwest Pacific link to Northern Hemisphere and
55 tropical climate", "url": "http://dx.doi.org/10.1029/2004PA001061"}], "version": "0.0.0"}, {"keywords": "paleoclimate, climate", "distribution": [{"@type": "DataDownload", "encodingFormat": "LPP", "contentUrl": "http://
56 /wiki.linked.earth/wikil/index.php?Special:WTLiPD?op=export&lipid=A7.Oppo.2005"}]}
57 </script>
58 <div style="margin-bottom:5px"><a class="lcbbutton" href="/wikil/index.php?
59 /Special:WTLiPD?op=export&lipid=A7.Oppo.2005">Download LiPD</a></div><div id="pageid-
60 suggestion" class='props-table'></div><div id="main-std-props" class='props-table'>
61 </div>
62 <!--
63 NewPF limit report
64 Cached time: 20180306024808
65 Cache expiry: 86400
66 Dynamic content: false
67 [ESMM] In-text annotation parser time: 0.001 seconds
68 CPU time usage: 0.033 seconds
69 Real time usage: 0.045 seconds
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The Google Knowledge Graph



Google john lennon

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About 62,900,000 results (0.50 seconds)

John Lennon Official Website
www.johnlennon.com/ ▾
An official website that features news, biography, videos, historical timeline, downloads, and drawings.

John Lennon - Wikipedia, the free encyclopedia
https://en.wikipedia.org/wiki/John_Lennon ▾ Wikipedia ▾
John Winston Ono Lennon, MBE (born John Winston Lennon; 9 October 1940 – 8 December 1980) was an English singer and songwriter who rose to worldwide ...
Death of John Lennon · Mark David Chapman · Yoko Ono · Cynthia Lennon

Death of John Lennon - Wikipedia, the free encyclopedia
https://en.wikipedia.org/wiki/Death_of_John_Lennon ▾ Wikipedia ▾
John Lennon was an English musician who gained worldwide fame as one of ...
Deaths: 1 Location: The Dakota, New York, New York
Date: 10:50 pm, 8 December 1980 (US ...) Weapon: Charter Arms Undercover.38 ...

John Lennon

Singer-songwriter · johnlennon.com

John Winston Ono Lennon, MBE was an English singer and songwriter who rose to worldwide fame as a co-founder of the band the Beatles, the most commercially successful band in the history of popular music.
[Wikipedia](#)

Born: October 9, 1940, Liverpool, United Kingdom

Assassinated: December 8, 1980, New York City, NY

Spouse: Yoko Ono (m. 1969–1980), Cynthia Lennon (m. 1962–1968)

Children: Sean Lennon, Julian Lennon

Songs

Jealous Guy	Imagine
Beautiful Boy	Double Fantasy
Starting Over	Double Fantasy
Stand By Me	Rock 'n' Roll
Watching the Wheels	Double Fantasy

Quotes

[View 7+ more](#)

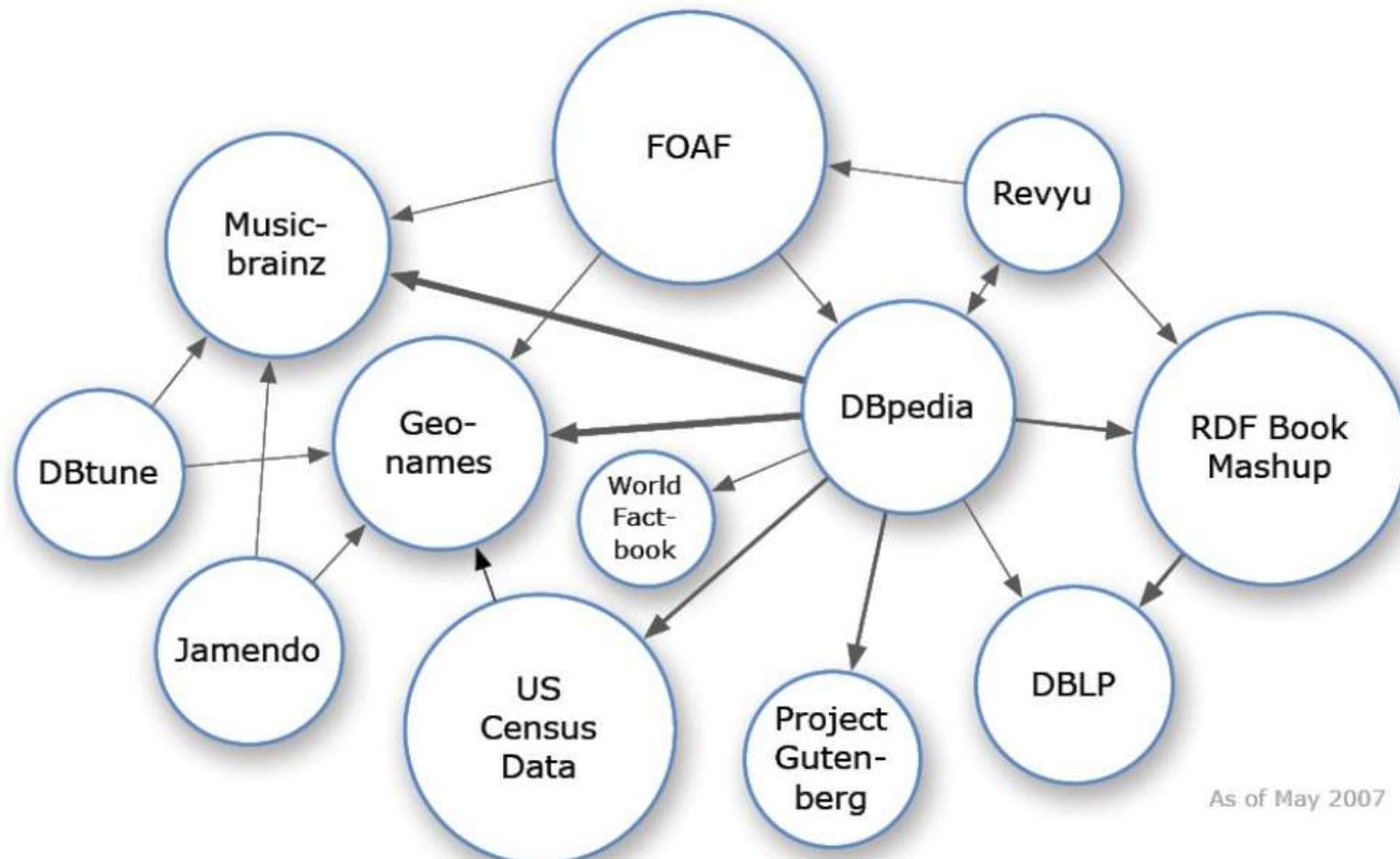
If everyone demanded peace instead of another television set, then there'd be peace.

Reality leaves a lot to the imagination.

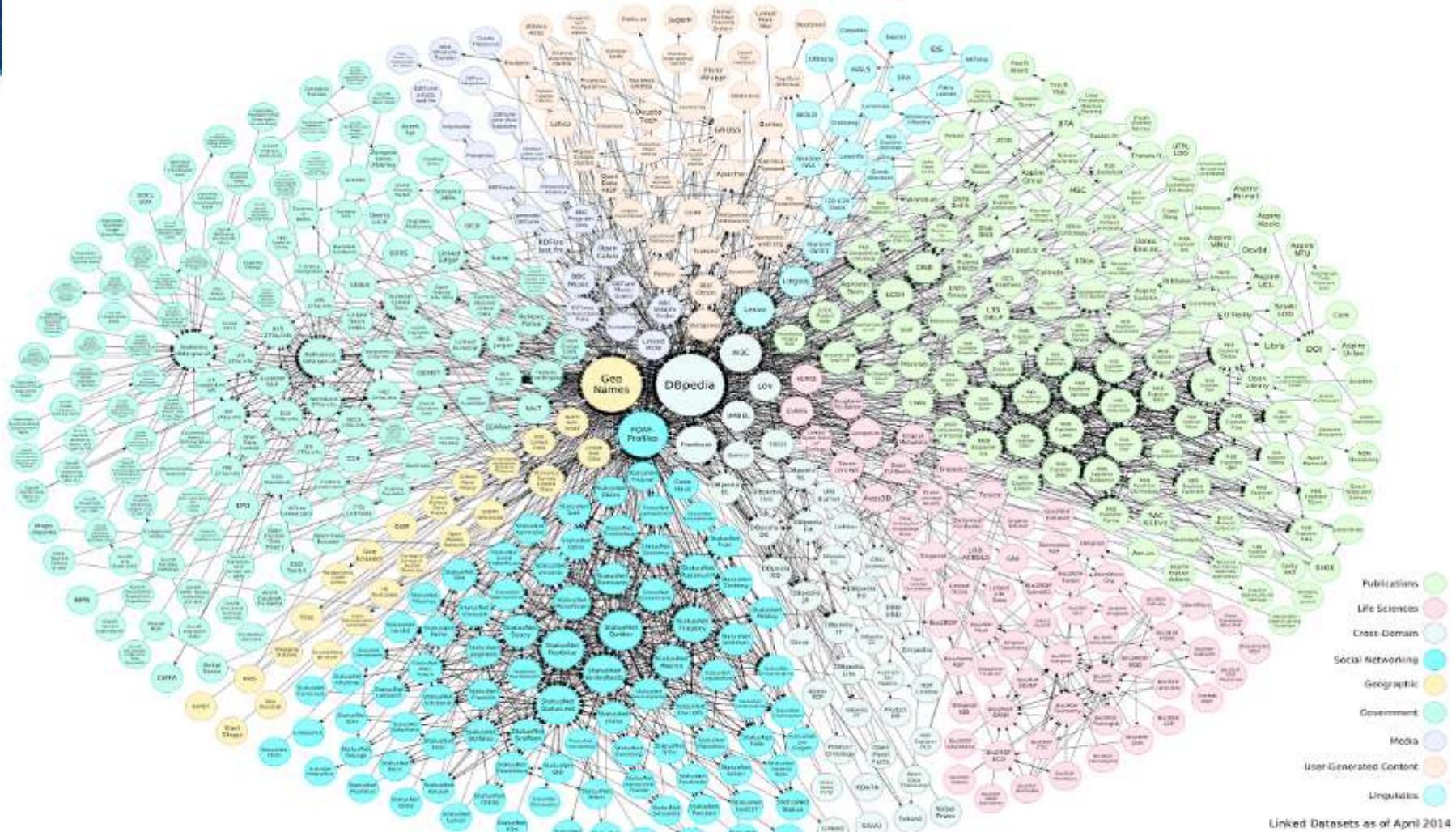
Time you enjoy wasting, was not wasted.

Linked Open Data

Connecting Data on the Web

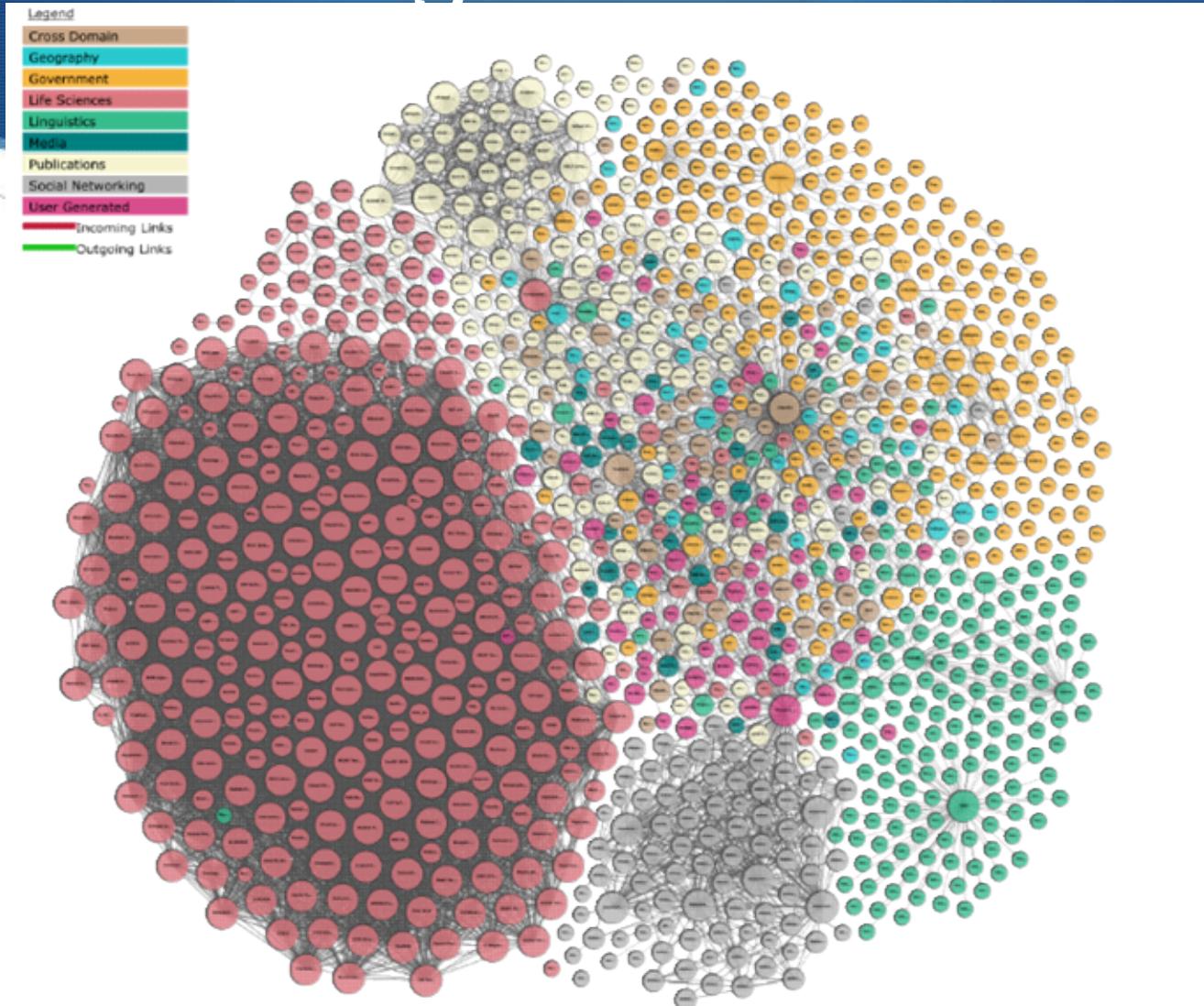


Interlinked Data and Ontologies on the Web



"Linking Open Data cloud diagram 2014, by Max Schmachtenberg, Christian Bizer, Anja Jentzsch and Richard Cyganiak. <http://lod-cloud.net/>"

Interlinked Data and Ontologies on the Web



Interlinked Data and Ontologies on the Web



BBC
ONTOLOGIES



OS OpenData
Ordnance Survey Linked Data
36,773,887 triples

GeoNames



	2007	2011	2015
Datasets	294	571	3426
Triples	2B	31B	85B
Cross-refs	2M	500 M	

74% of datasets in a weakly connected component

FOAF: from 27% to 59%

DC: from 31% to 56%

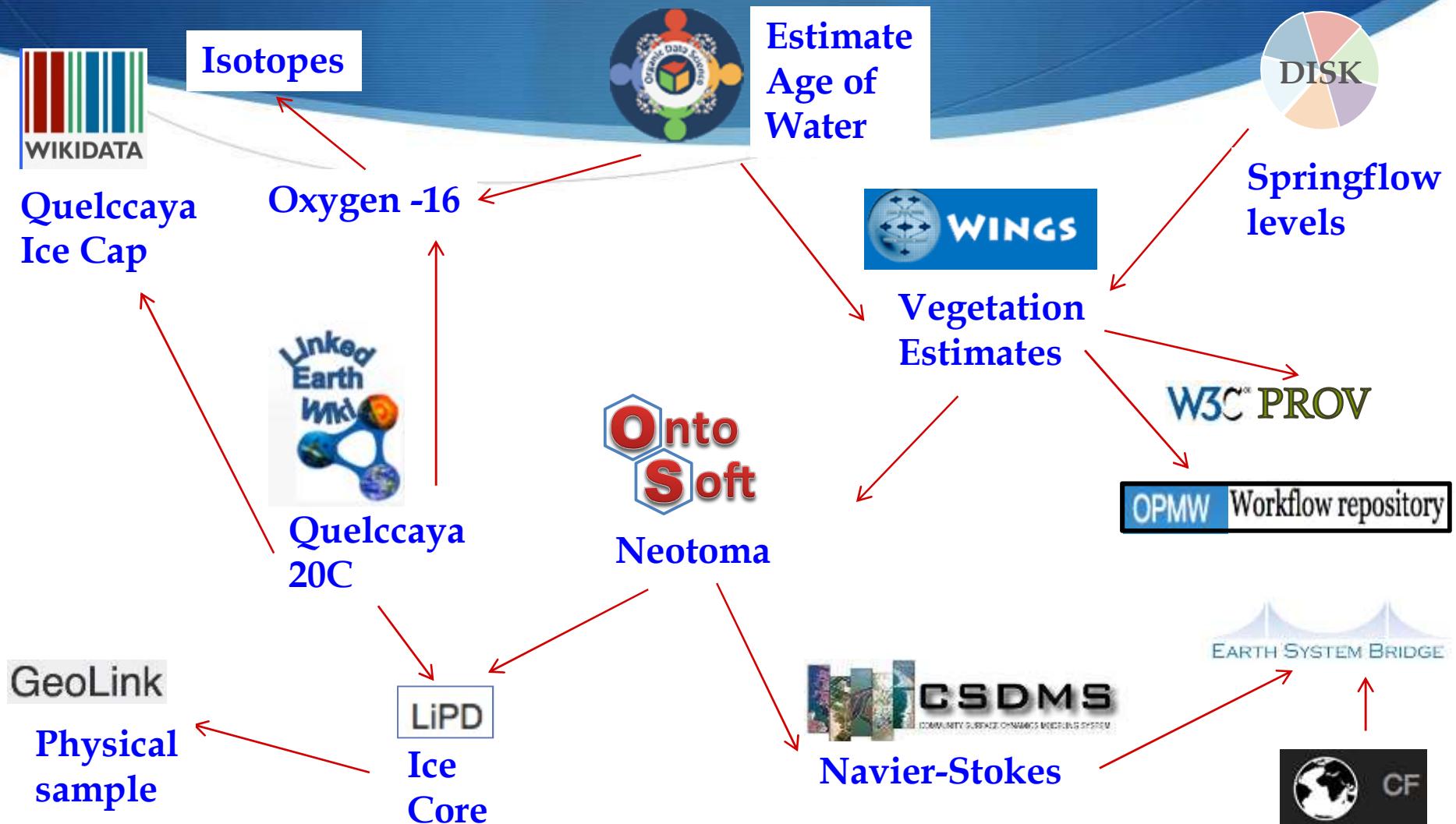
<http://lod-cloud.net>
<http://stats.lod2.eu>

Linked Open Data Principles: URIs, HTTP, RDF

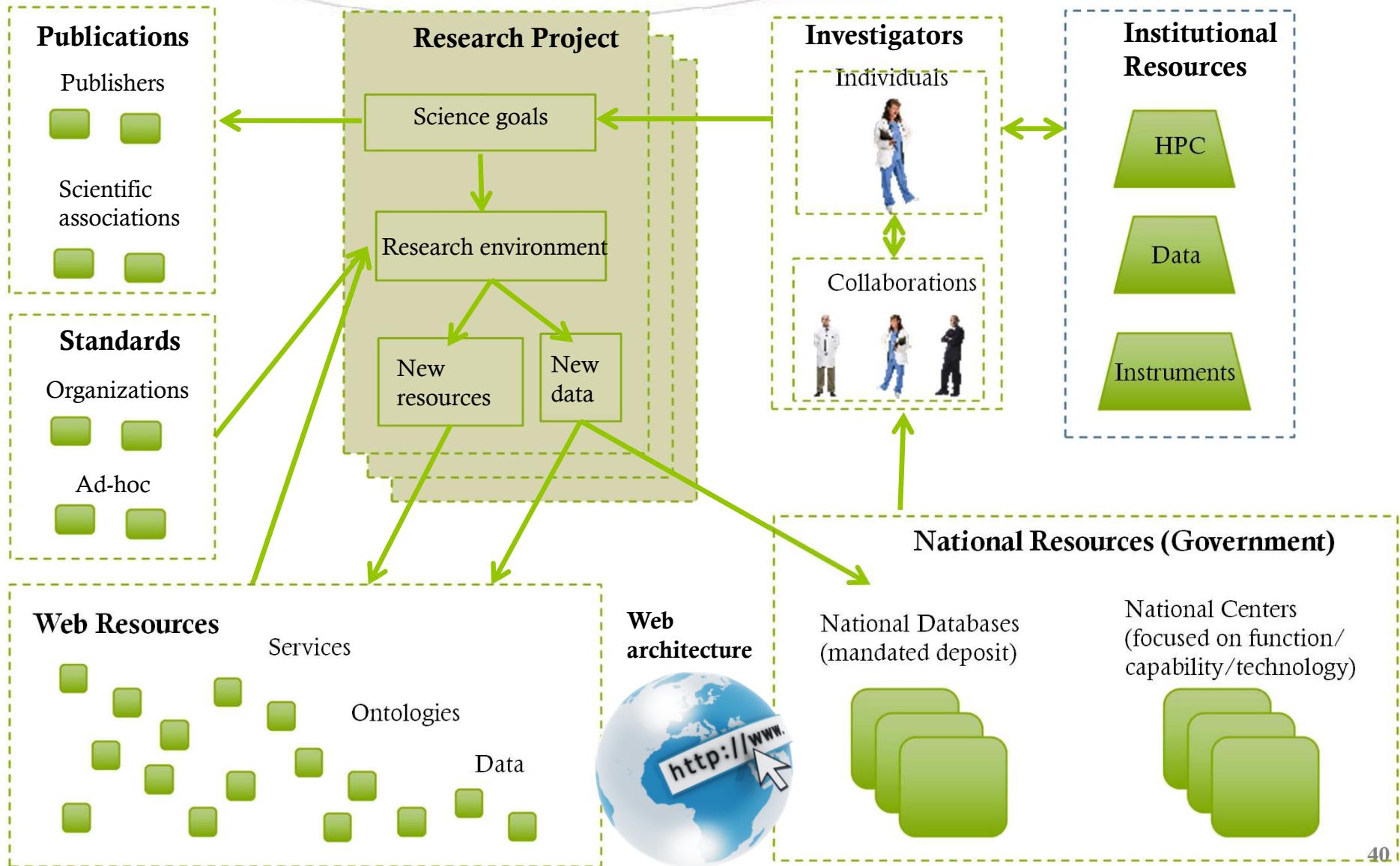
1. URIs are used to access any entity
2. HTTP can be used to access information about entities through their URIs
3. Information about entities is available in RDF, SPARQL, etc.
4. References to other entities are done through relationships that point to their URIs



LinkedEarth: Linked Data



Web Architecture



Benefits – Take 2

1. Provide standards for data integration
 - ◆ eg the Gene Ontology
2. Data validation
 - ◆ Ensure that the data represent what was intended
3. Programmatic access to data
 - ◆ Enable structured queries
4. Linking and reusing other ontologies and data
 - ◆ Connecting across the Web
5. Publishing data in open web-accessible formats

Hands on:
Time for Pizza

Time for Pizza

- ◆ Divide in 2 groups
 - ◆ A group will aim to describe the pizzas in a restaurant menu
 - ◆ A group will aim to describe pizzas in a supermarket
- ◆ How do you define a Pizza Margherita?
- ◆ How do you define a 4 cheese pizza?
- ◆ How do you define a vegetarian pizza?
- ◆ Can I order a pizza with no tomato?
- ◆ Can I order a plain pizza?

Time for Pizza

- ◆ **What are your Classes? Are there Dubclasses?**
- ◆ **What are your Properties? Domain and Range?**
- ◆ **What are your Data Properties?**
- ◆ **What are your axioms?**

- ◆ **Finished?**
- ◆ **Do a diagram of your ontology:**
http://visualdataweb.de/webowl_editor/ or
- ◆ **Download Protégé:** <https://protege.stanford.edu/>

Introductory Readings on Semantics and Ontologies

- ◆ “Ontology Development 101: A Guide to Creating Your First Ontology.” Natalya F. Noy and Deborah McGuinness.
http://protege.stanford.edu/publications/ontology_development/ontology101.pdf
- ◆ “A short study on the success of the Gene Ontology.” Bada, M.; Stevens, R.; Goble, C. A.; Gil, Y.; Ashburner, M.; Blake, J. A.; Cherry, J. M.; Harris, M. A.; and Lewis, S. Journal of Web Semantics, 1(2): 235-240. 2004. DOI: 10.1016/j.websem.2003.12.003
- ◆ “Social Knowledge Collection.” Yolanda Gil. Handbook of Human Computation. Michelucci P. (Ed), MIT Press 2014.