Linked Data for Digital Twins

Jan Top, Hannelore Heuer, December 14, 2022

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Digital twin

- Digital model of something, for example a human being
- Can tell us something about this person that we do not see immediately
- Can relate to scientific knowledge
- Is used for forecasting, visualisation, diagnosis, advice, control

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Data for digital twins

- For creating the twin
  - Learn from response of the real system to external stimuli
  - Learning can happen in advance or in real time
  - Example data: food intake, triglyceride and sugar levels, ...
  - Twins also use expert knowledge!
- For feeding the twin
  - Adapt twin model or parameter values in the model
  - Monitor current status of the subject and its environment
  - Example data: heart beat, blood pressure, weight, ...
  - The twin cannot (and should not try to) predict everything

Digital twin for nutritional advice

What could a digital twin of your field do for you?

Which data or knowledge would it need?

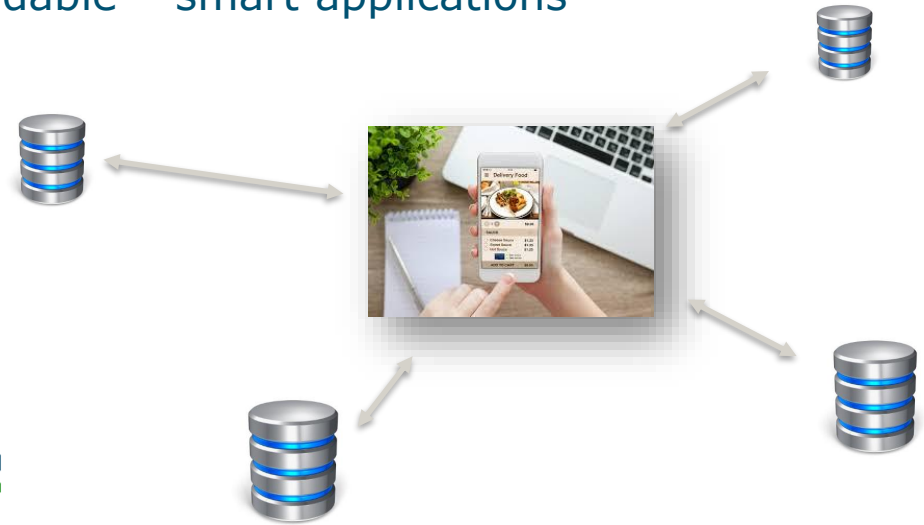
Data sharing and reuse – a complex process

- Internal and external resources
- Legacy systems
- Data quality (fit-for-use) never perfect
    - Different objectives
    - Different versions
    - …

Manual selection and combination: laborious, costly and error prone

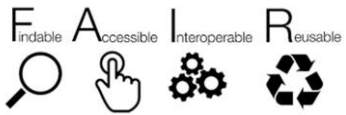
The ideal picture

- Direct access to primary sources
- Get it right at the source (smart devices)
- Access to what is needed for a specific task and user
- Machine readable – smart applications



How to share information?

- Know that a resource exists and where to find it
- Being able to access it and read it
- Ensure that machines can read it such that they show correct behaviour
- Ensure that it can be used in multiple contexts

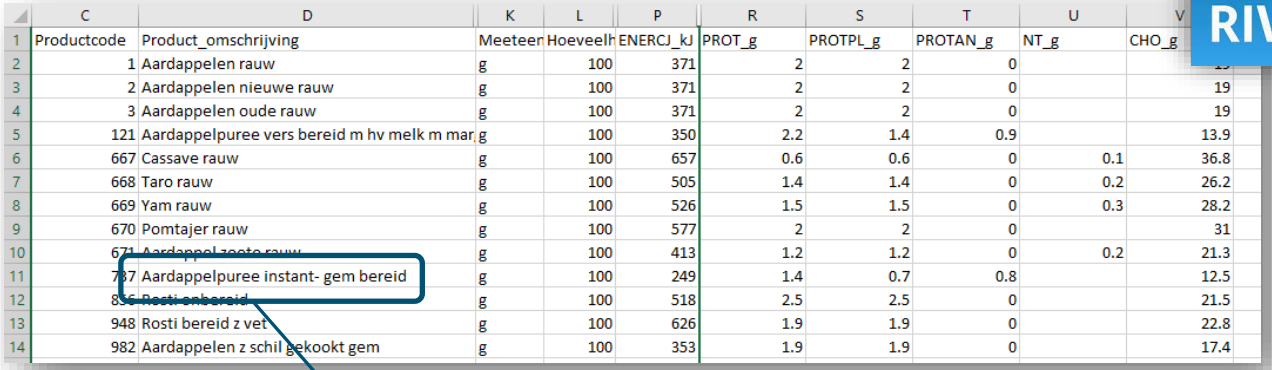


The FAIR principles

- Enable sharing information on the web
- Raw data, processed data, algorithms, software, documents, ...
- FAIR is not equal to ‘open’
- FAIR can contribute to ‘fair’

But also: link to other datasets

Example: linking food product data



	C	D	K	L	P	R	S	T	U	V
1	Productcode	Product_omschrijving	Meeteen	Hoeveelh	ENERCJ_kJ	PROT_g	PROTPL_g	PROTAN_g	NT_g	CHO_g
2	1	Aardappelen rauw	g	100	371	2	2	0		
3	2	Aardappelen nieuwe rauw	g	100	371	2	2	0		19
4	3	Aardappelen oude rauw	g	100	371	2	2	0		19
5	121	Aardappelpuree vers bereid m hv melk m mar	g	100	350	2.2	1.4	0.9		13.9
6	667	Cassave rauw	g	100	657	0.6	0.6	0	0.1	36.8
7	668	Taro rauw	g	100	505	1.4	1.4	0	0.2	26.2
8	669	Yam rauw	g	100	526	1.5	1.5	0	0.3	28.2
9	670	Pomtajer rauw	g	100	577	2	2	0		31
10	671	Aardappel zoete rauw	g	100	413	1.2	1.2	0	0.2	21.3
11	737	Aardappelpuree instant- gem bereid	g	100	249	1.4	0.7	0.8		12.5
12	856	Rosti onbereid	g	100	518	2.5	2.5	0		21.5
13	948	Rosti bereid z vet	g	100	626	1.9	1.9	0		22.8
14	982	Aardappelen z schil gekookt gem	g	100	353	1.9	1.9	0		17.4

	A	B	K	M	N	O	P	Q
1	Food_code	Product_brand	Preparation_method	no_sweet	m_sweet	sd_sweet	se_sweet	no_sc
2	121	AH aardappelpuree met boter	microwave 5 minutes 850 watt	10	7	6	2	
3	948	Aviko Rösti rondjes naturel	oven 220 degrees, 15 minutes	9	9	7	2	
4	982	AH krieltjes	boil for 10 minutes	12	5	3	1	
5	1150	AH Aardappelschijfjes	fry with 15% Blue Band Iedere dag voor koken, bal	7	6	6	2	
6	1456	Aviko Pommes Frites	deep-fry in Diamant original frituurvet at 175 °C fo	9	9			
7	2325	AH Vastkokende aardappelen	boil for 20 minutes	7	6			
8	2834	AH aardappelbolletjes	deep-fry in Diamant original frituurvet at 175 °C fo	10	7			
9	383	Appelsientje Goudappel		12	46			
10	395	Coca cola regular		12	56	10	3	
11	400	Seven up regular		12	51	12	3	
12	410	Appelsientje sinaasappelsap		12	28	10	3	
13	411	Spa blauw		11	1	1	0	
14	413	AH Tomatensap		9	10	8	3	
15	414	Royal Club Tonic		8	24	8	3	

RIVM

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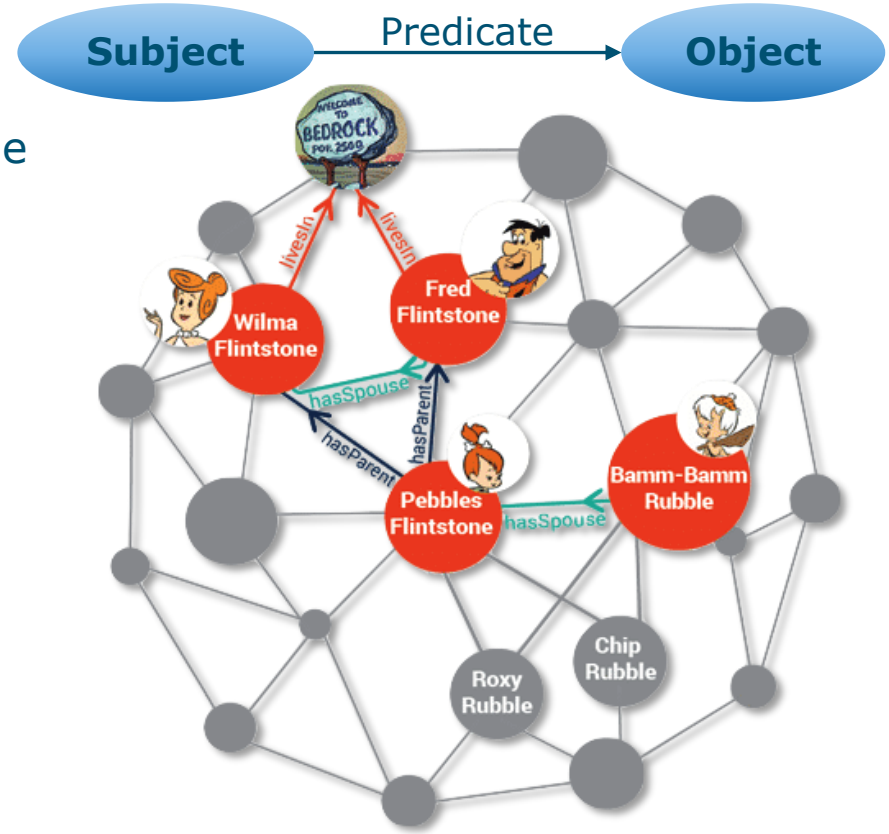
Linking data points as triples

- Data are measurements, observations, facts, ..., that can be structured as **triples**
- Entities and properties require **global identifiers**
- Numbers, strings remain anonymous



Play-a-LOD

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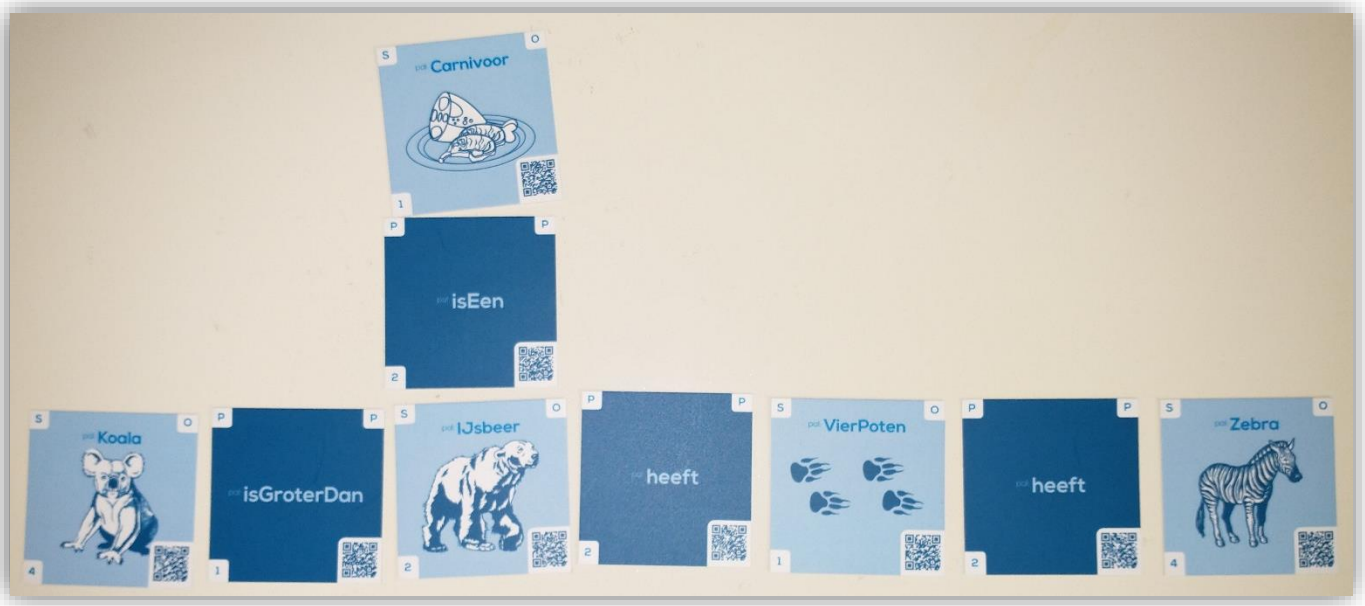
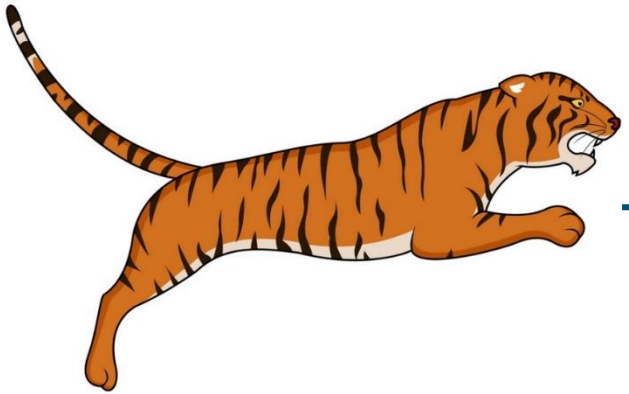
Play-a-LOD


Carnivoor
isEen
Koala
isGroterDan
IJsbeer
heeft
VierPoten
heeft
Zebra

Play-a-LOD

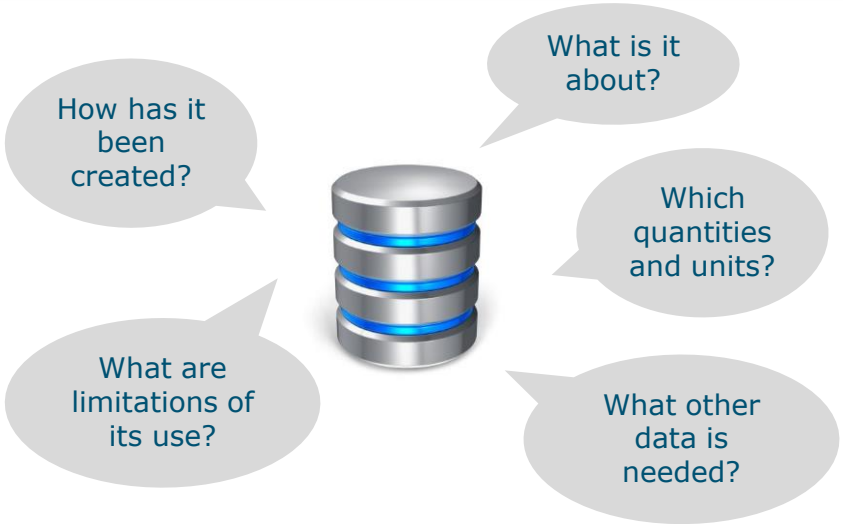
- Take nine cards each from the stack
- Build as many triples as you can, extending the current graph
- Take new cards, until nine



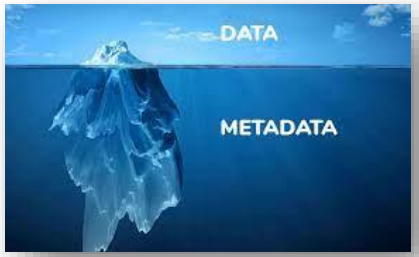
is a

Data without meaning is meaningless

01001	BUTTER,WITH SALT	15.87	717	0.85	81.11	2.11	0.06	0	0.06
01002	BUTTER,WHIPPED,WITH SALT	15.87	717	0.85	81.11	2.11	0.06	0	0.06
01003	BUTTER OIL,ANHYDROUS	0.24	876	0.28	99.48	0	0	0	0
01004	CHEESE,BLUE	42.41	353	21.4	28.74	5.11	2.34	0	0.5
01005	CHEESE,BRICK	41.11	371	23.24	29.68	3.18	2.79	0	0.51
01006	CHEESE,BRIE	48.42	334	20.75	27.68	2.7	0.45	0	0.45
01007	CHEESE,CAMEMBERT	51.8	300	19.8	24.26	3.68	0.46	0	0.46
01008	CHEESE,CARAWAY	39.28	376	25.18	29.2	3.28	3.06	0	
01009	CHEESE,CHEDDAR	37.1	406	24.04	33.82	3.71	1.33	0	0.28



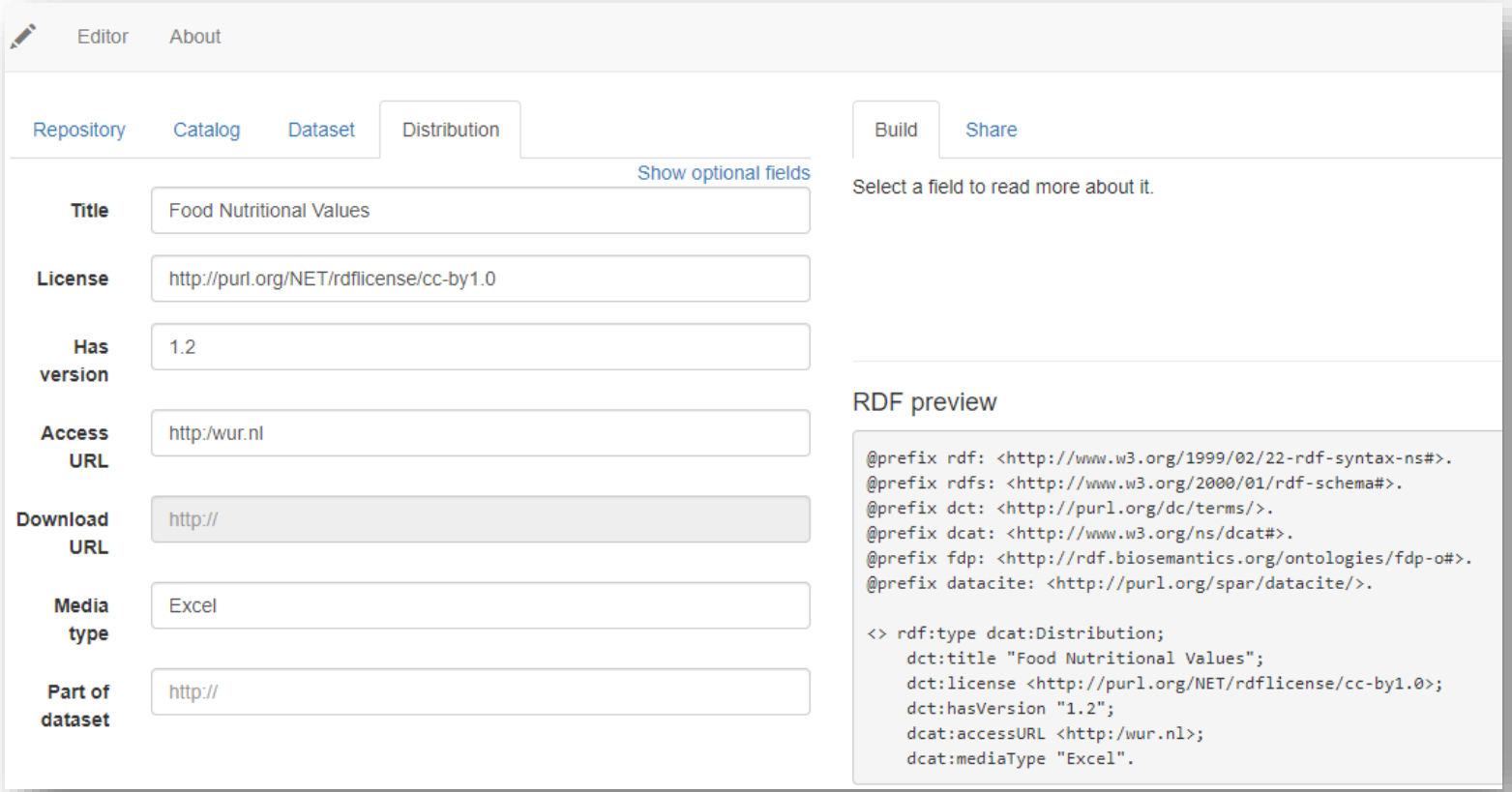
Metadata



- Explanation: for proper use
  - Observed properties, quantities, units
  - Which objects, events or materials are being observed
  - External conditions, circumstances

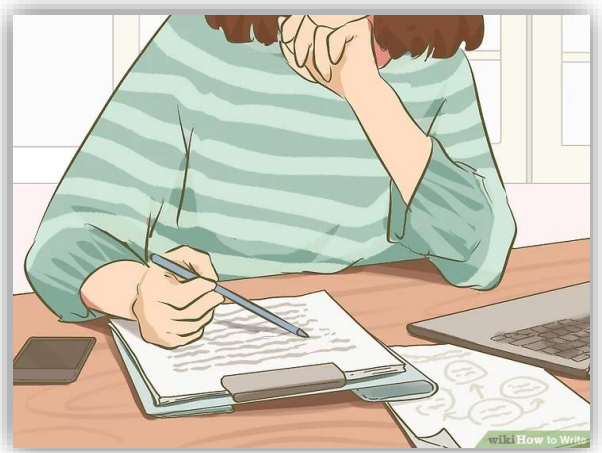
- Provenance: for reliability, reproduction, tracing
  - ‘Library’ metadata: creator, date, institute, ...
  - Acquisition method, experiment, production method, ...

Metadata – machine readable



Your metadata

How do you currently describe your data?



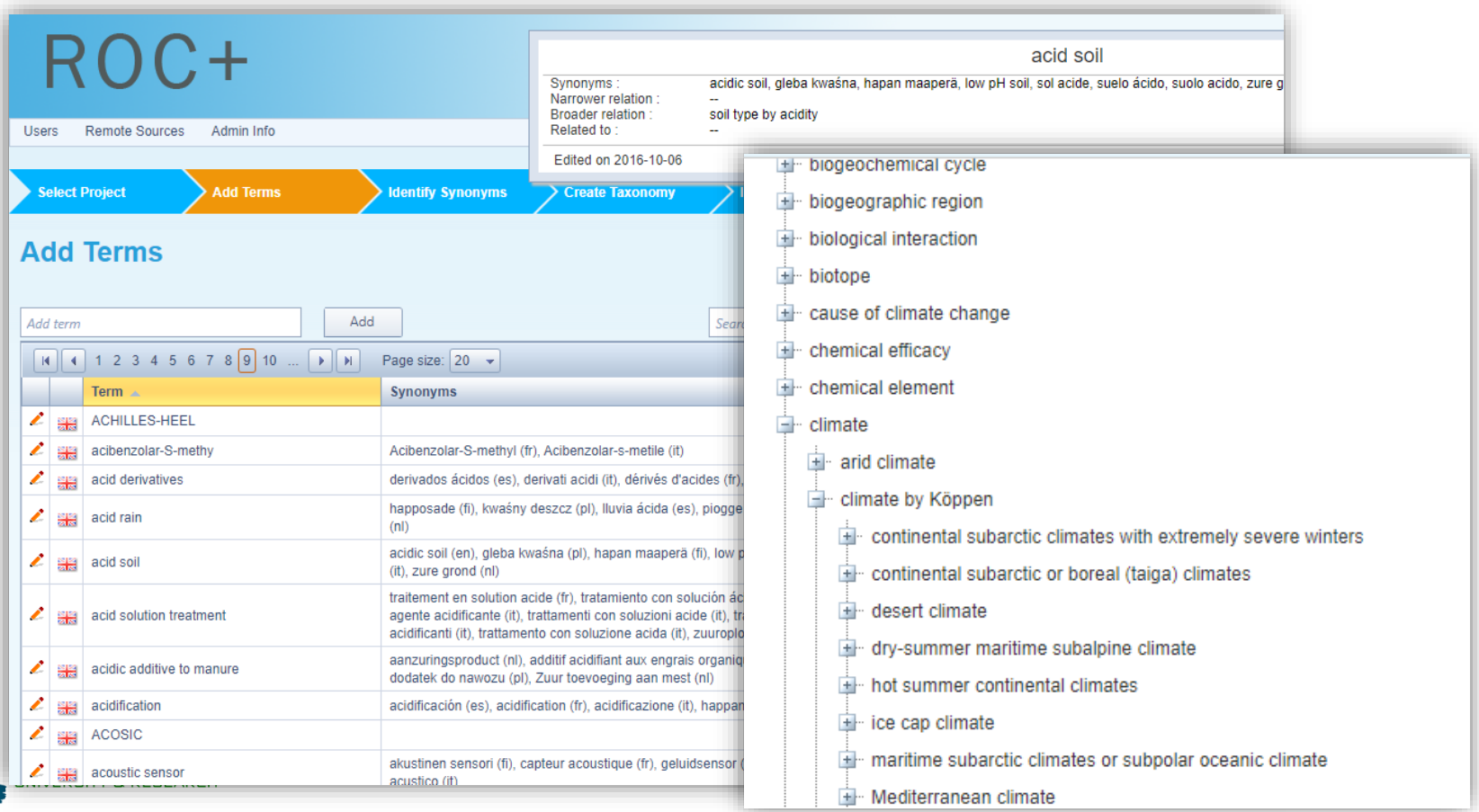
Metadata: use a shared vocabulary or ontology

http://www.foodvoc.org/resource/FoodTaxonomy/BlueCheese

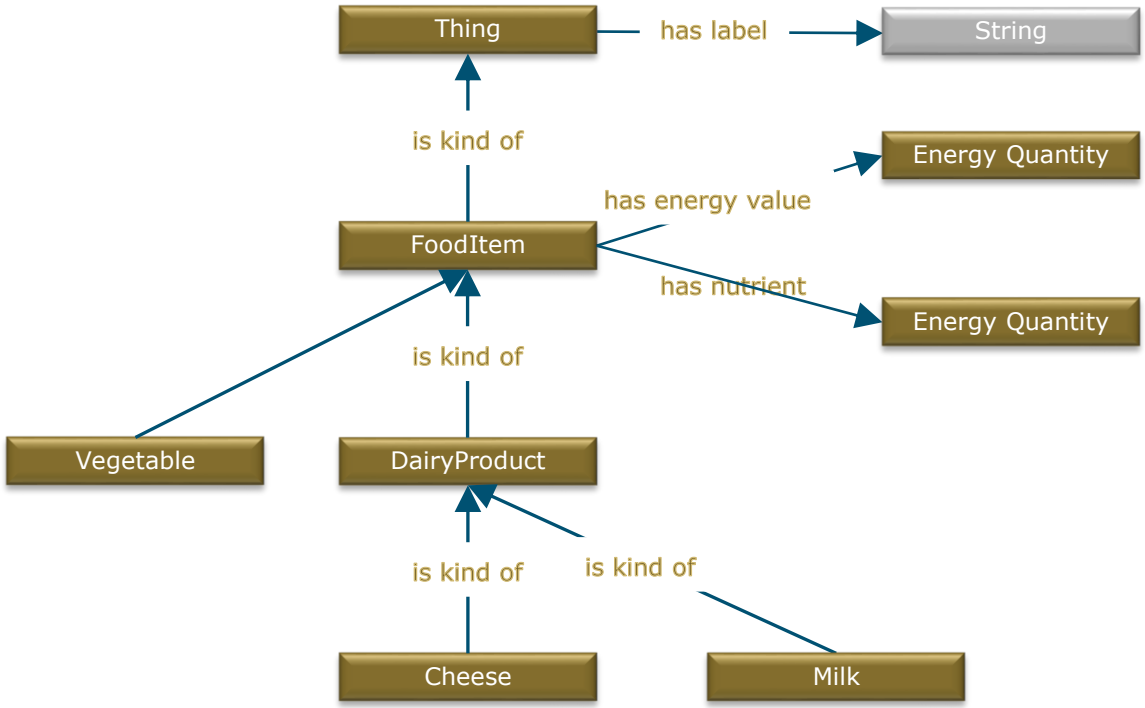
http://www.ontology-of-units-of-measure.org/resource/om-2/Mass

	A	B	C	D	E	F	G	H	I	J
1	NDB_No	Shrt_Desc	Water_(g)	Energ_Kcal	Protein_(g)	Lipid_Tot_(g)	Ash_(g)	Carbohydrt_(g)	Fiber_TD_(g)	Sugar_Tot_(g)
2	01001	BUTTER,WITH SALT	15.87	717	0.85	81.11	2.11	0.06	0	0.06
3	01002	BUTTER,WHIPPED,WITH SALT	15.87	717	0.85	81.11	2.11	0.06	0	0.06
4	01003	BUTTER OIL,ANHYDROUS	0.24	876	0.28	99.48	0	0	0	0
5	01004	CHEESE,BLUE	42.41	353	21.4	28.74	5.11	2.34	0	0.5
6	01005	CHEESE,BRICK	41.11	371	23.24	29.68	3.18	2.79	0	0.51
7	01006	CHEESE,BRIE	48.42	334	20.75	27.68	2.7	0.45	0	0.45
8	01007	CHEESE,CAMEMBERT	51.8	300	19.8	24.26	3.68	0.46	0	0.46
9	01008	CHEESE,CARAWAY	39.28	376	25.18	29.2	3.28	3.06	0	
10	01009	CHEESE,CHEDDAR	37.1	406	24.04	33.82	3.71	1.33	0	0.28

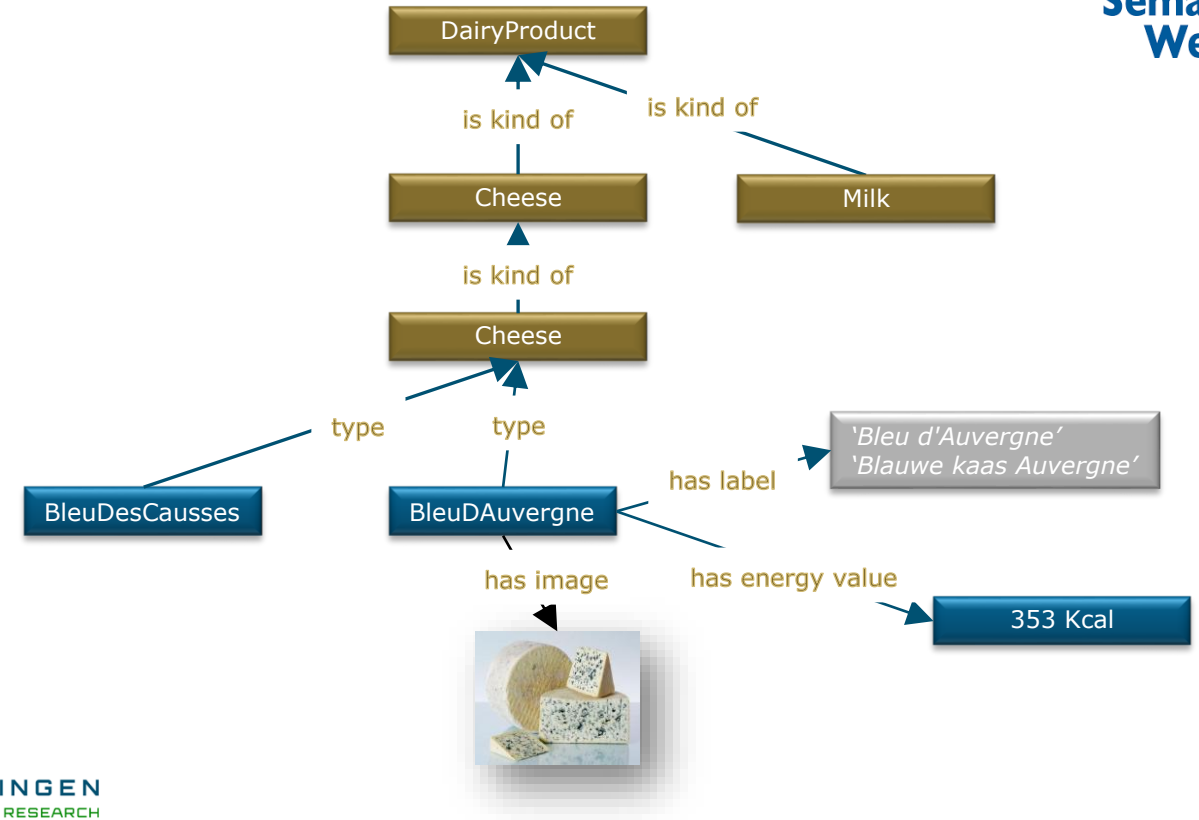
Controlled vocabulary (typically for search)



Ontology

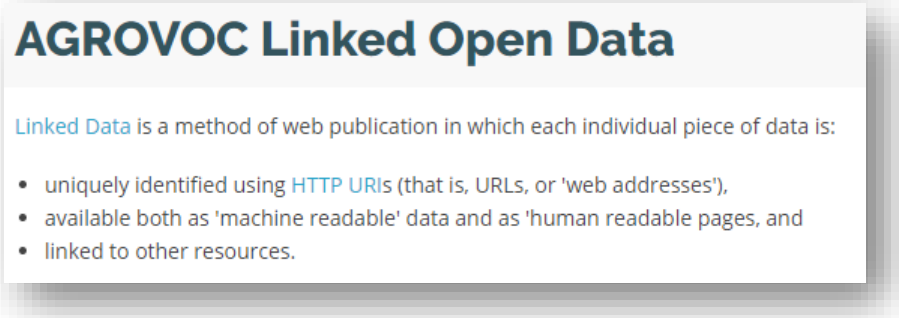

Thing
has label
String
is kind of
Energy Quantity
has energy value
FoodItem
has nutrient
Energy Quantity
is kind of
Vegetable
DairyProduct
is kind of
is kind of
Cheese
Milk

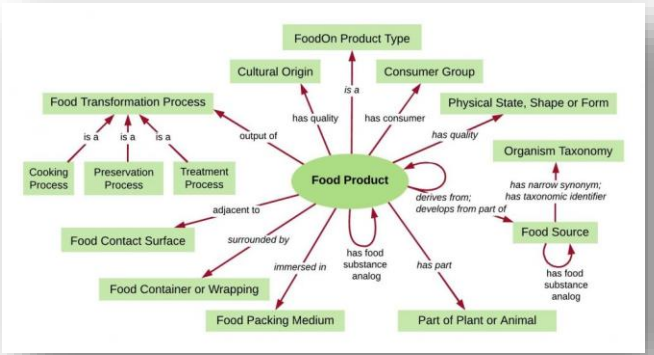
Knowledge graph: ontology and data



Current ontologies and vocabularies

- OBO Foundry
- Ontobee
- The Ontology Lookup Service
- Bioportal
- Agroportal



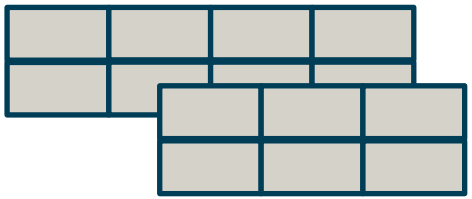


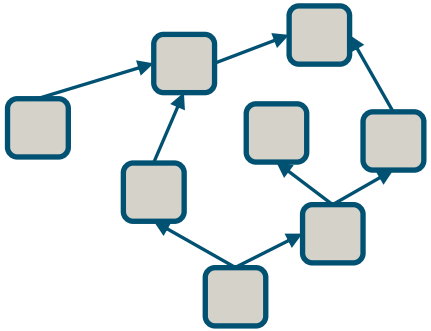
Linked data versus relational data

No pre-set table structure, so easier to add just any other fact; no need to update the database design

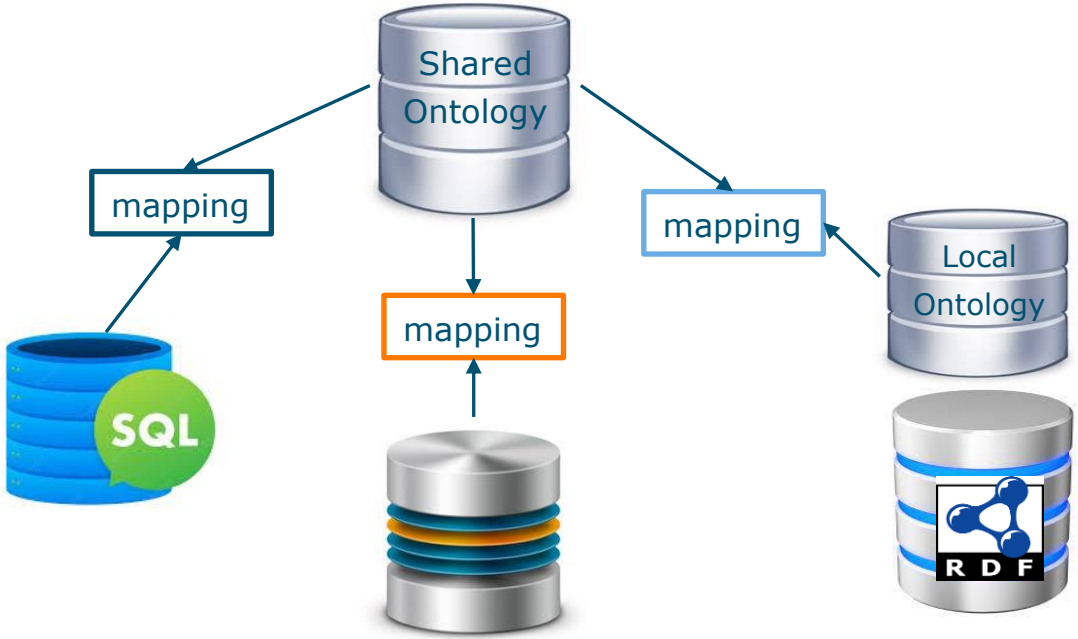
Table headers are data as well, allowing automatic merging and reasoning without human intervention

Combining relational data with semantic wrapper: best of both worlds

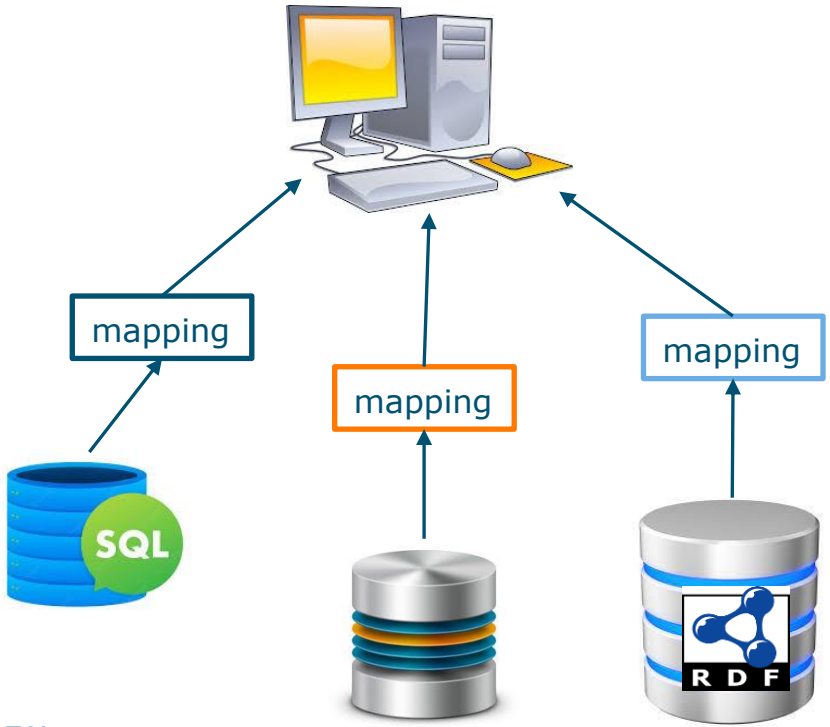




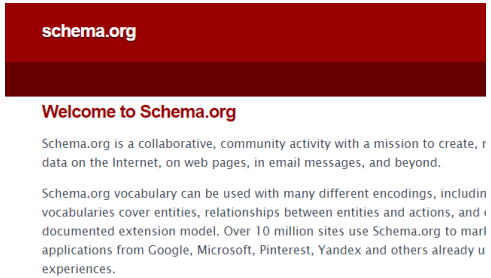
Merging data sources

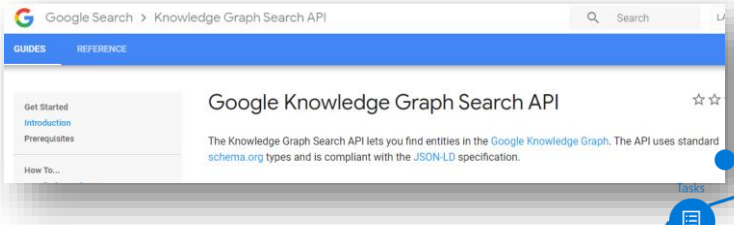


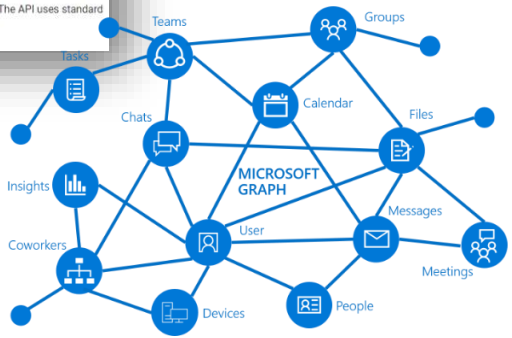
Merging data sources



It’s happening already







Digital twins need linked data and semantics