Towards principles and methods for good ontologies

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Outline

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Quality of the ontology

- "Bad ontologies are (inter alia) those whose general terms lack the relation to corresponding universals in reality, and thereby also to corresponding instances." $\Rightarrow$ need for grounding

[Smith(2004)]

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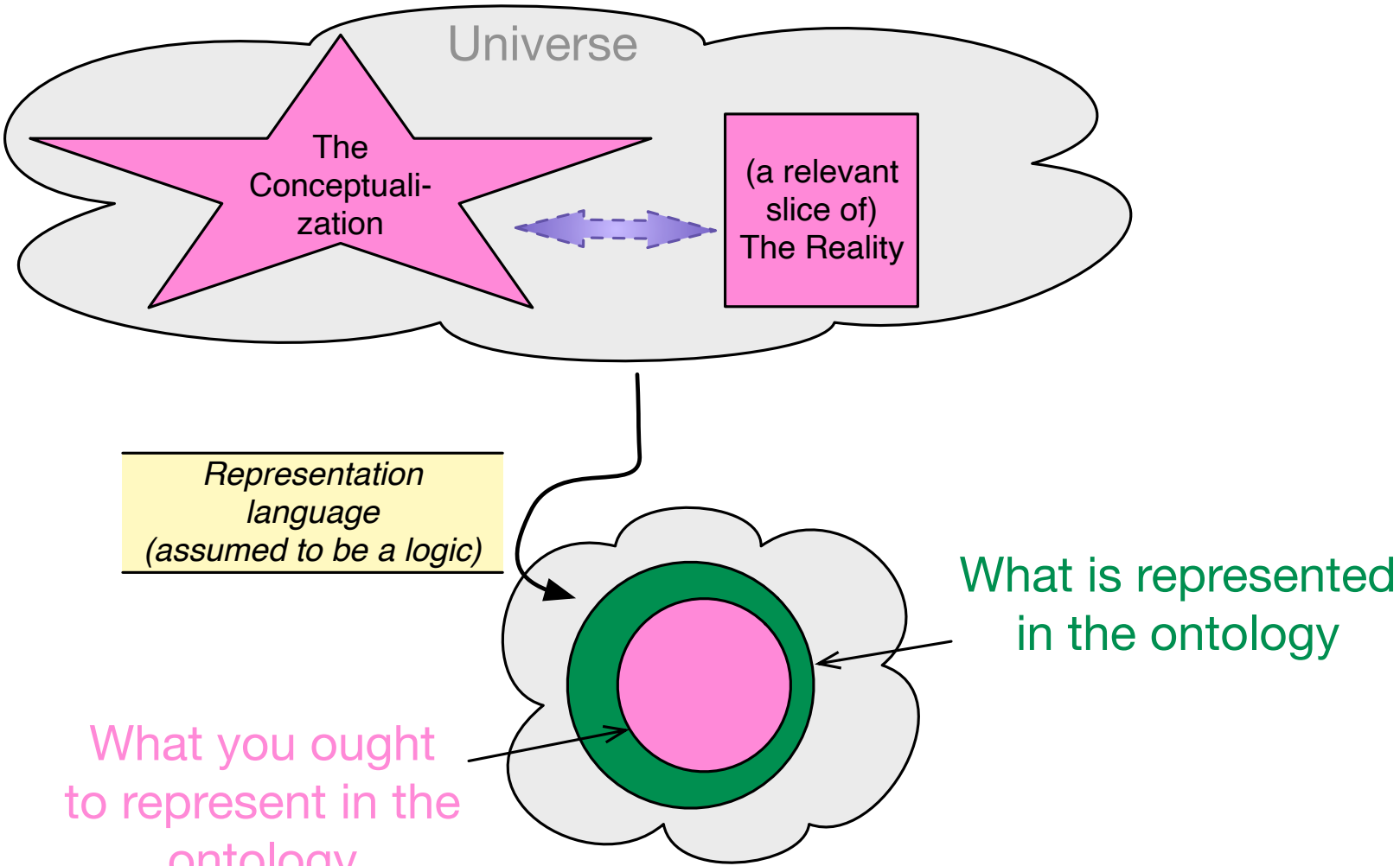
- "Bad ontologies are (inter alia) those whose general terms lack the relation to corresponding universals in reality, and thereby also to corresponding instances." $\Rightarrow$ need for grounding
- "Good ontologies are reality representations, and the fact that such representations are possible is shown by the fact that, as is documented in our scientific textbooks, very many of them have already been achieved, though of course always only at some specific level of granularity and to some specific degree of precision, detail and completeness."

[Smith(2004)]

Quality of the ontology – the basic players



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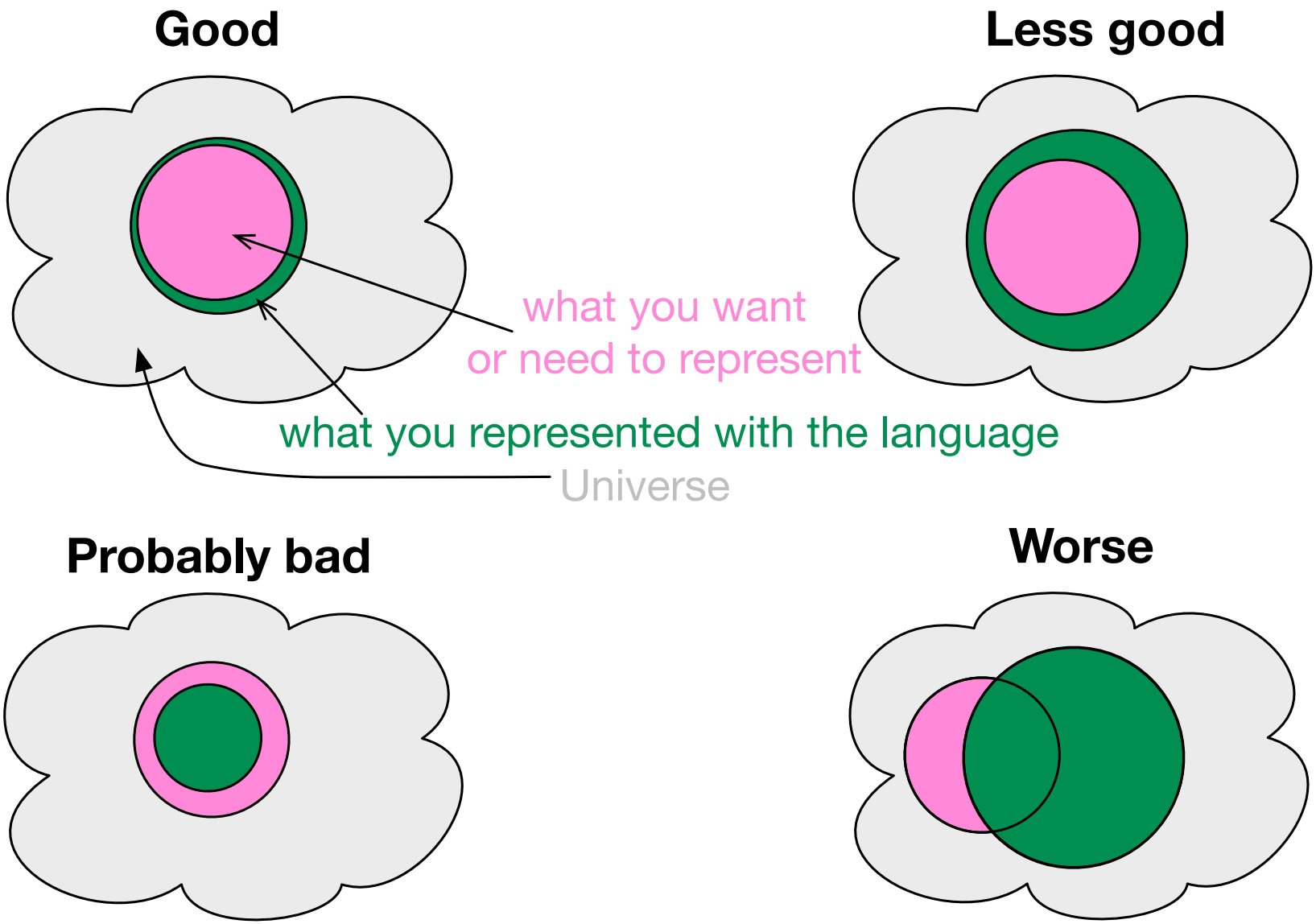

Why the difference between the pink and green circles (1/3)

- Example: 'each car has exactly 4 wheels' (except for 3-wheelers)
- OWL DL: $Car \sqsubseteq = 4\, hasPart.\top$ and/or $Car \sqsubseteq \exists hasPart.Wheel$

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$\Rightarrow$ The representation language you choose matters

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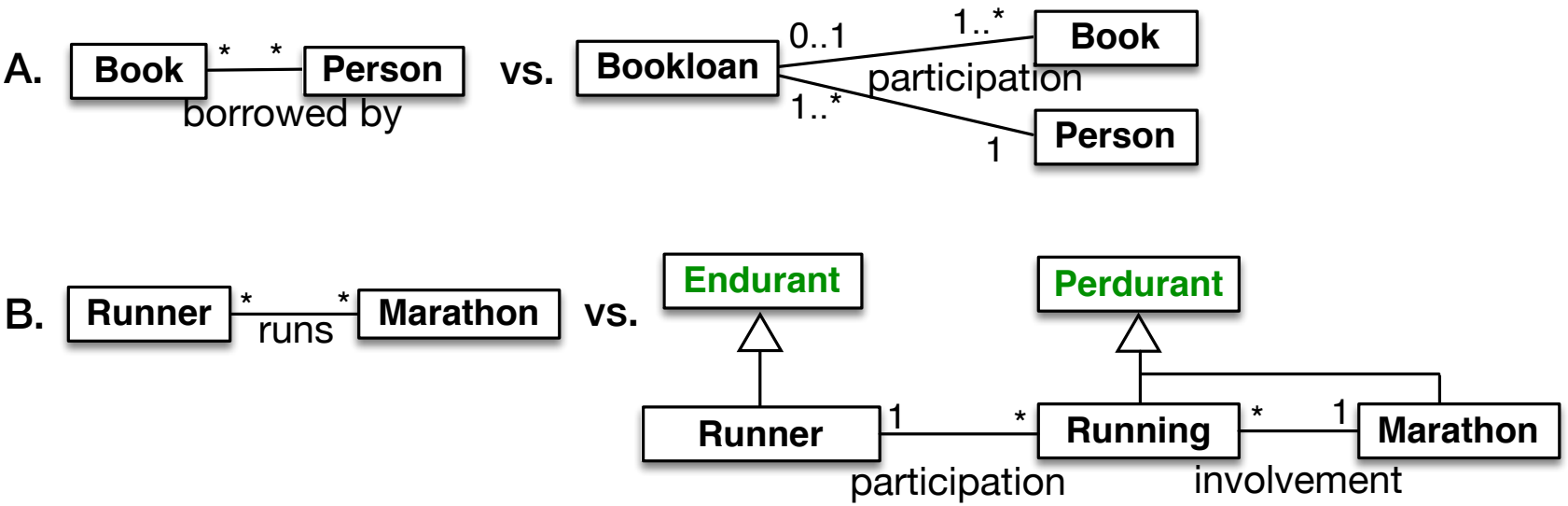

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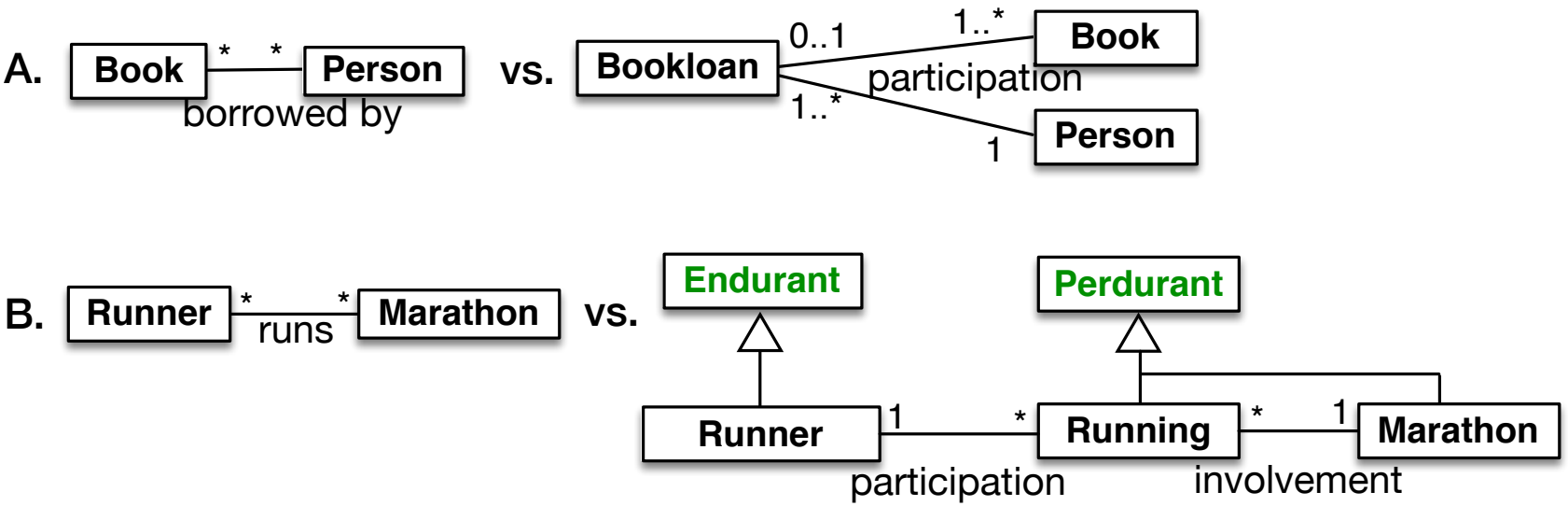

⇒ modelling style and granularity & precision ontologically (also when same language for both) [Fillottrani and Keet(2017)]

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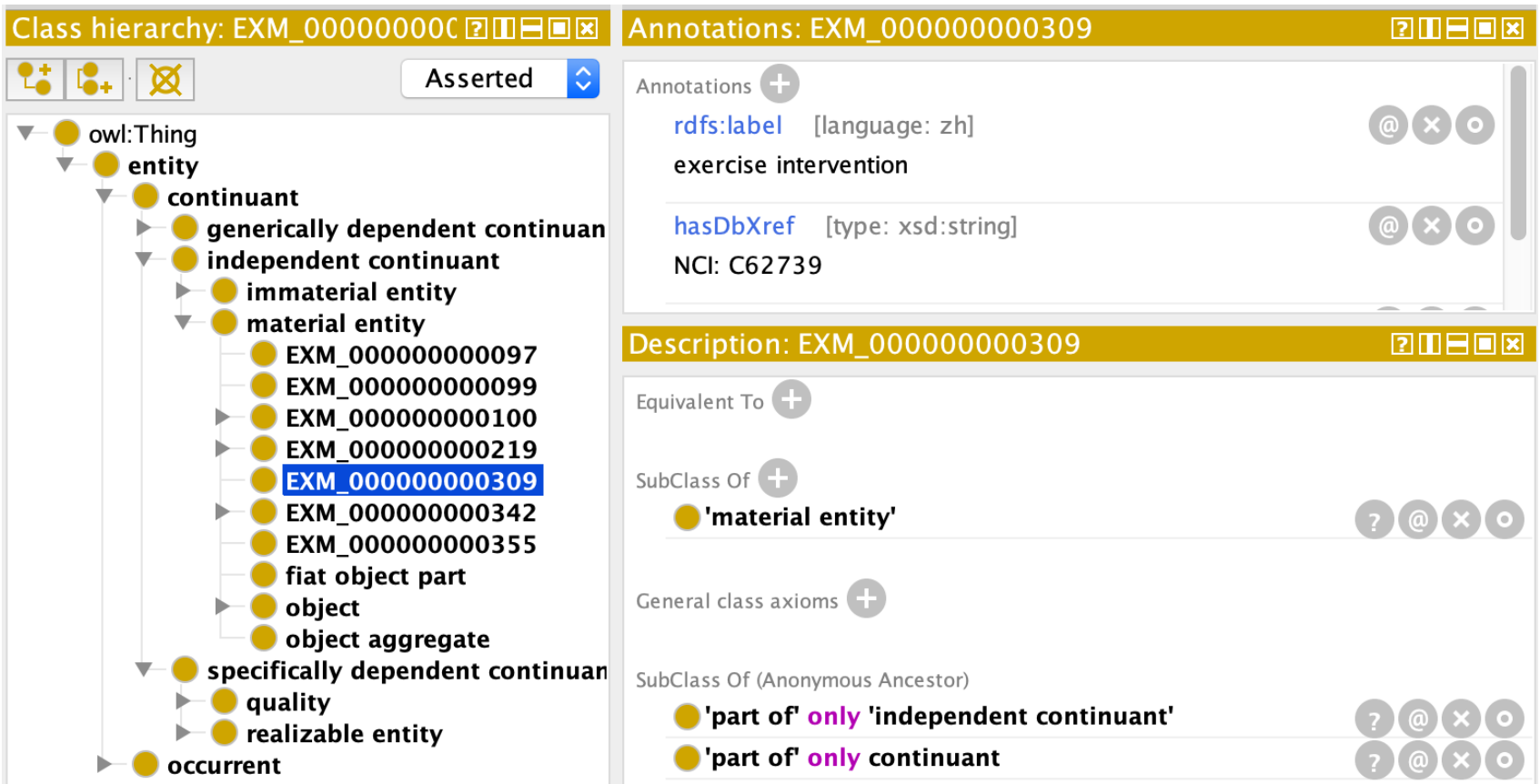

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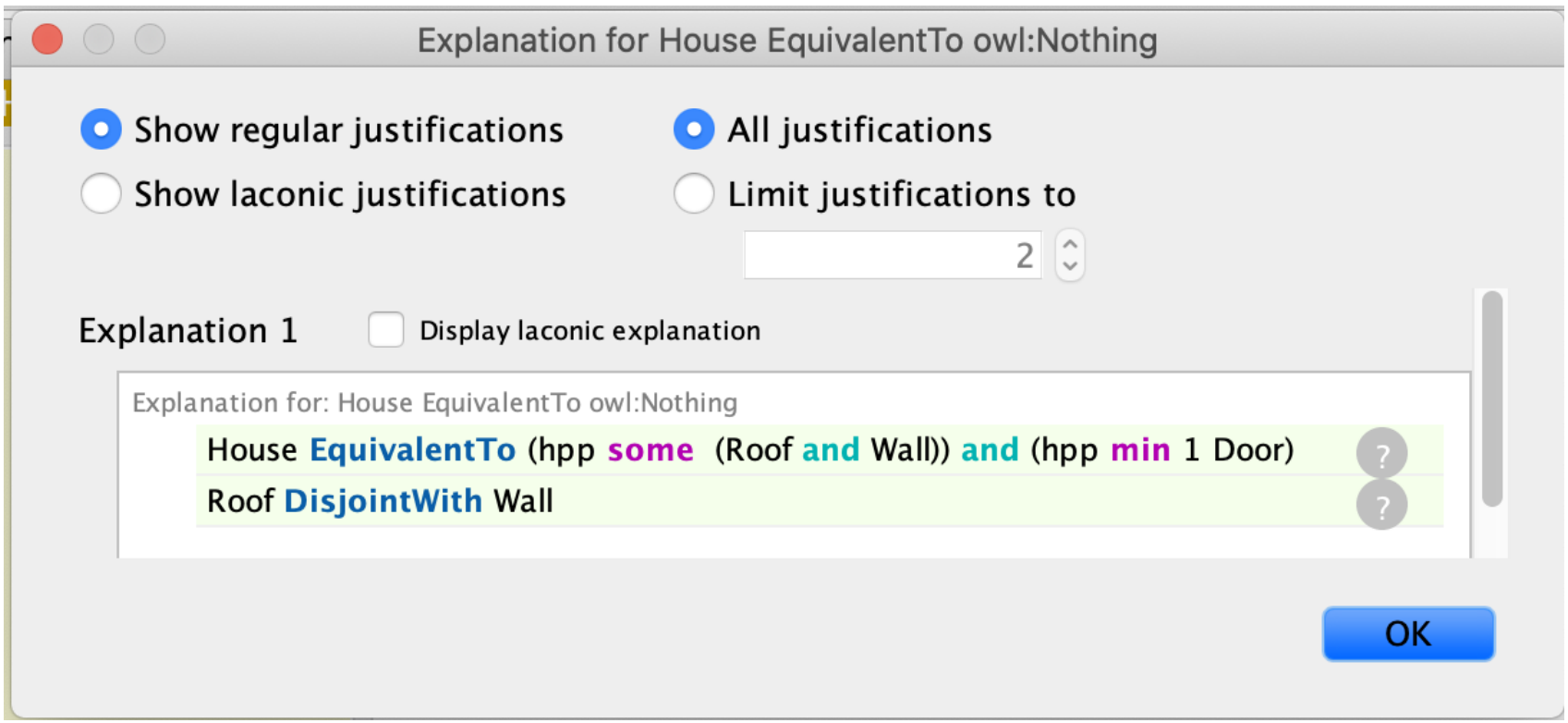

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How to develop good ontologies?

- Avoid common mistakes, with, e.g., "TIPS" (Typical Pitfall Prevention Scheme) [Keet et al.(2015)]
- Choose your language wisely (or create one) [Fillottrani and Keet(2020)]
- Use the automated reasoner
  - Common 'culprits' it detects: due to disjointness, cardinality constraints, domain & range axioms, violations of the logic and data types
- Reuse known working modelling solutions: a foundational ontology, one or more core ontologies, maybe also a relation ontology, ODPs
- Use modelling assistance, guidelines, and tools where available

Ontological, extra-logical, and logical principles that *explain*

- Different categories that the kinds of things are based on philosophical properties
  - e.g., rigidity and what follows from it (sortal, role etc); see OntoClean, OntoUML etc
- The meaning of class (/entity type/concept/universal) subsumption with property inheritance
- The meaning of class (/entity type/concept/universal) vs instance
- The meaning of property subsumption

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- An instance/individual is that thing that cannot be instantiated (any further)
- (notwithstanding the a representation language may let you 'play' with it, recast, and pun)

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- An instance/individual is that thing that cannot be instantiated (any further)
- (notwithstanding the a representation language may let you 'play' with it, recast, and pun)
- A subclass has all the properties of its superclass, and either or both:
  - at least one more property
  - at least one of the properties it inherited has its range more constrained

RBoxes: Questions and Problems

- What does subbumption mean for properties?
- What are the features of a 'good' RBox w.r.t. object property expressions?
- Modelling flaws in the RBox show up as unexpected or undesirable deductions regarding classes in the TBox, but current explanation algorithms mostly do not point to the actual flaw in the RBox
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$\Rightarrow$ With Sub-Property compatibility Service (*SubProS* and *ProChainS*) [Keet(2012)]

Preliminaries (1/2)—OWL 2/$\mathcal{SROIQ}$

- "basic form" for sub-properties, i.e., $S \sqsubseteq R$,
- "complex form" with property chains
- $R \sqsubseteq C_1 \times C_2$ as shortcut for domain and range axioms $\exists R \sqsubseteq C_1$ and $\exists R^- \sqsubseteq C_2$ where C_1 and C_2 are generic classes; `ObjectPropertyDomain(OPE CE)` and `ObjectPropertyRange(OPE CE)` in OWL.
- $R \sqsubseteq \top \times \top$ when no domain and range axiom has been declared

Definition (User-defined Domain and Range Classes)

Let R be an OWL object property and $R \sqsubseteq C_1 \times C_2$ its associated domain and range axiom. Then, with the symbol D_R we indicate the *User-defined Domain* of R—i.e., $D_R = C_1$—and with the symbol R_R we indicate the *User-defined Range* of R—i.e., $R_R = C_2$.

Object sub-properties

- Given $S \sqsubseteq R$, then all individuals in the property assertions involving property S must also be related to each other through property R.
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- Two ways to constrain a property, and either one suffices:
  - By specifying its domain or range
  - By declaring the property's characteristics

Constraining a property

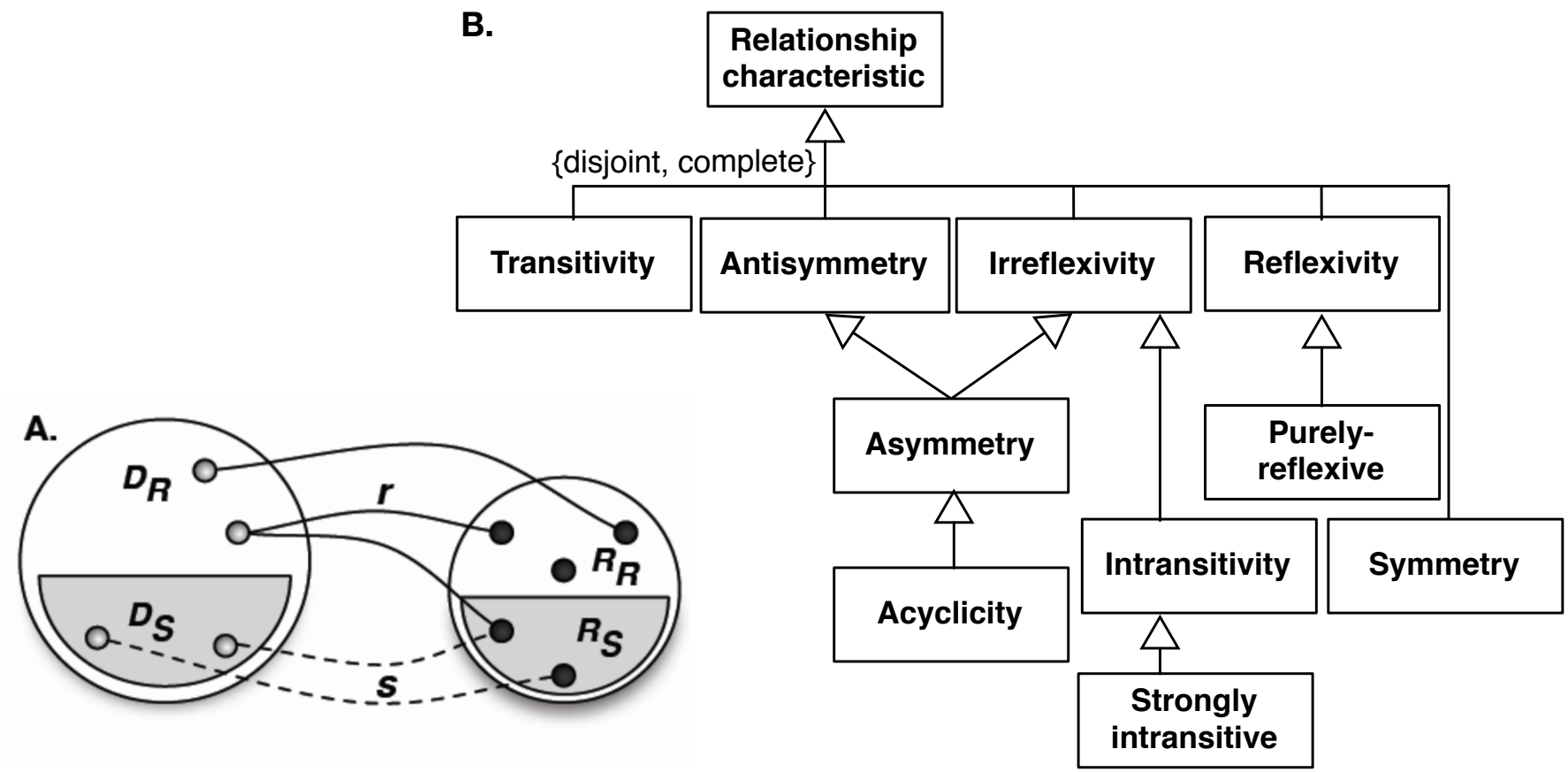

Figure: A: Example, alike the so-called 'subsetting' idea in UML; B: hierarchy of property characteristics (Based on Halpin 2001)

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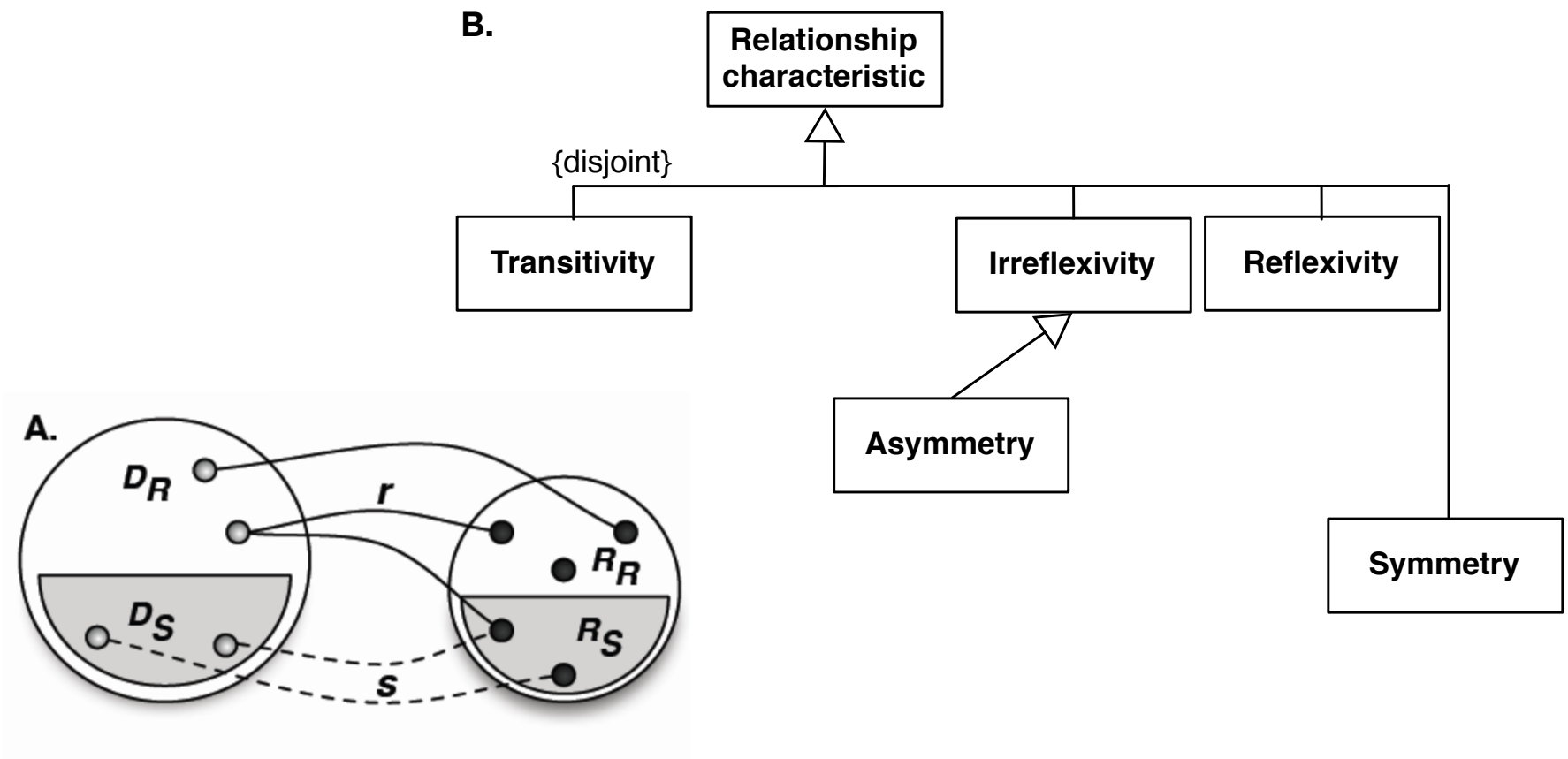

Figure: A: Example, alike the so-called 'subsetting' idea in UML; B: hierarchy of property characteristics relevant for OWL 2.

Outline Sub-Property compatibility Service

- First part extends the basic notions from the *RBox compatibility* (defined for $\mathcal{ALCQI}$) [Keet and Artale(2008)]
- Checks the 'compatibility' of domain and range axioms w.r.t the object property hierarchy and the class hierarchy

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- Checks the 'compatibility' of domain and range axioms w.r.t the object property hierarchy and the class hierarchy
- Then checks whether the object property characteristic(s) conform to specification

Definition (Sub-Property compatibility Service (*SubProS*))

For each pair of object properties, $R, S \in \mathcal{O}$ such that $\mathcal{O} \models S \sqsubseteq R$, and $\mathcal{O}$ an OWL ontology adhering to the syntax and semantics as specified in OWL 2 Standard, check whether:

- Test 1. $\mathcal{O} \models D_S \sqsubseteq D_R$ and $\mathcal{O} \models R_S \sqsubseteq R_R$;
- Test 2. $\mathcal{O} \not\models D_R \sqsubseteq D_S$;
- Test 3. $\mathcal{O} \not\models R_R \sqsubseteq R_S$;
- Test 4. If $\mathcal{O} \models \mathrm{Asym}(R)$ then $\mathcal{O} \models \mathrm{Asym}(S)$;
- Test 5. If $\mathcal{O} \models \mathrm{Sym}(R)$ then $\mathcal{O} \models \mathrm{Sym}(S)$ or $\mathcal{O} \models \mathrm{Asym}(S)$;

...

- Test 11. If $\mathcal{O} \models \mathrm{Trans}(R)$ then $\mathcal{O} \not\models \mathrm{Irr}(R)$, $\mathcal{O} \not\models \mathrm{Asym}(R)$, $\mathcal{O} \not\models \mathrm{Irr}(S)$, and $\mathcal{O} \not\models \mathrm{Asym}(S)$;

An OWL object property hierarchy is said to be compatible iff

- *Test 1* and (*2* or *3*) hold for all pairs of property-subproperty in $\mathcal{O}$, and
- *Tests 4-11* hold for all pairs of property-subproperty in $\mathcal{O}$.

What to do if not compatible

- Guidelines for fixing a flaw, with one or more options for revision
  - "raising a warning" denotes that it is not a logical error but an ontological one
  - "forcing" a revision indicates there is a logical error that must be fixed in order to have a consistent ontology with satisfiable classes
  - "propose" indicates suggestions how the flaw can be best revised

Revisions (selection)

A. If `Test 1` fails, raise a warning "domain and range restrictions of either R or S are in conflict with the property hierarchy", and propose to
   - Change the object property hierarchy, i.e., either remove $S \sqsubseteq R$ and add $R \sqsubseteq S$ or add $S \equiv R$ to $\mathcal{O}$, or
   - Change domain and range restrictions of R and/or S, or
   - If the test on the domains fails, then propose a new axiom $R \sqsubseteq D'_R \times R_R$, where $D'_R \equiv D_R \sqcap D_S$ (and similarly when `Test 1` fails on the range).

B. ...

C. Run *SubProS* again if any changes have been made in steps A or B, and record changes in the hierarchy (to be used in step I).

BioTop's inconsistent 'has process role'

'has process role' in BioTop (v. June 17, 2010) is inconsistent.
Relevant axioms are:

'has process role' $\sqsubseteq$ 'temporally related to' (E.1)

'has process role' $\sqsubseteq$ 'processual entity' $\times$ role (E.2)

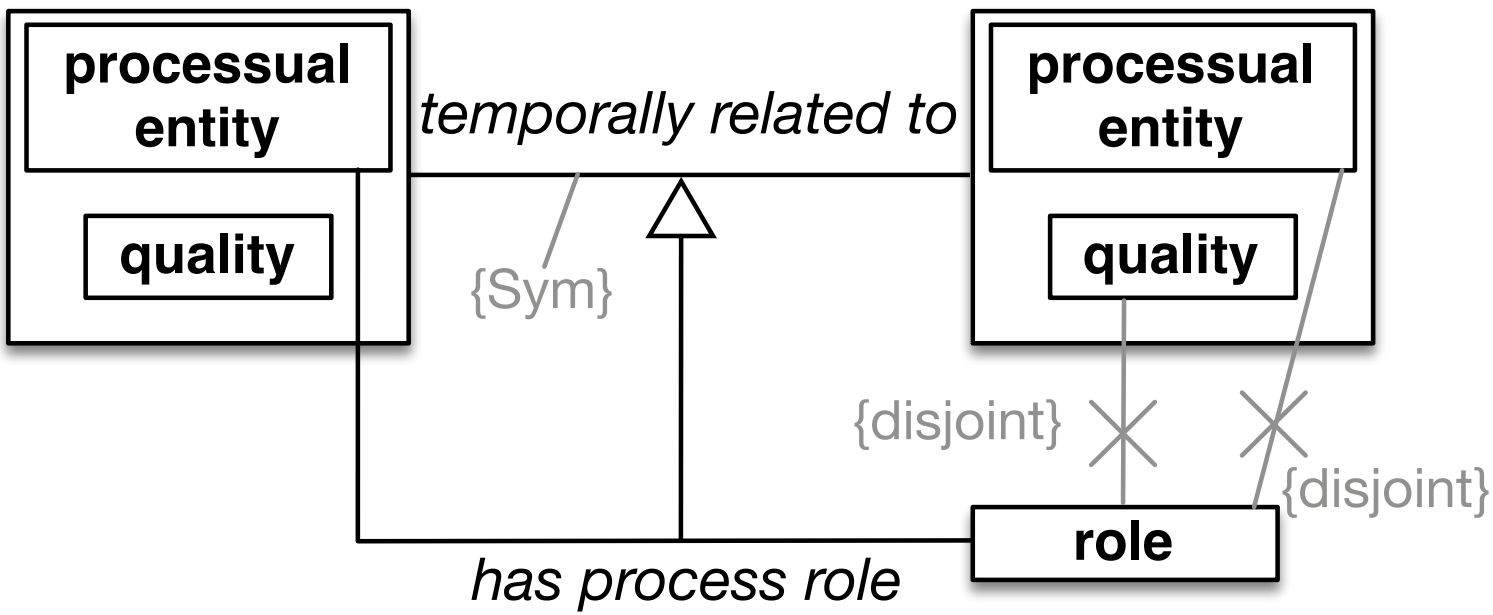
'temporally related to' $\sqsubseteq$
'processual entity' $\sqcup$ quality $\times$
'processual entity' $\sqcup$ quality (E.3)

role $\sqsubseteq \neg$quality (E.4)

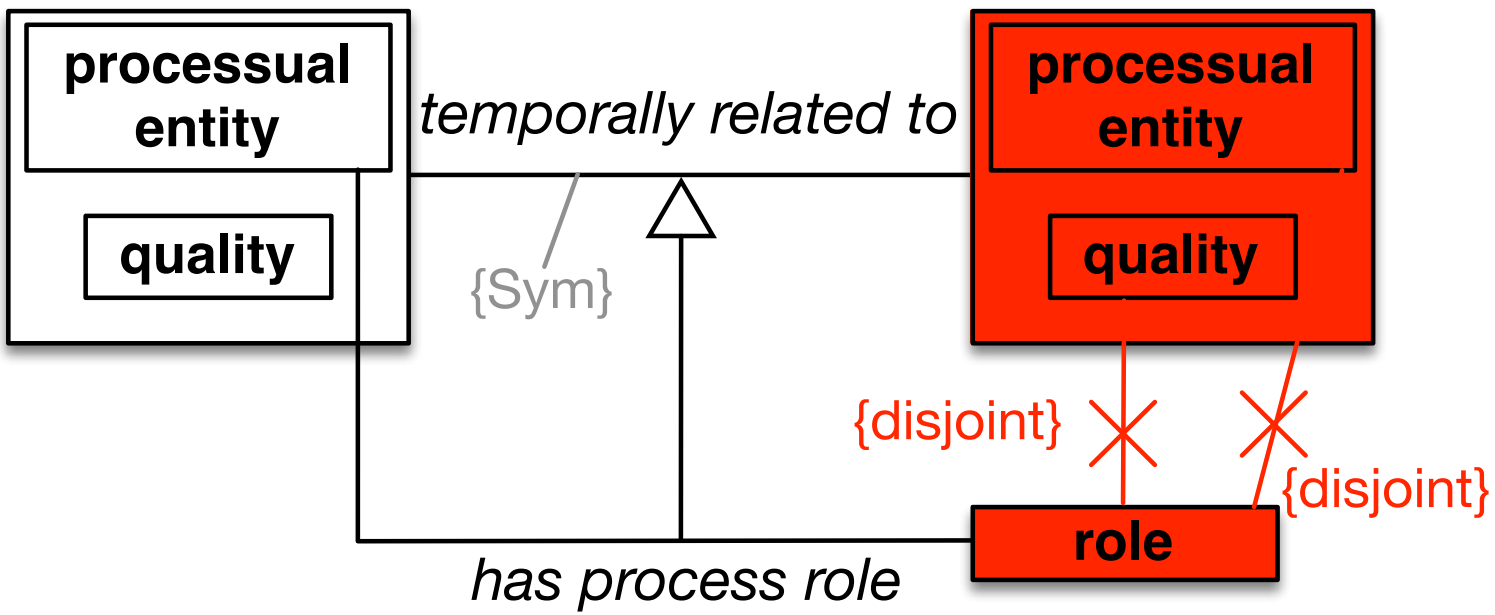
role $\sqsubseteq \neg$'processual entity' (E.5)

Sym('temporally related to') (E.6)

Diagrammatically



test 1 fails, test 2 passes, test 5 fails



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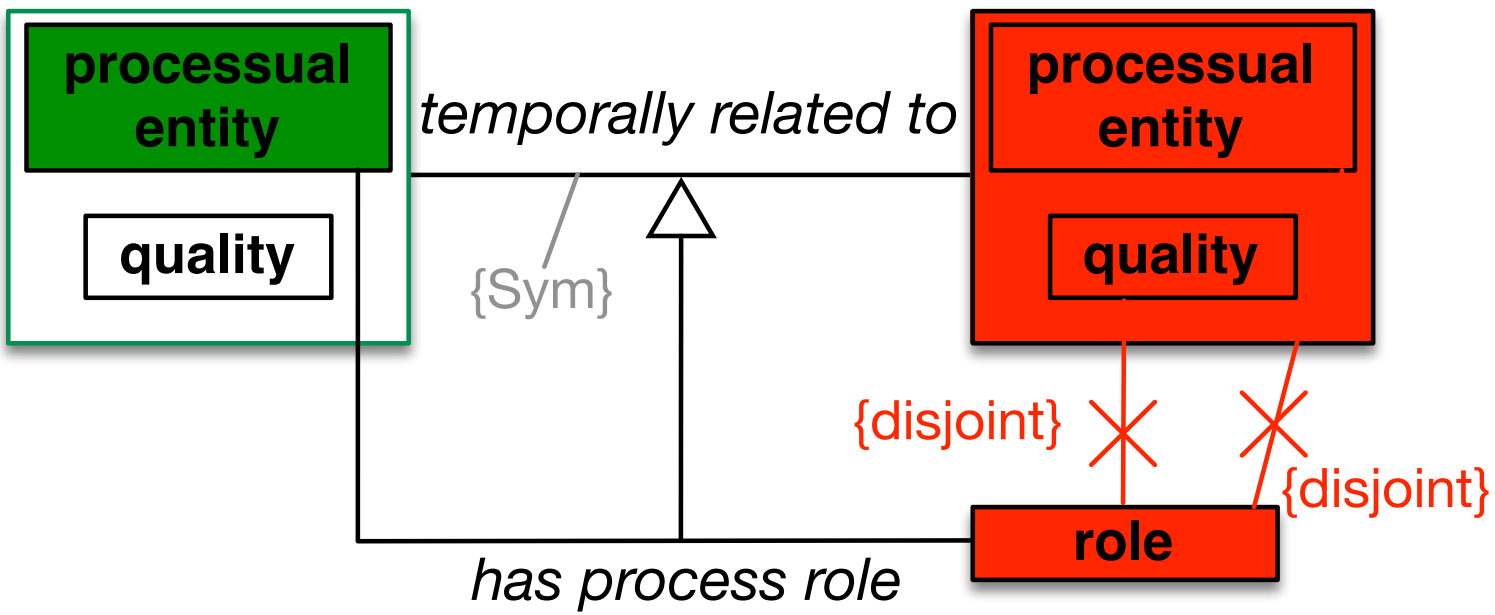

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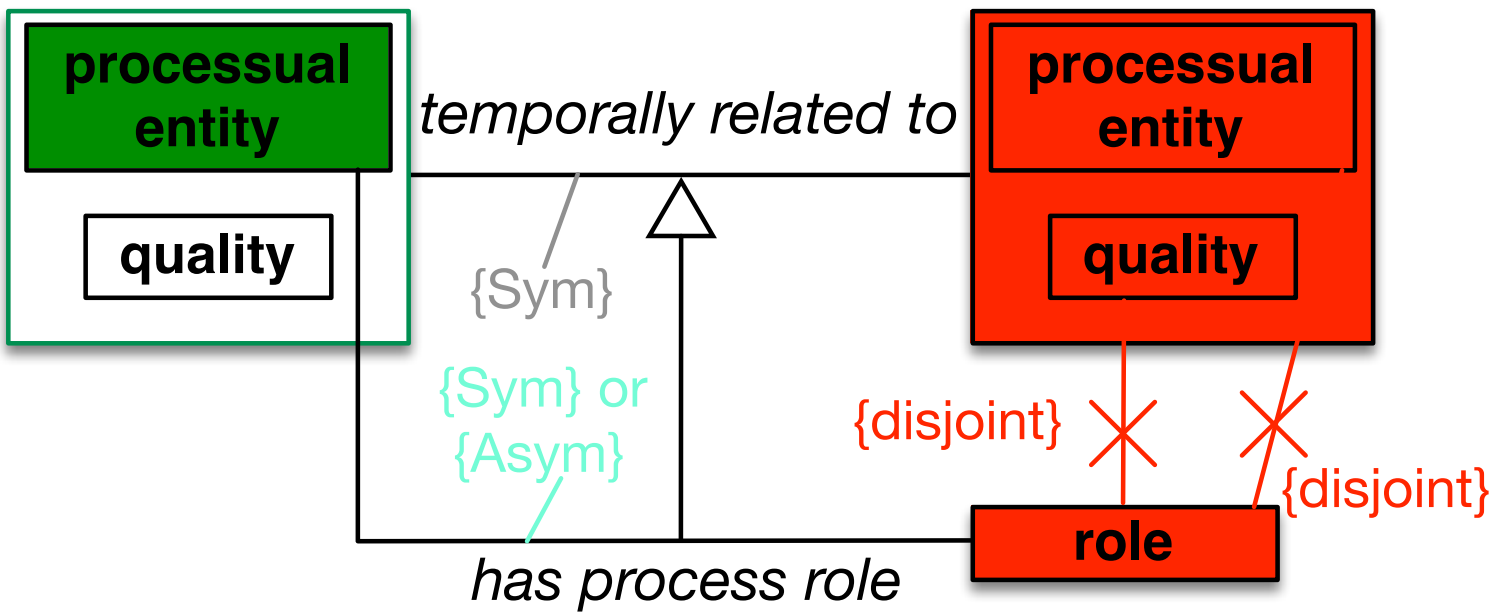
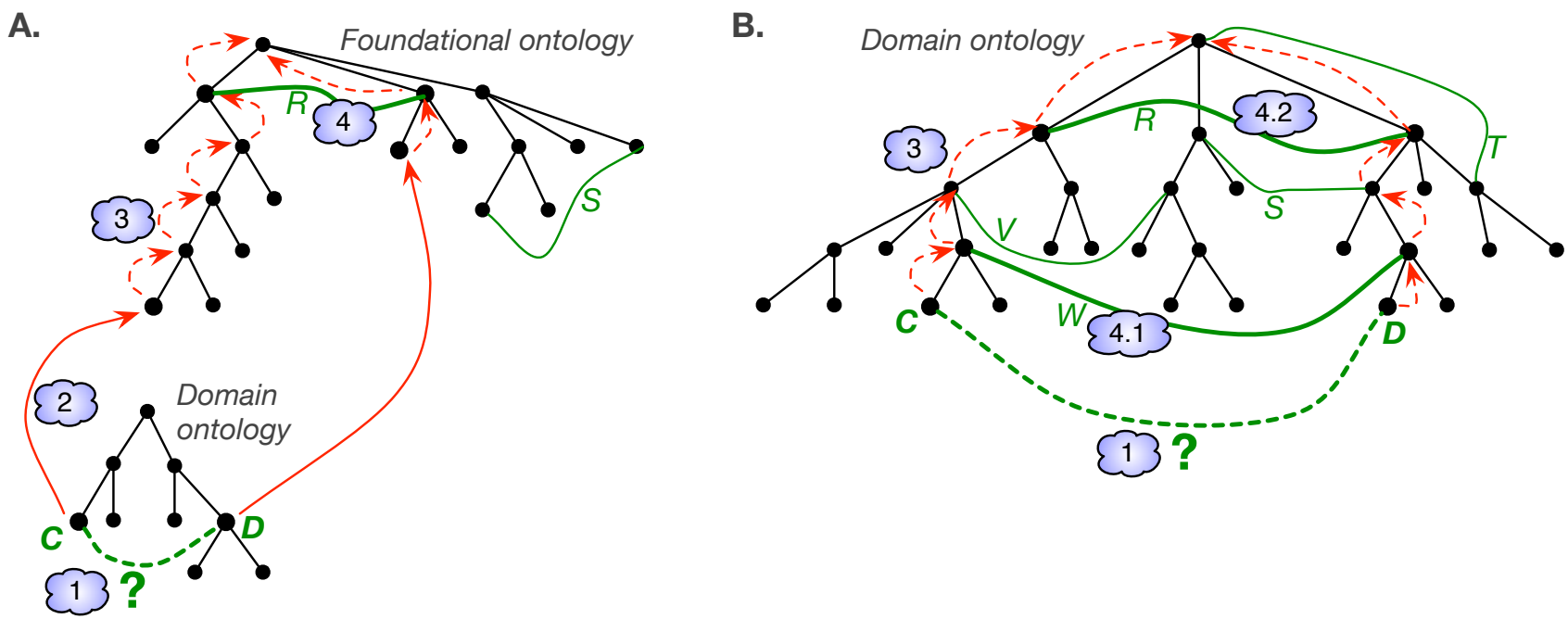


BioTop's inconsistent 'has process role'

Use *SubProS* to isolate the flaw:

- `Test 1`: fail, because $R_{\text{hasprocessrole}} \sqsubseteq R_{\text{temporallyrelatedto}}$ is false, as the ranges (see E.2 cf. E.3) are disjoint (see E.4, E.5) and therewith 'has process role' is inconsistent;
- `Test 2` and `3`: pass.
- `Test 4`: not applicable.
- `Test 5`: fail, because $\mathcal{O}$ does not contain Sym('has process role').
- `Test 6-11`: not applicable.

Avoid it: GENERATOR, the Guided ENtity reuse and class Expression geneRATOR

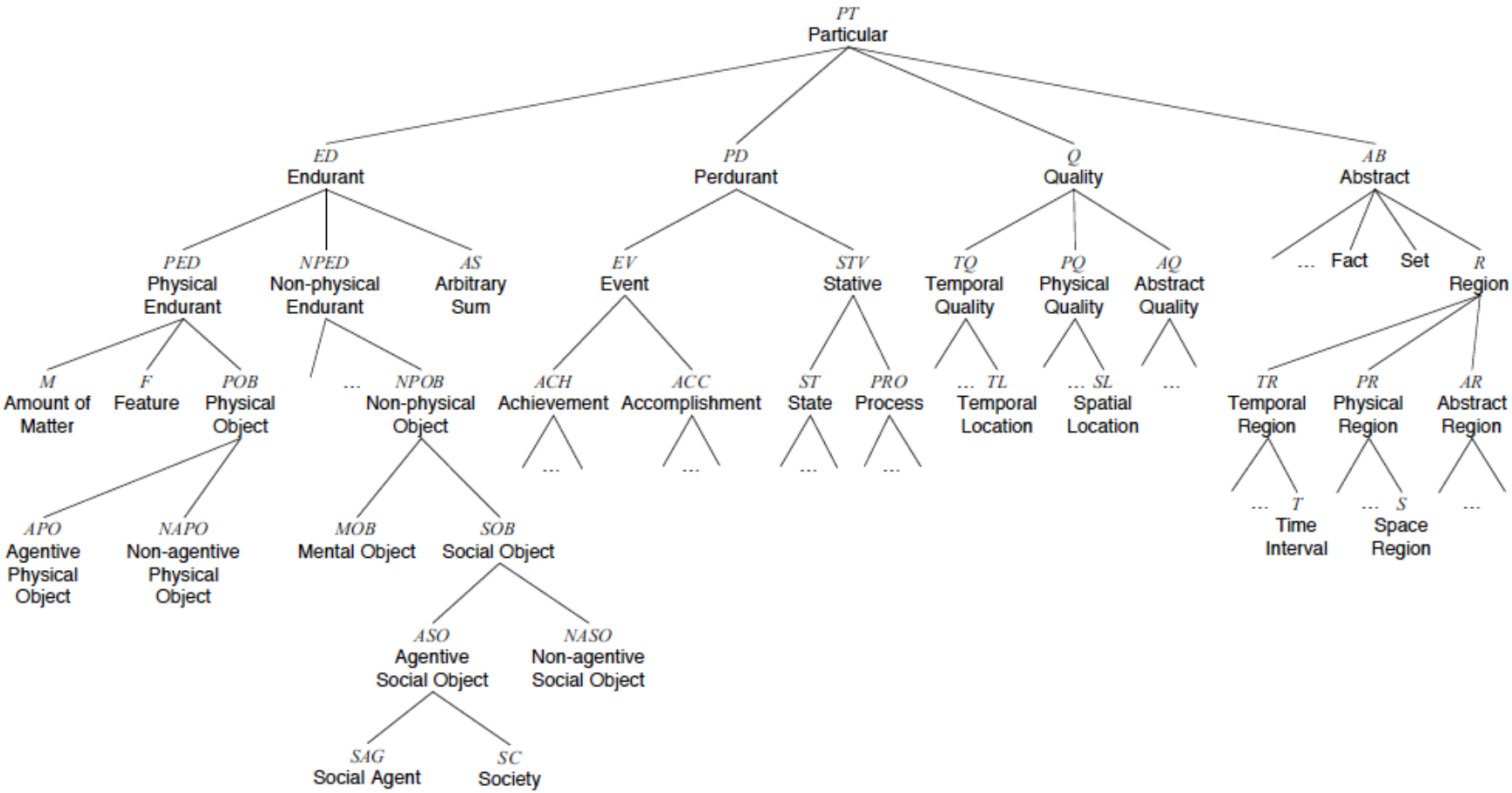


Option A (with a reasoner, a taxonomy of part-whole relations and DOLCE) is instantiated as FORZA (Foundational Ontology and Reasoner-enhanced axiomatiZAtion) [Keet et al.(2013)]

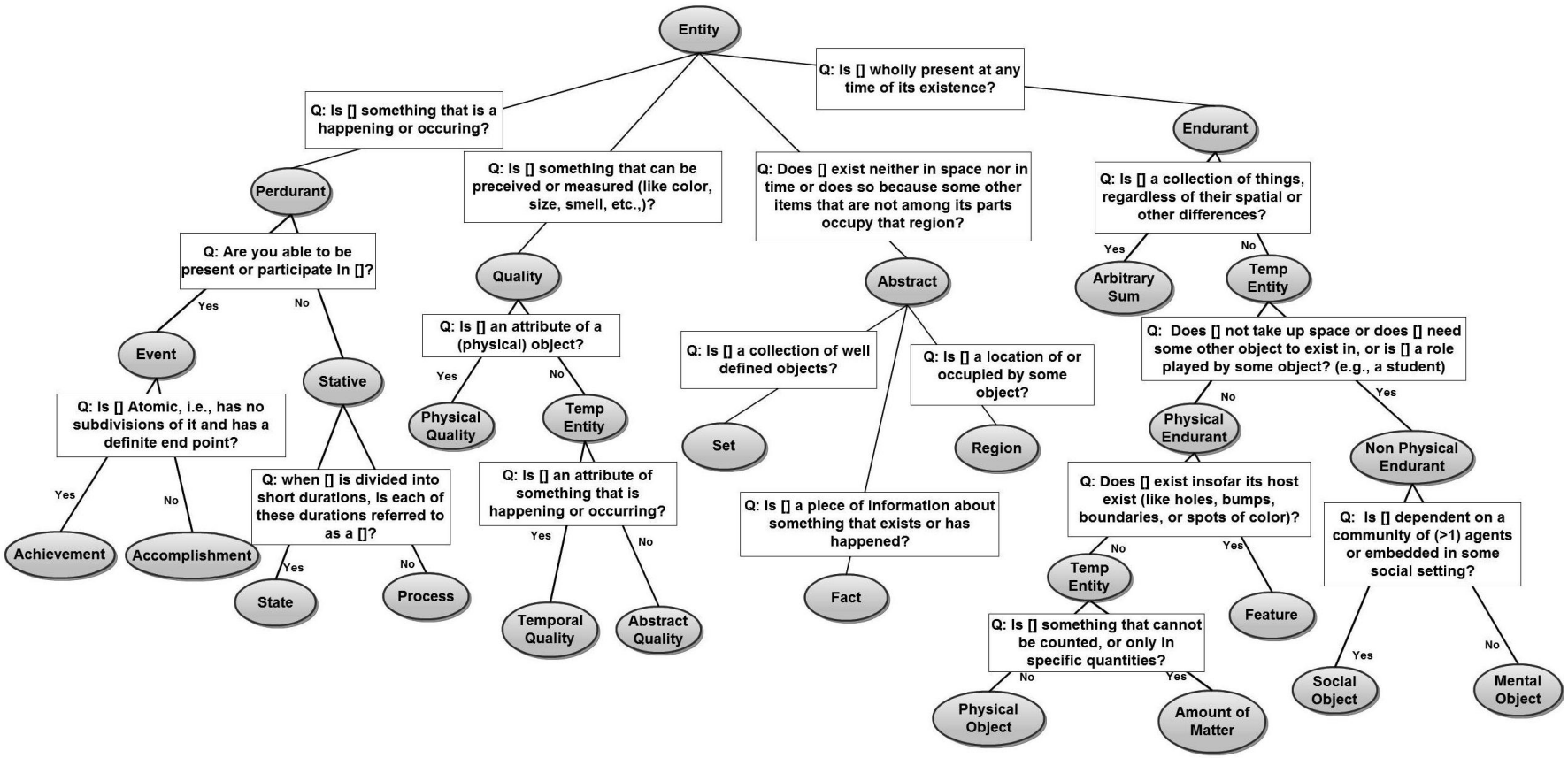
So you want to use a foundational ontology?

- Find the right one for you:
  - Mostly: *a* foundational ontology or module thereof is better than none
  - Ontological and non-ontological parameters that determine the outcome (e.g., ONSET [Khan and Keet(2012)])
- Use it:
  - Typically: import, don't extend
  - Align your top entities to FO entities (D3 [Keet et al.(2013)], BFO classifier [Bernabé et al.(2023)]) and try to reuse or refine properties as much as possible

Outline of DOLCE categories



D3


Entity
Q: Is [] something that is a happening or occuring?
Q: Is [] wholly present at any time of its existence?
Q: Is [] something that can be preceived or measured (like color, size, smell, etc.,)?
Q: Does [] exist neither in space nor in time or does so because some other items that are not among its parts occupy that region?
Perdurant
Endurant
Q: Are you able to be present or participate In []?
Quality
Abstract
Q: Is [] a collection of things, regardless of their spatial or other differences?
Yes
No
Arbitrary Sum
Temp Entity
Event
Stative
Q: Is [] an attribute of a (physical) object?
Q: Is [] a collection of well defined objects?
Q: Is [] a location of or occupied by some object?
Q: Is [] Atomic, i.e., has no subdivisions of it and has a definite end point?
Physical Quality
Temp Entity
Set
Region
Q: Does [] not take up space or does [] need some other object to exist in, or is [] a role played by some object? (e.g., a student)
Physical Endurant
Non Physical Endurant
Achievement
Accomplishment
Q: when [] is divided into short durations, is each of these durations referred to as a []?
Q: Is [] an attribute of something that is happening or occurring?
Q: Is [] a piece of information about something that exists or has happened?
Q: Does [] exist insofar its host exist (like holes, bumps, boundaries, or spots of color)?
Q: Is [] dependent on a community of (>1) agents or embedded in some social setting?
State
Process
Temporal Quality
Abstract Quality
Fact
Temp Entity
Feature
Q: Is [] something that cannot be counted, or only in specific quantities?
Social Object
Mental Object
Physical Object
Amount of Matter

The African Wildlife Ontology and DOLCE

- Where does `Plant` fit in DOLCE?
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- Impalas run (fast). Where should we put `Running`?
- Lions eat impalas, and in the process, the impalas die. Where should we put `Death`?
- Generic examples of DOLCE's 'leaf' categories: see Table 1, p21 in the D18.pdf

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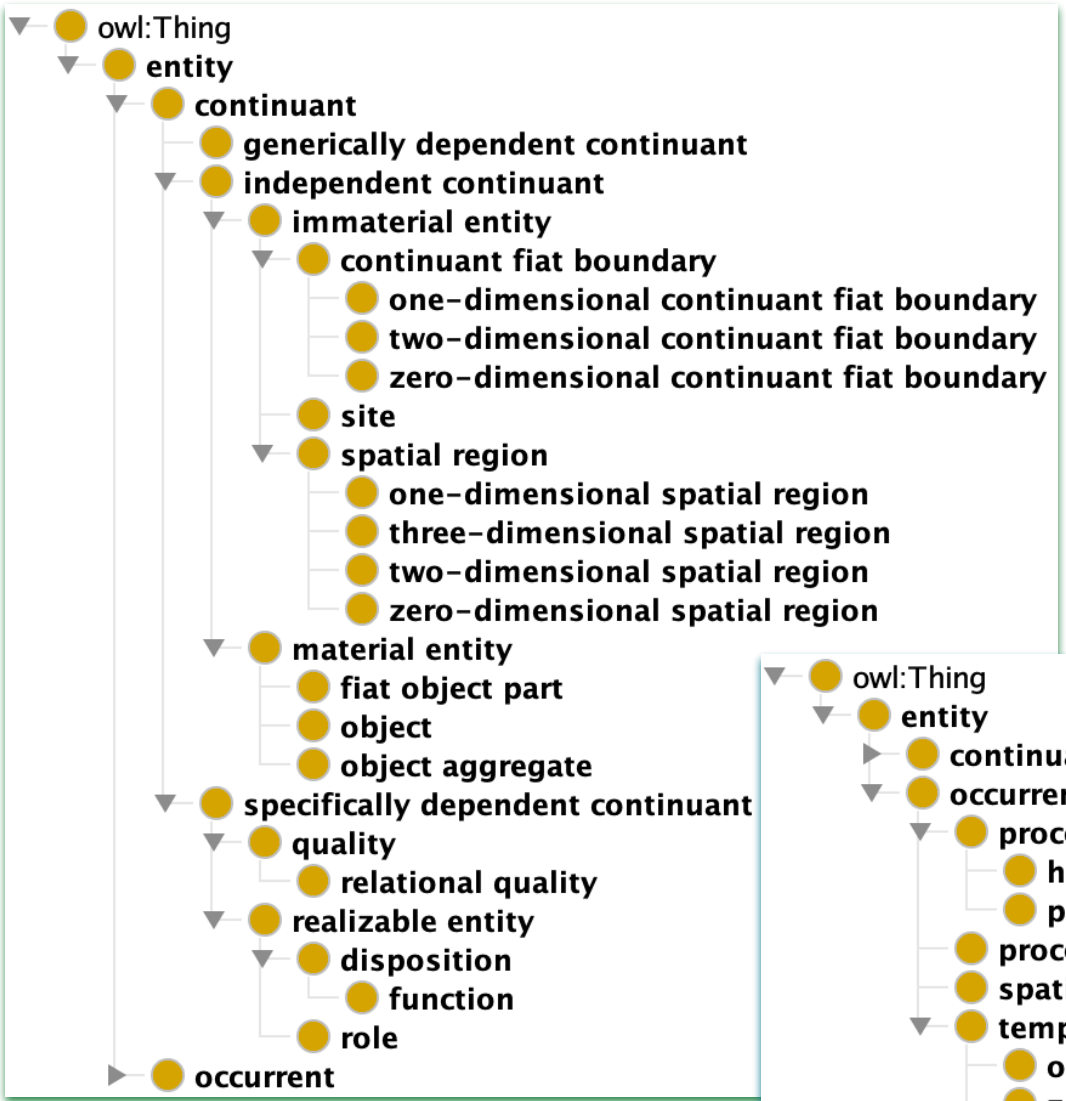
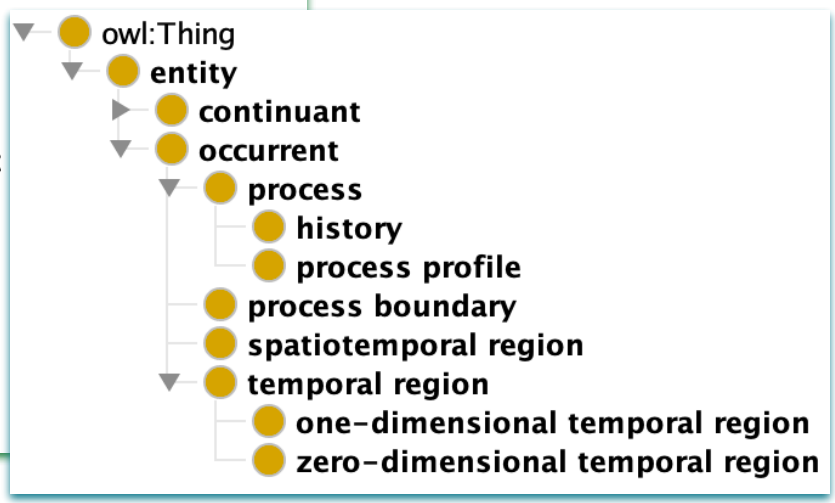
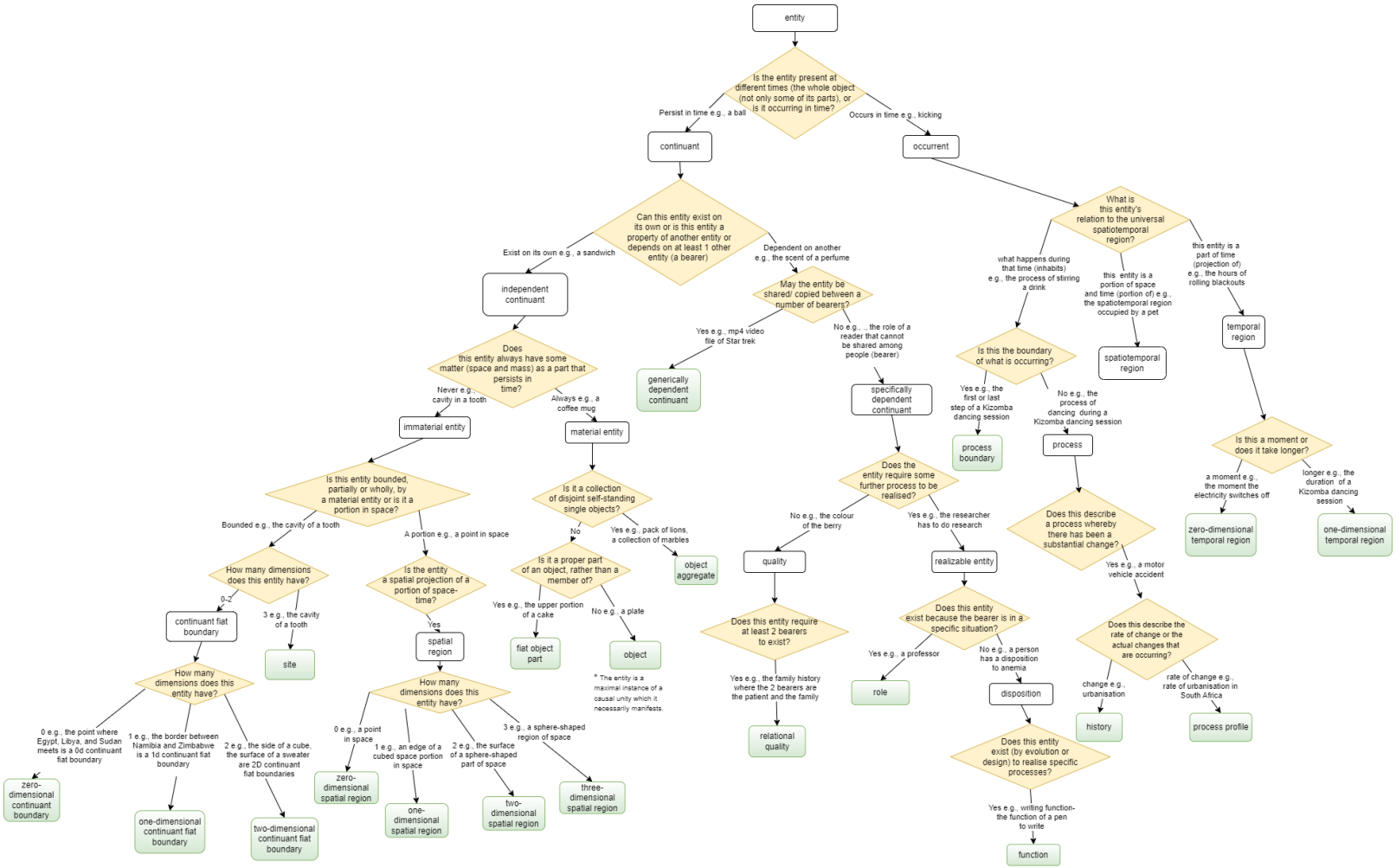
BFO Taxonomy





A decision diagram



and a tool: `https://github.com/mkeet/BFO2DecisionDiagram`

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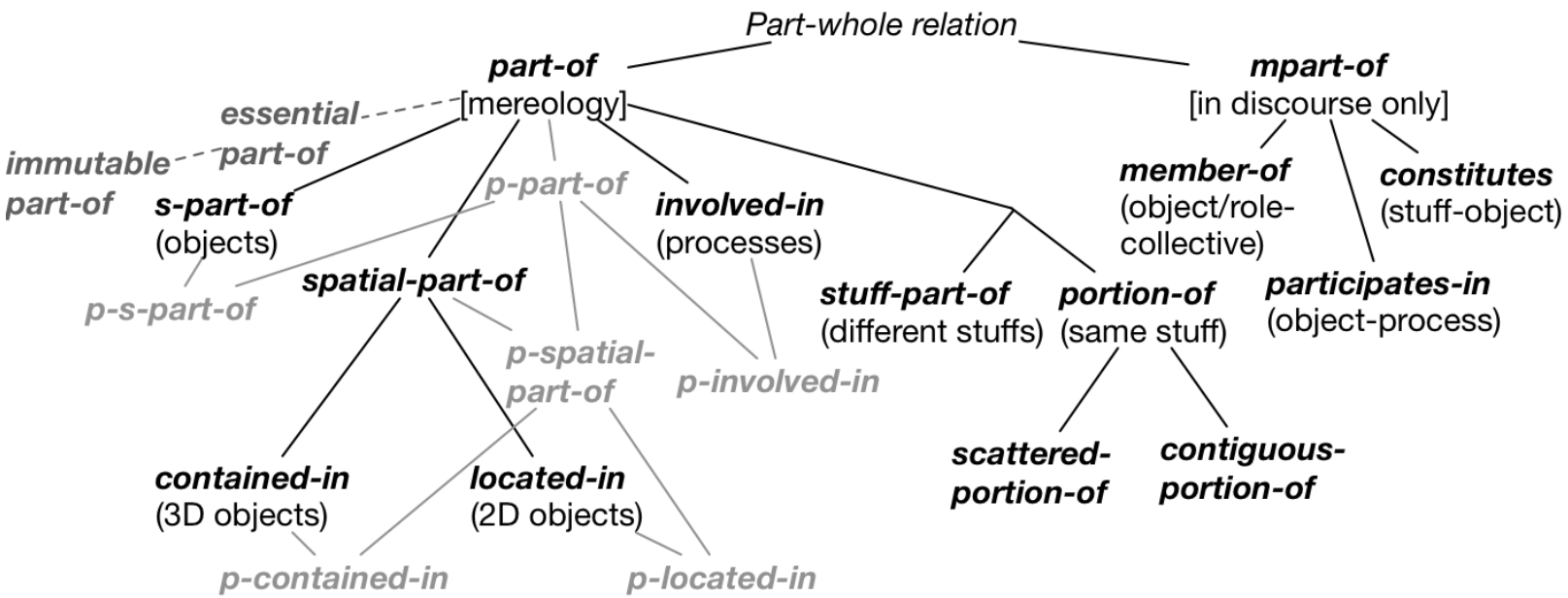
- Hand is part of musician, musician part of orchestra, but clearly, the musician's hands are not part of the orchestra. Is part-of then not transitive, or is there a problem with the example?

Try to be more precise with part-whole relations



pw hierarchy (aligned): `http://www.meteck.org/swdsont.html`

Sampling of range of methods and tools

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- Logic-based: Advocatus Diaboli, to add disjointness where there should be [Ferré and Rudolph(2012)], TDDonto2: test before you add the axiom [Davies et al.(2019)]
- Ontology- and modelling-based: OntoPartS, to select the right mereological or mereotopological relation [Keet et al.(2012)]
- Heuristics-based: OOPS! [Poveda-Villalón et al.(2012)]

Outline

Summary

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Thank you!

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