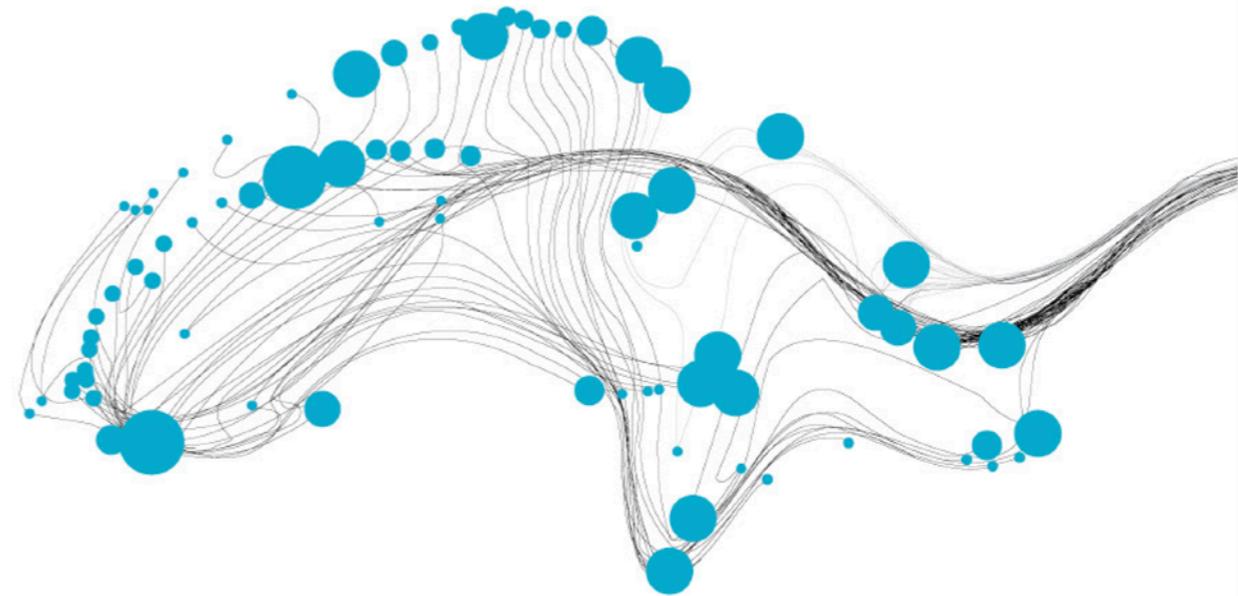


Unified Foundational Ontology



C-FORS Summer School
Oslo, 2025

Giancarlo Guizzardi et al.

**UNIVERSITEIT
TWENTE.**

**Semantics
Cybersecurity
Services**



Acknowledgements

- Gerd Wagner, Heinrich Herre, Nicola Guarino, João Paulo Almeida, Riccardo Baratella, Alessandro Botti, Tiago Sales, Claudenir Moraes, Renata Guizzardi, Daniele Porello, Michael Gruninger, etc.



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Information technology — Top level ontologies

Part 5: Unified Foundational Ontology (UFO)

Under development

A draft is being reviewed by the committee.

A large, light blue watermark with the text 'COMMITTEE DRAFT' is overlaid on the left side of the page. The text is rotated diagonally and is semi-transparent.

“I have chosen to look at **modelling** because it **exerts the most profound and...most important influence in the systems we build**...To build a model is to conceive of the world in a certain delimited way... It is with respect to these representations that computer systems work...they run by manipulating representations...This can all be summarised in a slogan: **no computation without representation**”

“Mediating between the [system and the world] is the inevitable model...[What we have been focusing on as a discipline]...is a study of the relationship [model-system]. What about the relationship [model-world]?...The answer, is that, at this point in intellectual history, we have no theory of this...

relationship...[and]...**any adequate theory of [system] correctness will have to take the model-world relationship into account”**

(Brian Cantrell Smith, The Limits of Correctness, 1985)

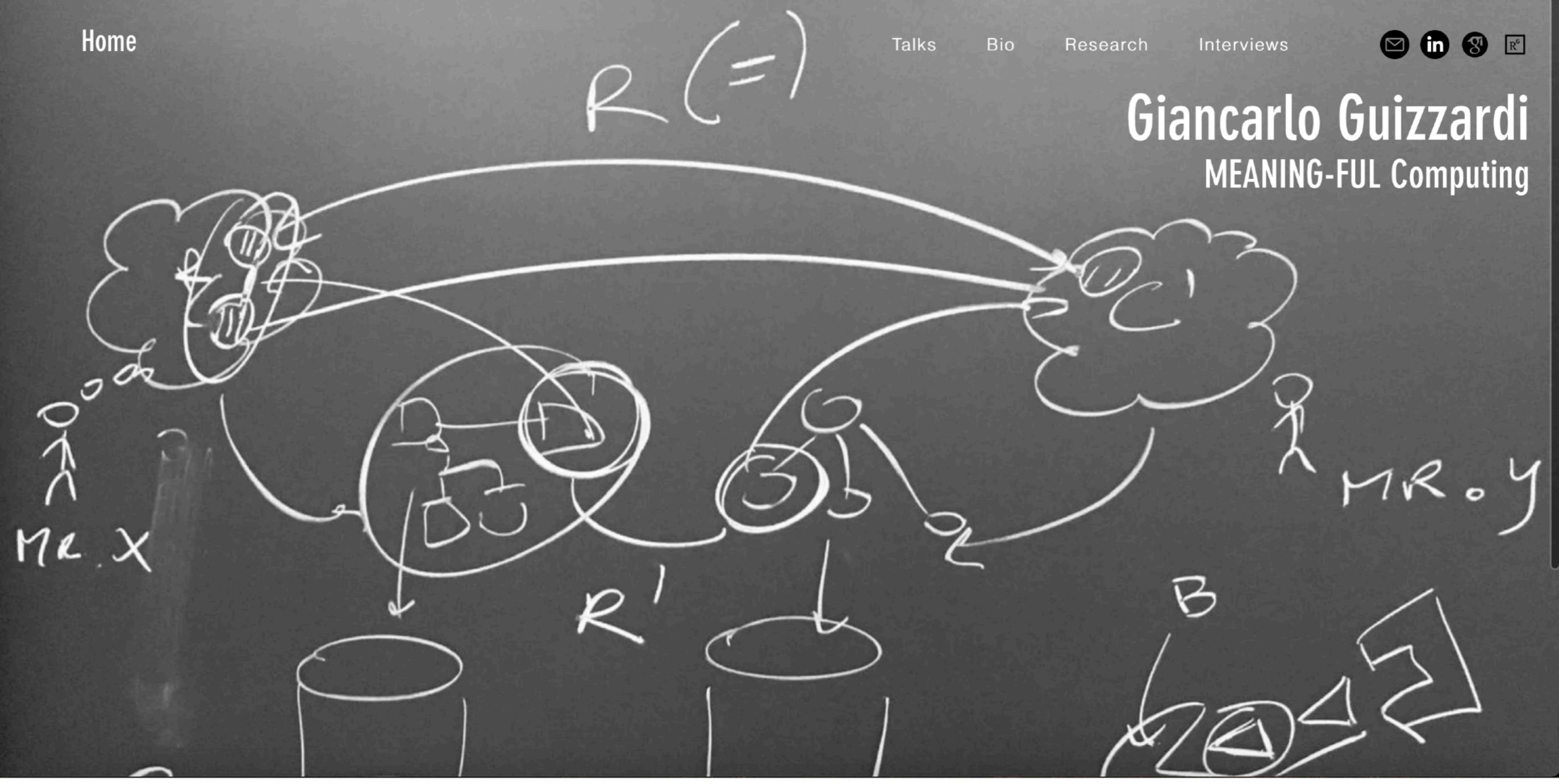
Home

Talks Bio Research Interviews



Giancarlo Guizzardi

MEANING-FUL Computing



1

Unified Foundational Ontology (UFO)

UFO

- The goal was “**Philosophy of Modeling**” in Computer Science/ Information Systems Engineering
- Started nearly **25 years** ago as a unification (hence the name) of GFO, DOLCE and OntoClean-Properties* but then very soon became a full-blown independent foundational ontology

Fundamental Requirements

- Dealing with different **types of types** (including **higher-order types**), **particularized properties**, a rich **theory of relations** (including reified relations), datatypes, **events**
- Modeling Languages and Tools
- Finitely-satisfiable models,...

How has it been developed?

- Elicited by conducting an ontological analysis of several modeling languages, reference models and standards, a multitude of models and applications
- Strongly driven by classical problems in the area (e.g., modeling of roles with multiple supertyping, problem of collapse of cardinality constraints, problem of transitivity of parthood...)

How has it been developed?

- It has an underlying *Design Science* agenda of continuously building a set of engineering artifacts as materializations of these ontological foundations. These artifacts are evaluated in practice in a number of ways

How has it been developed?

- We are also concerned about *pragmatic efficiency* of the derived representations (doing the type of empirical work that cognitive psychologists do): Can people make sense (reason, learn, recall) these categories? Can people effectively reason with models produced with these foundations?

ONTOUML/UFO

C a t a l o g

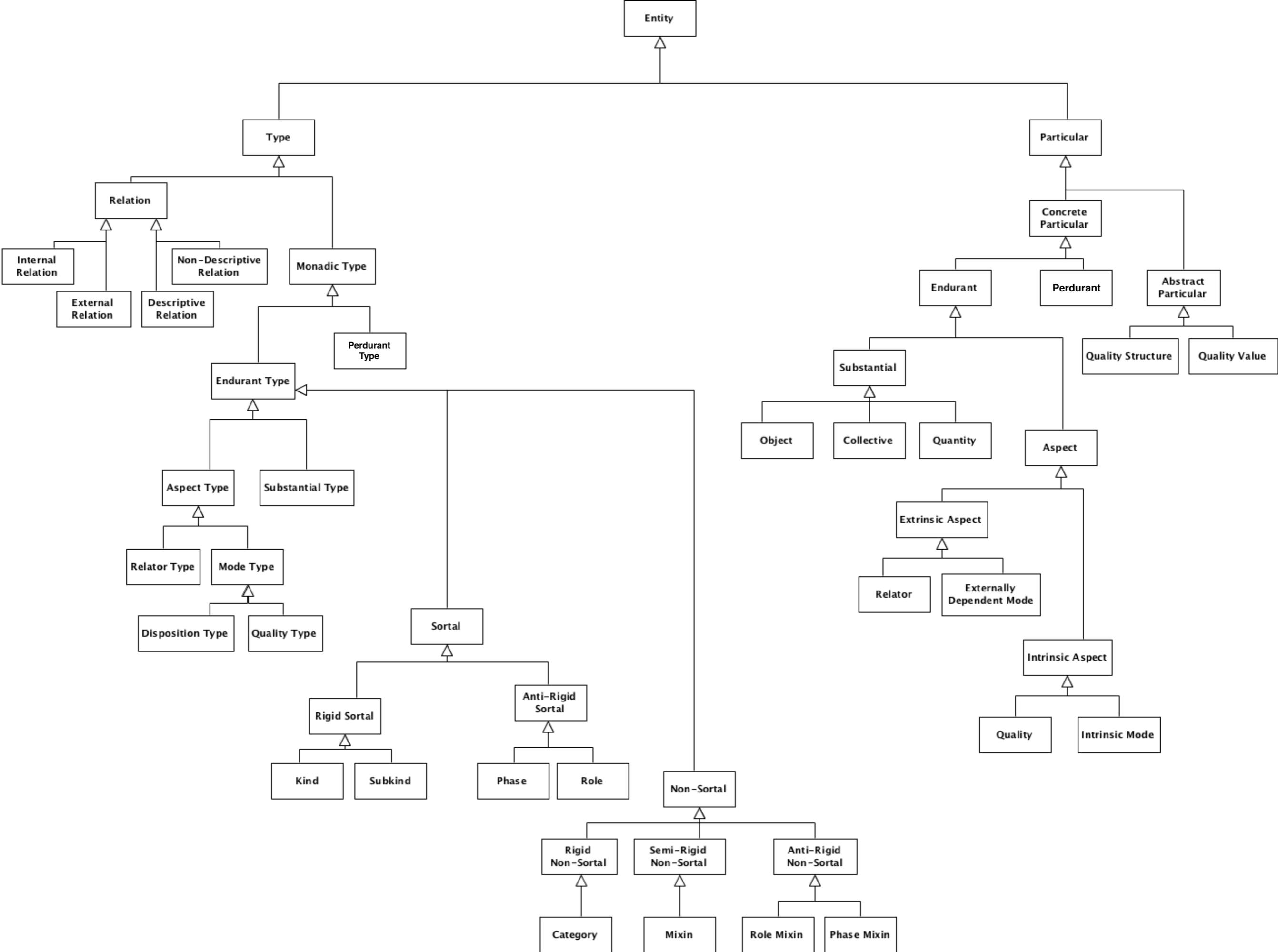


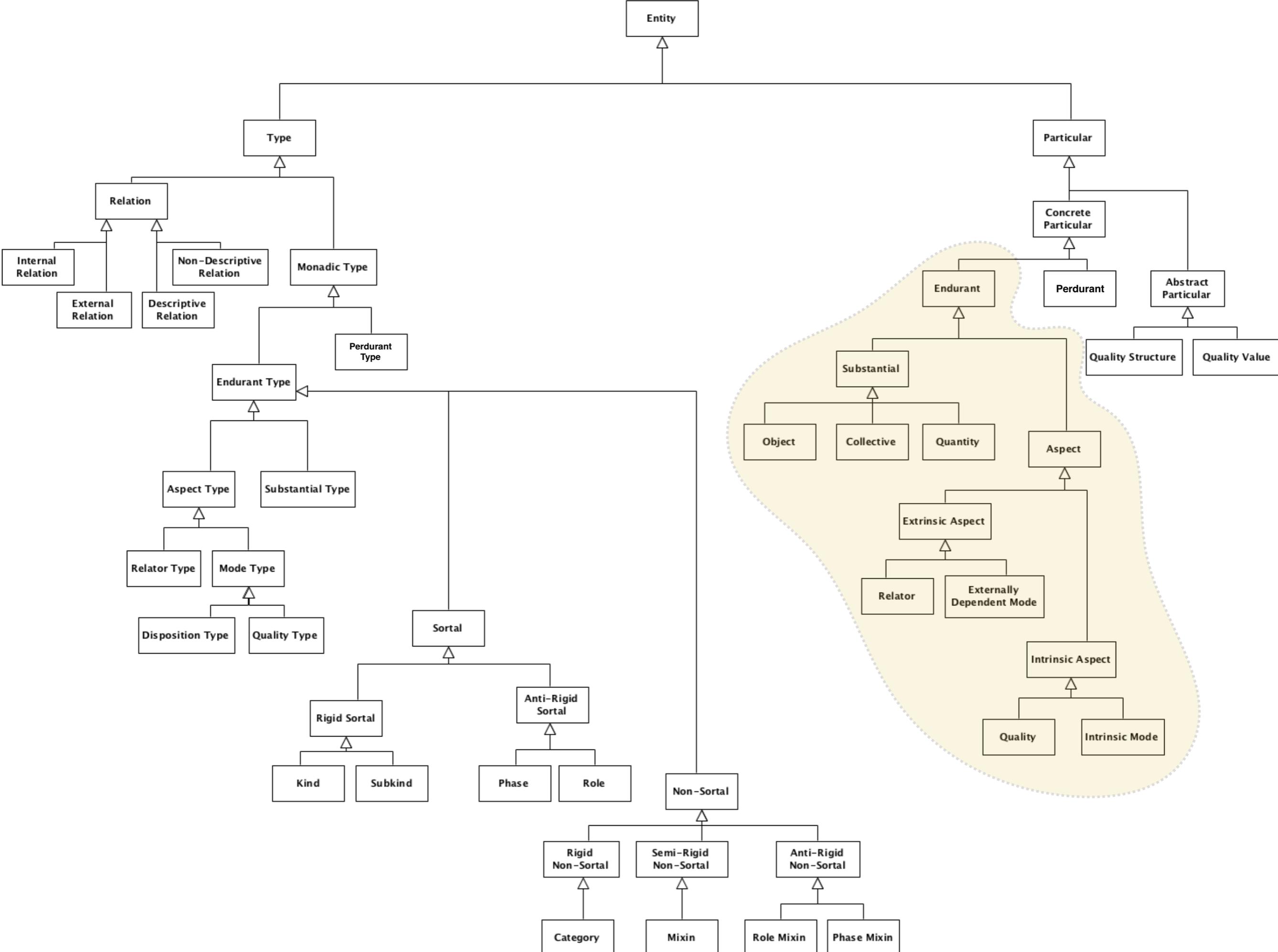
UFO-A (Endurants)

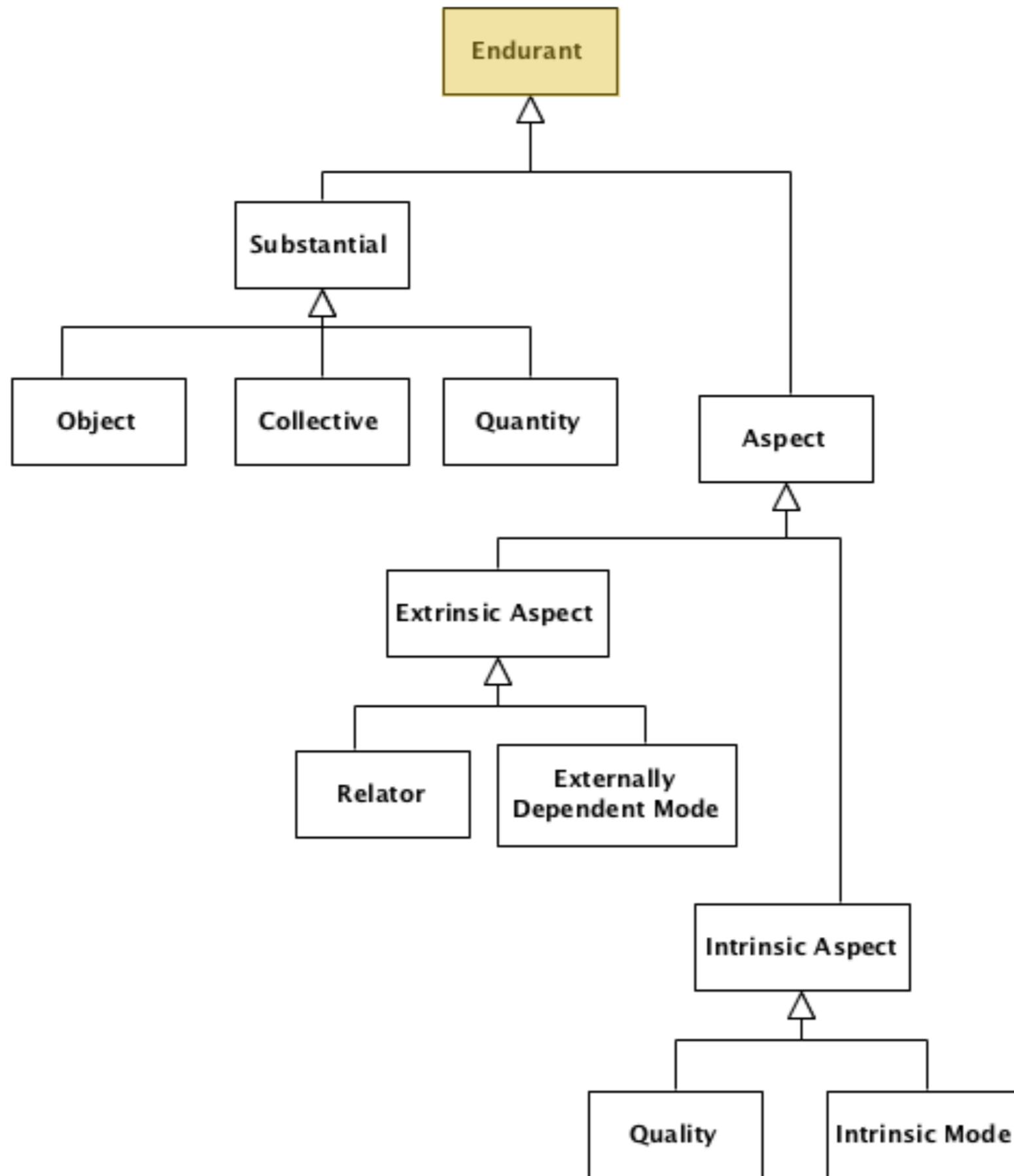
**Endurants, their Types and
Taxonomic Structures, Dependent
Entities (Qualities, Modes, Relators,
Dispositions), (Part-Whole)
Relations, Datatypes, Multi-Level
Structures, etc...**

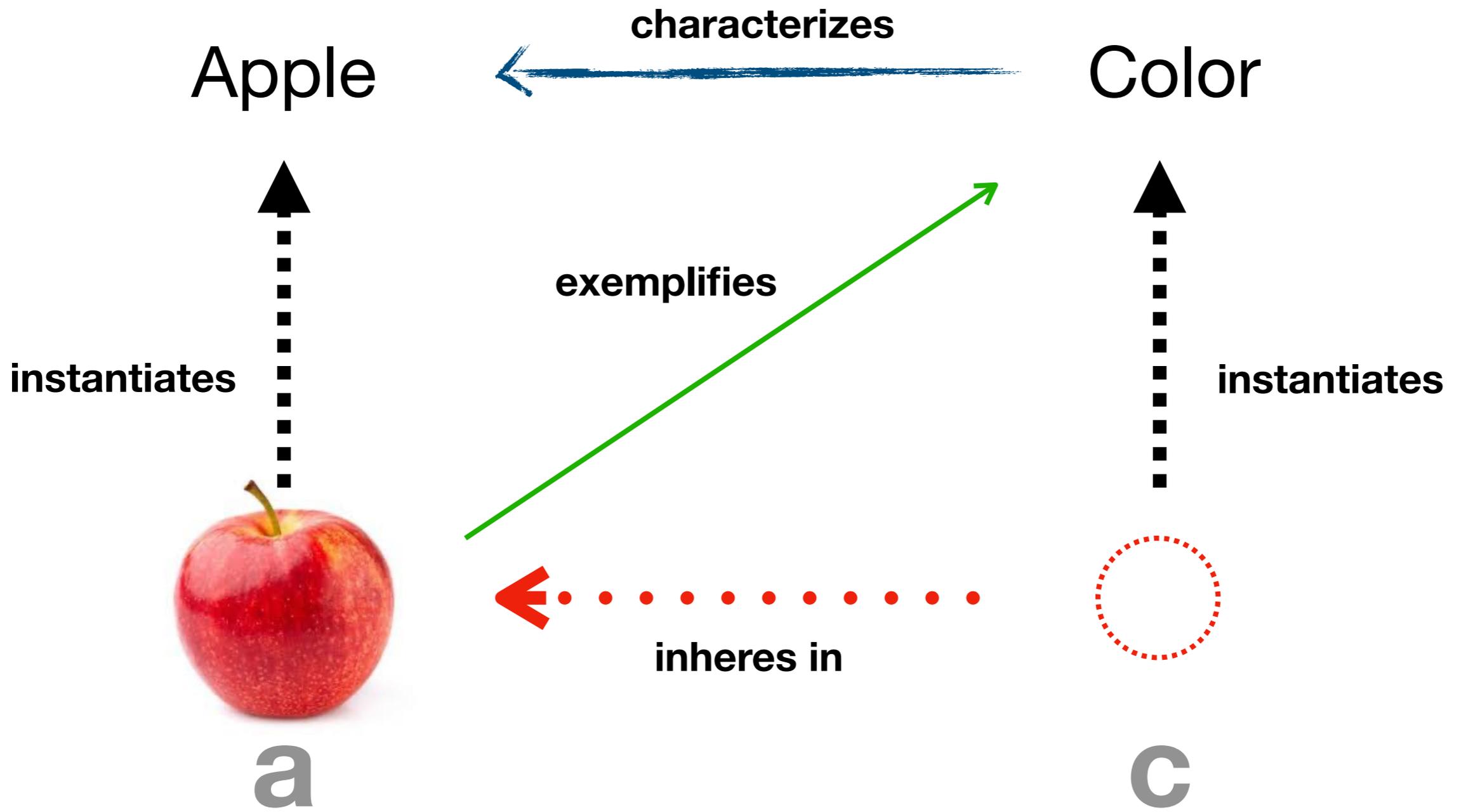


UFO-A (Endurants)







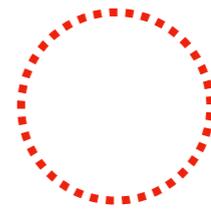




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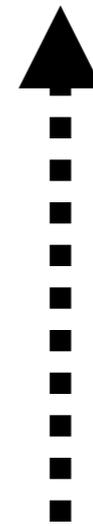


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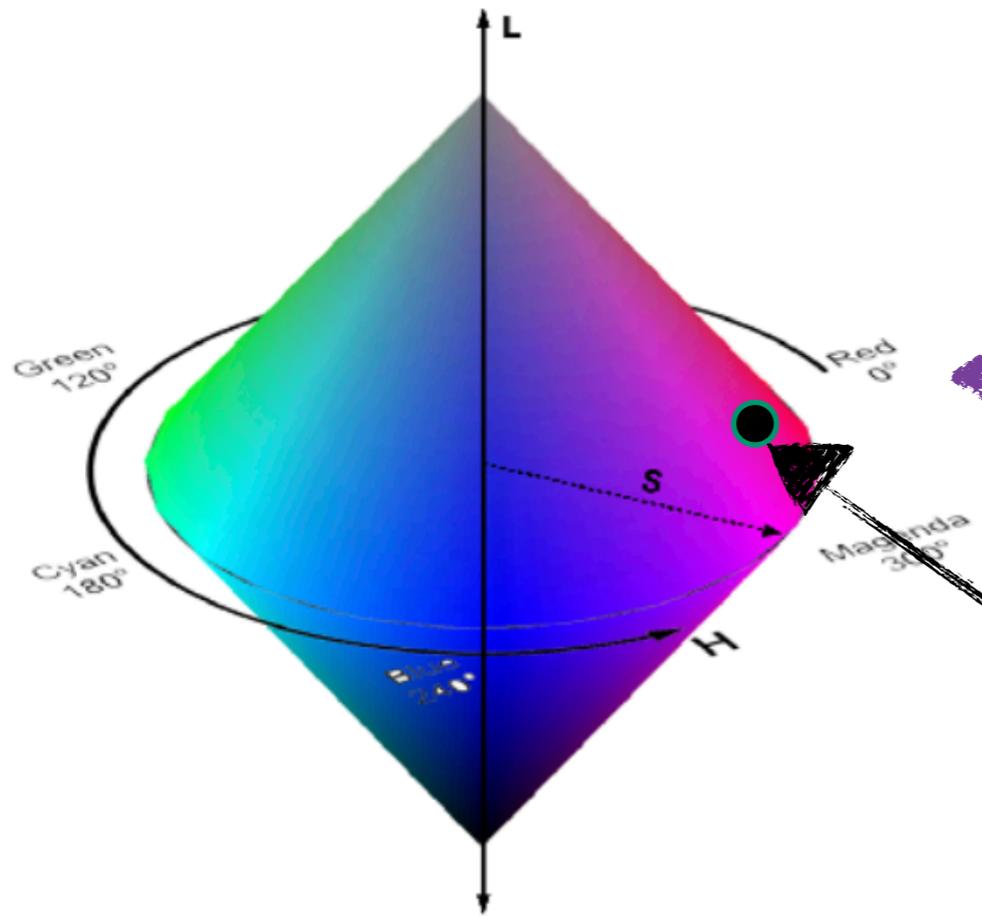


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Color



instantiates



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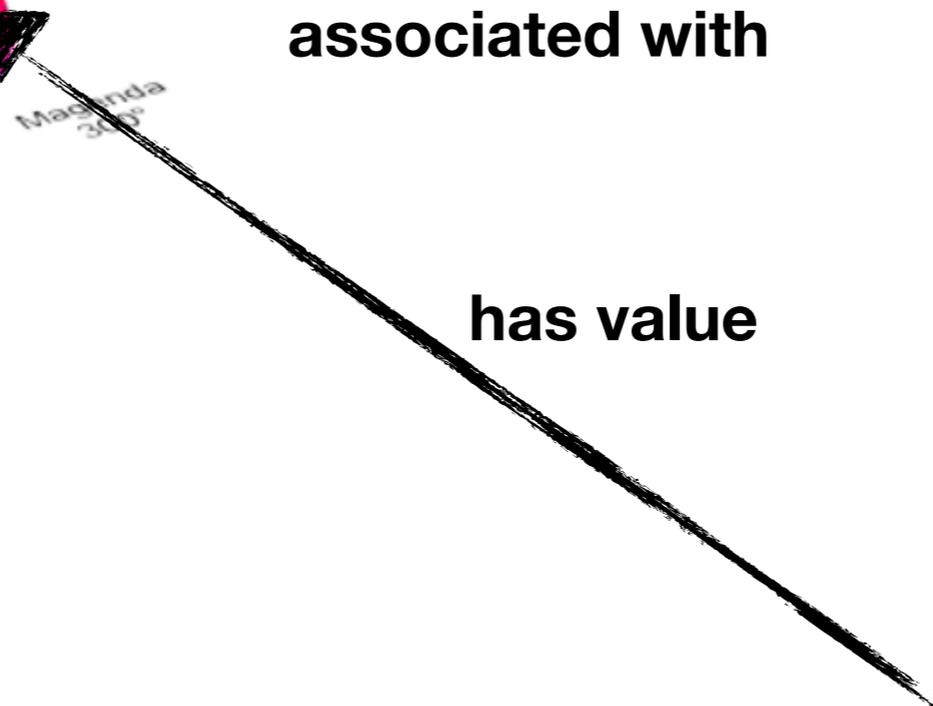
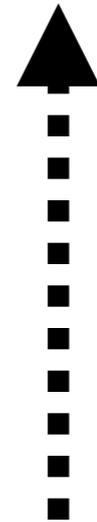
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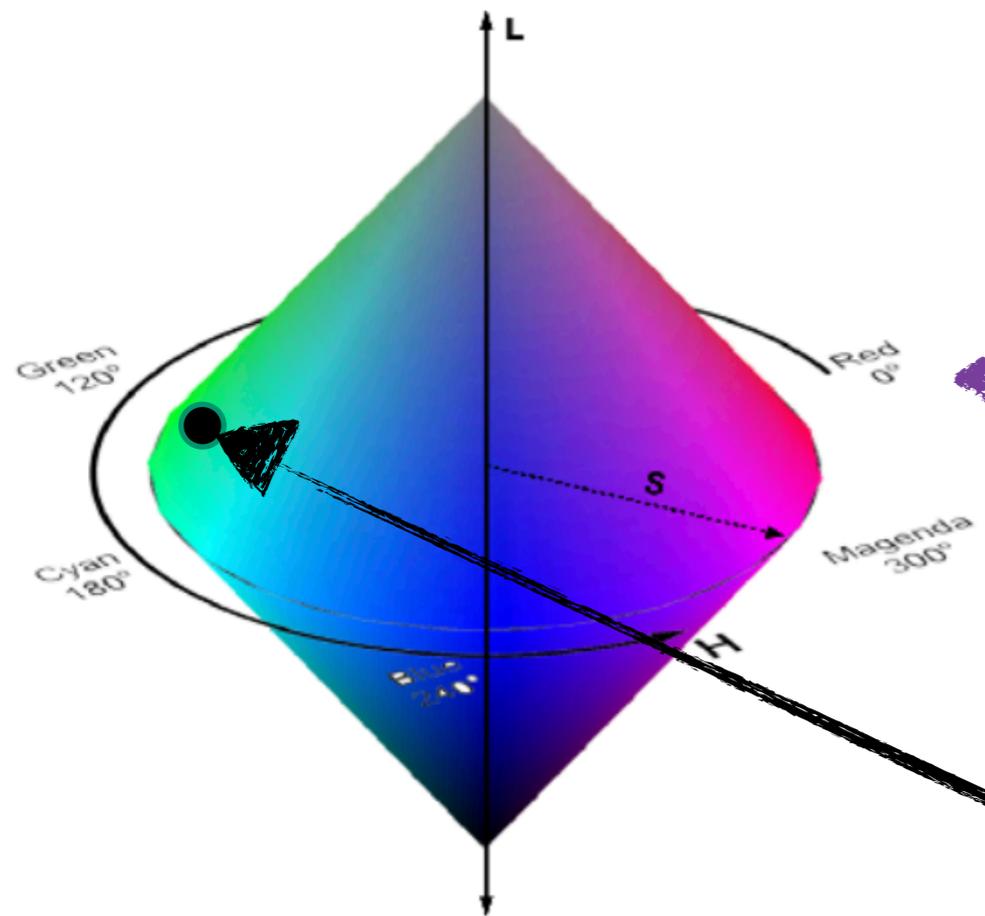
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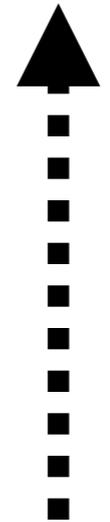
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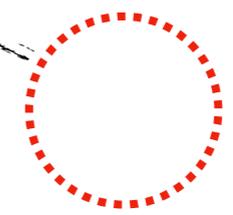
has value (t2)



a



inheres in



c

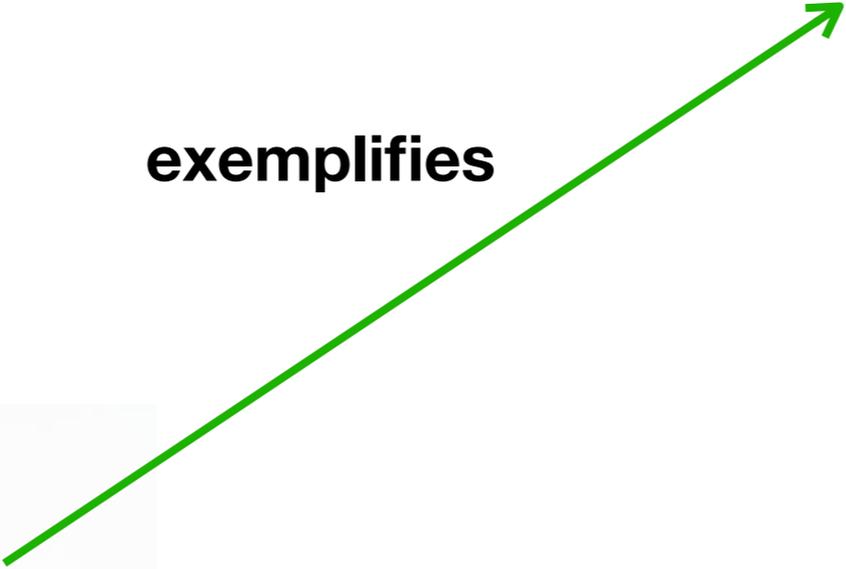
Person

Headache

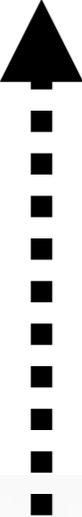
characterizes



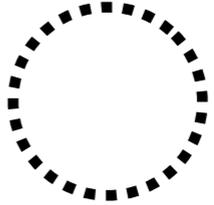
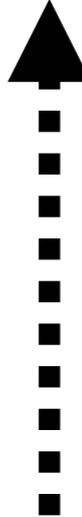
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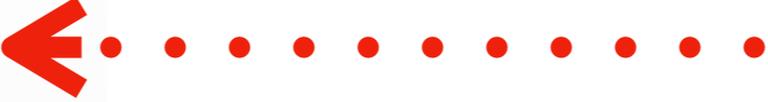


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inherits in



John

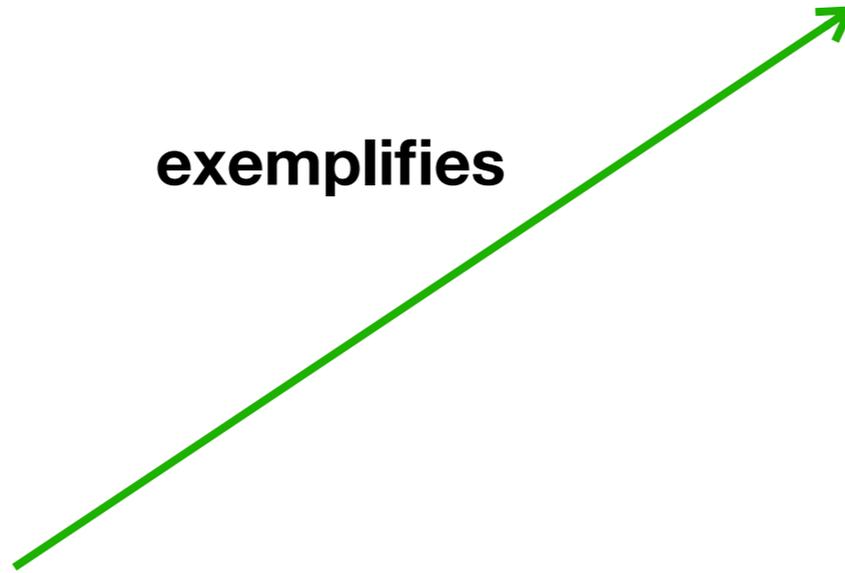
Person

Knowledge
of Greek

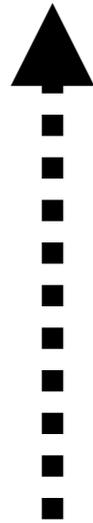
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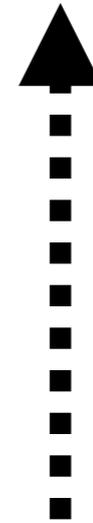
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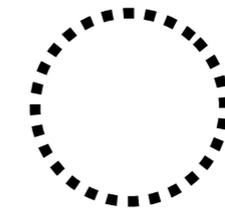
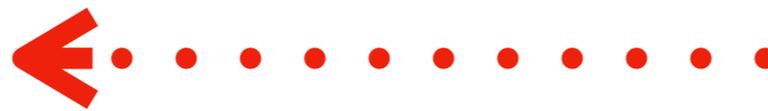
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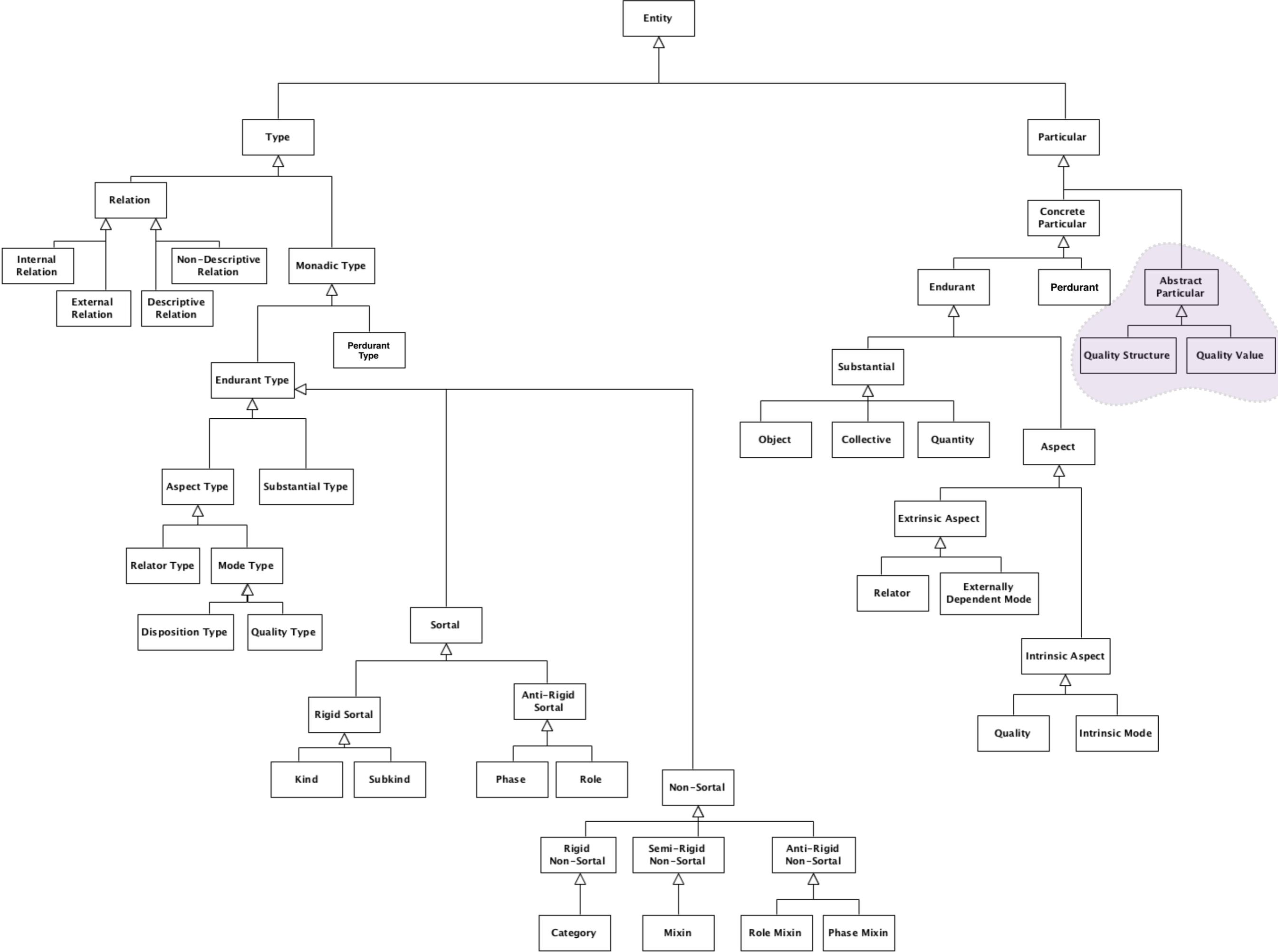
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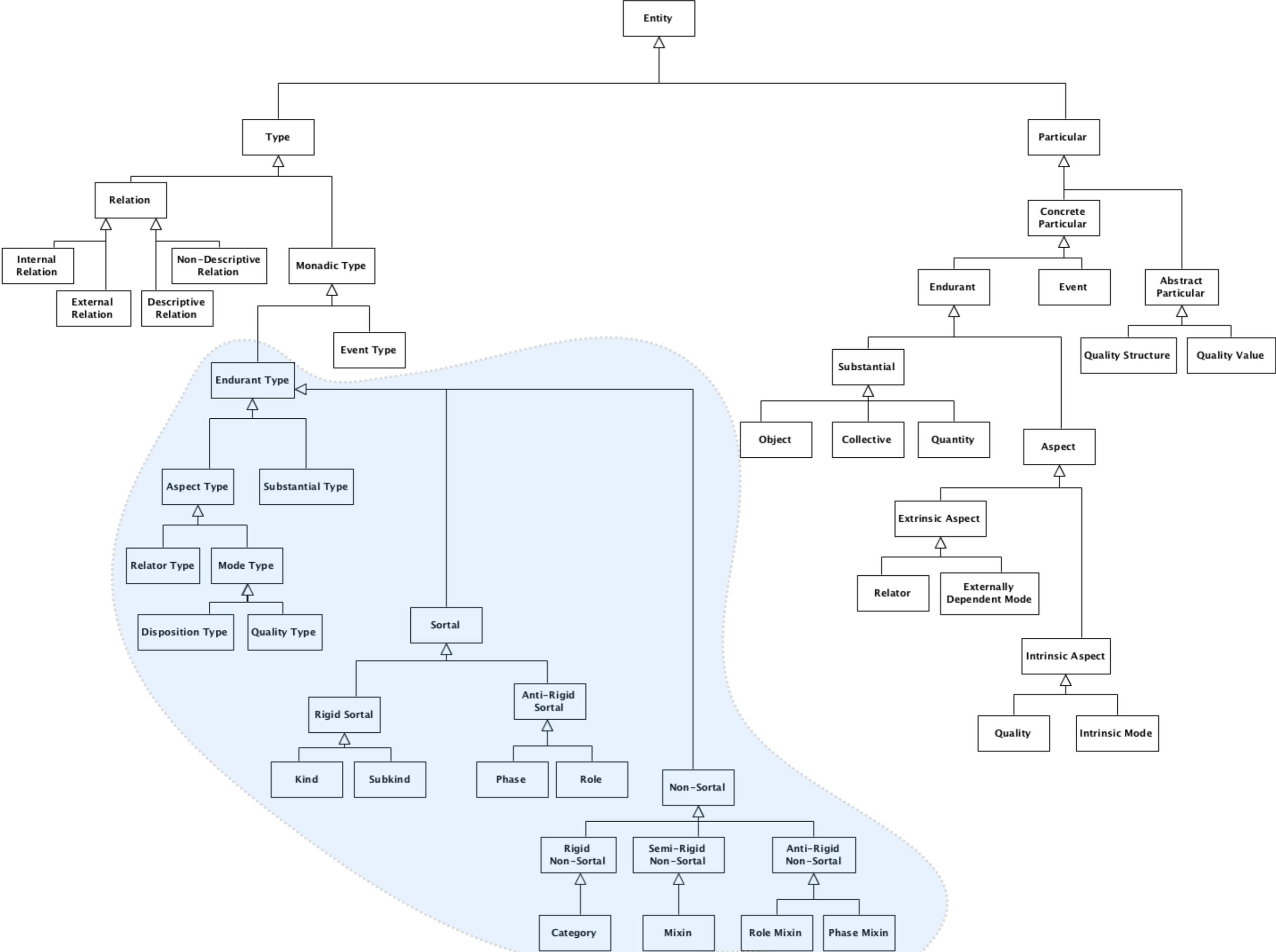


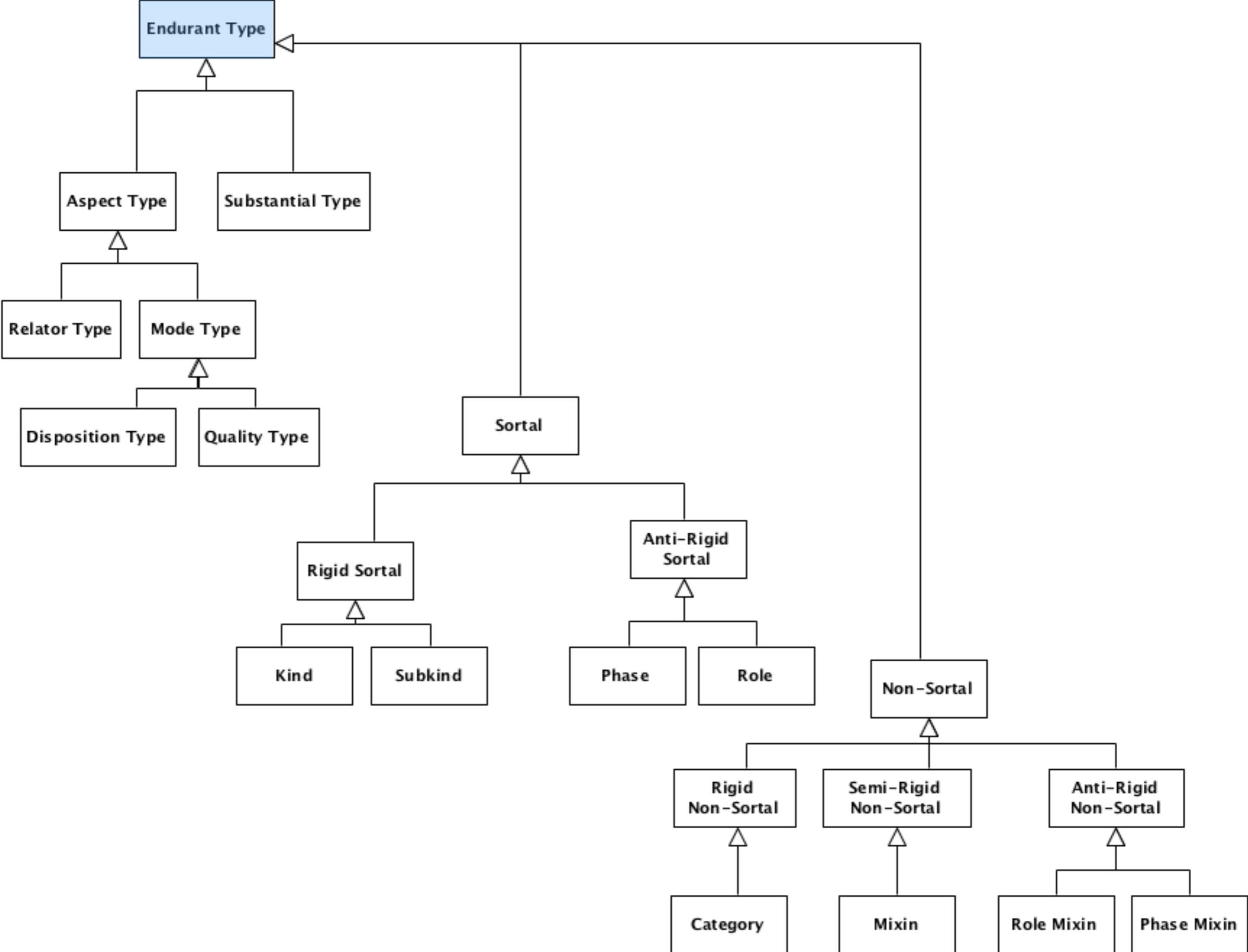
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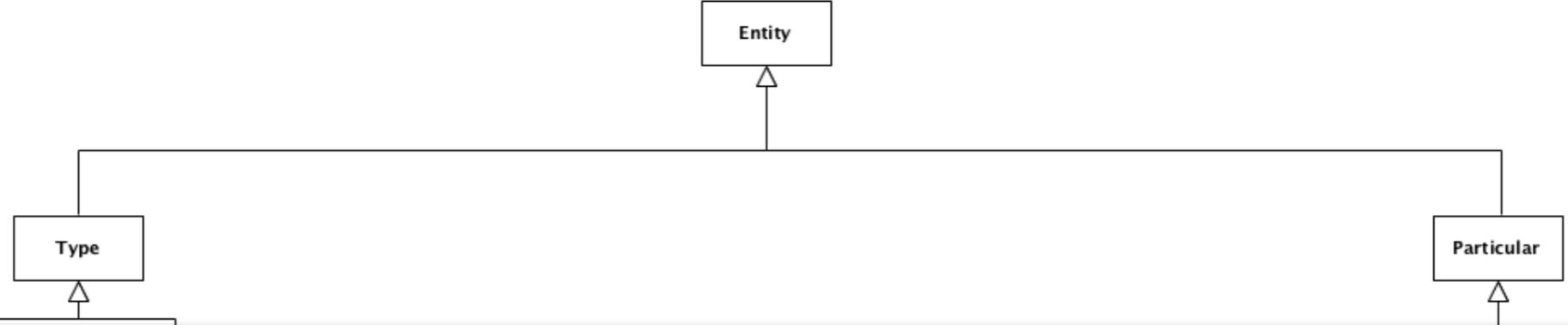


Mary

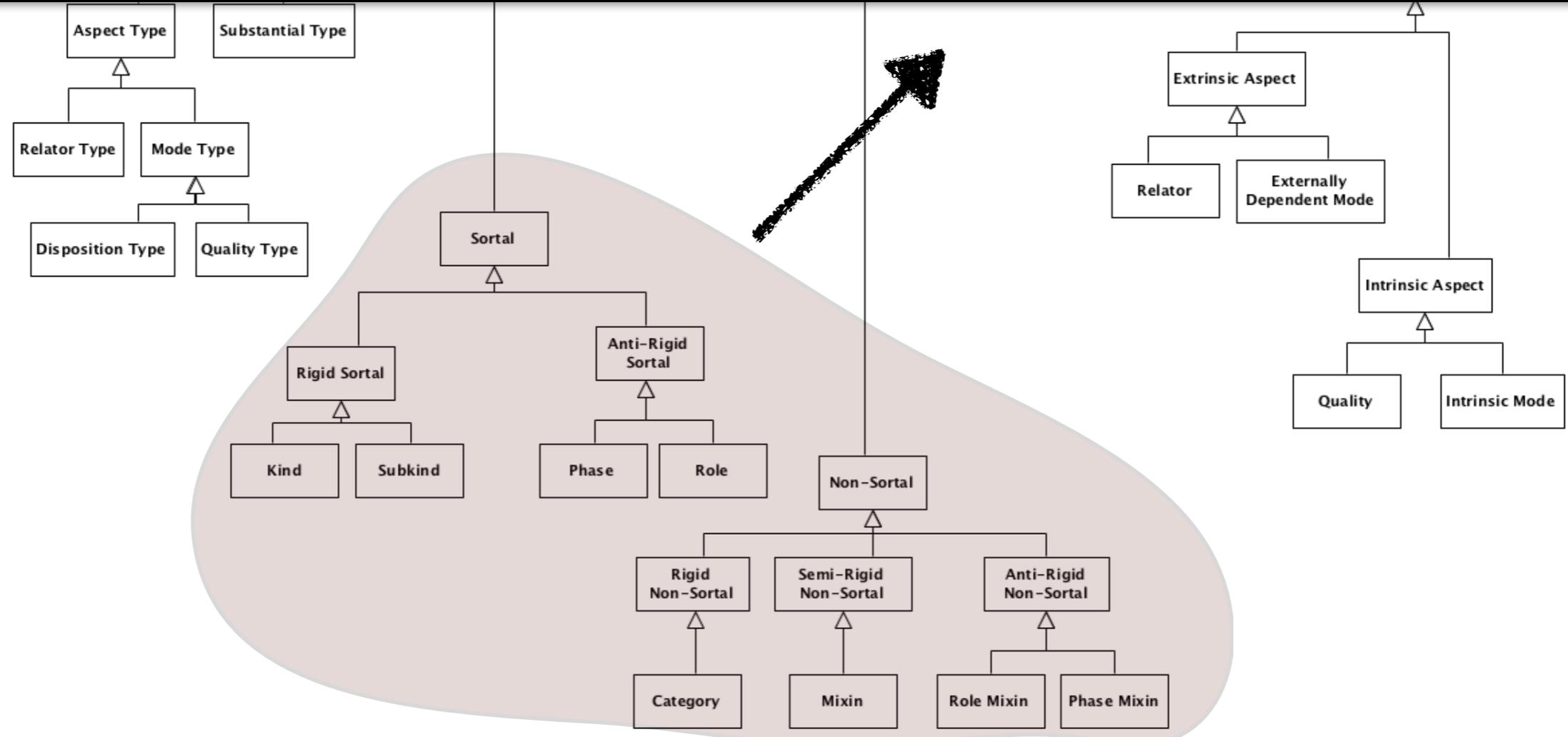








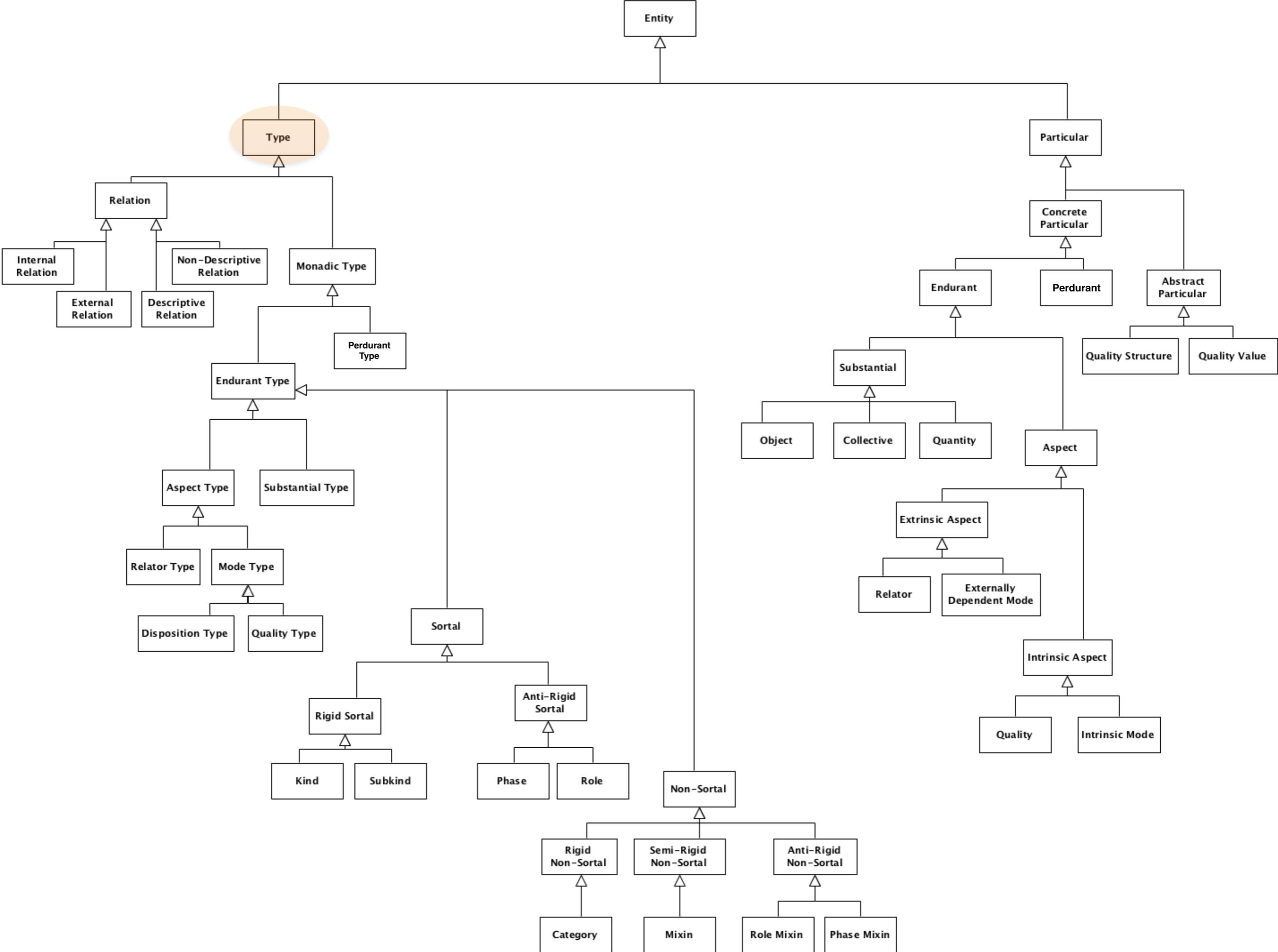
Notice that these apply to all endurants, not just to **substantials**. So, we can have, e.g., **phases of relators** (e.g., *tenured employment*) as well as **role of relators** (e.g., *legally recognized civil partnership*). Same for **qualities** and **modes**

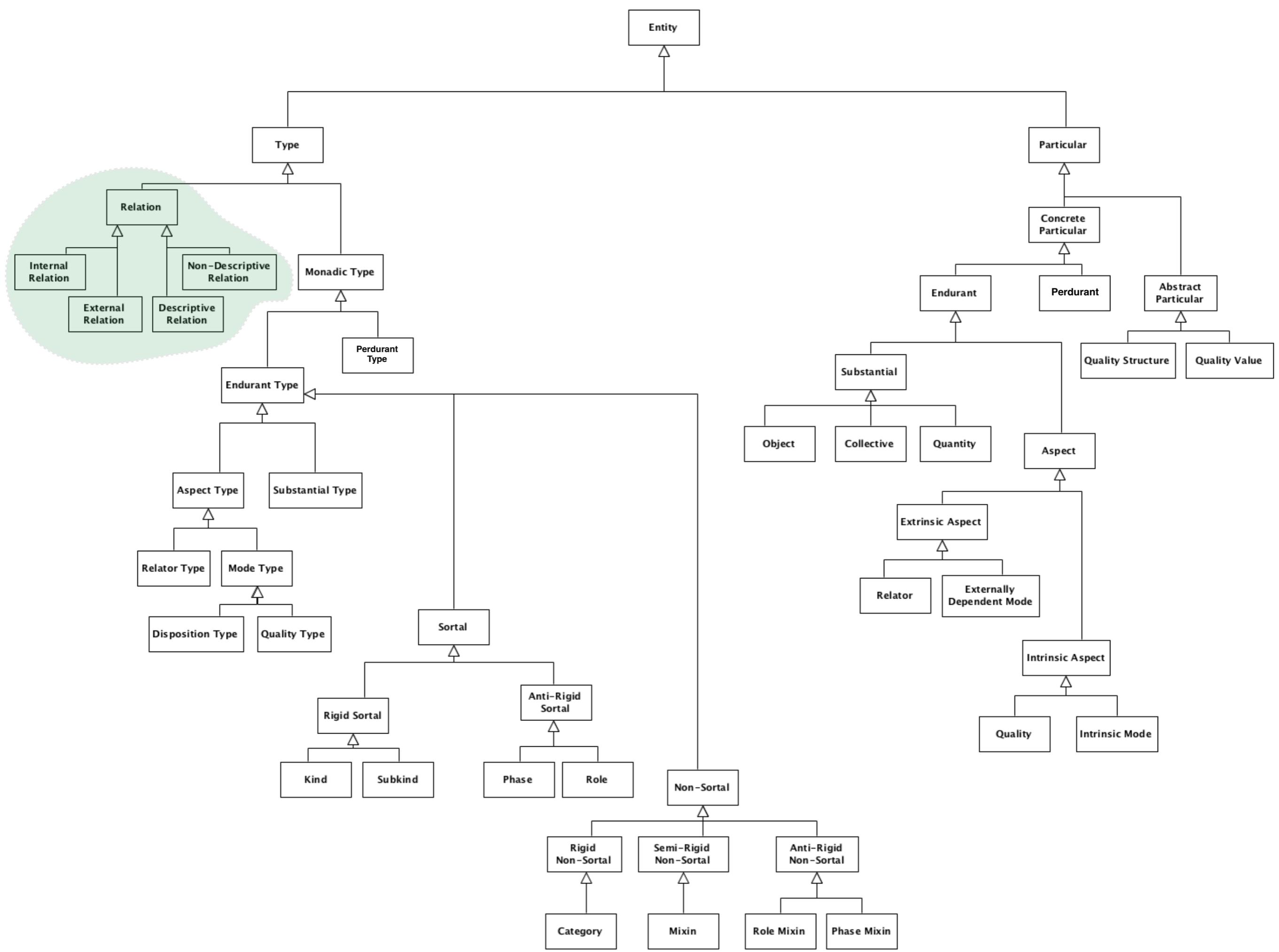


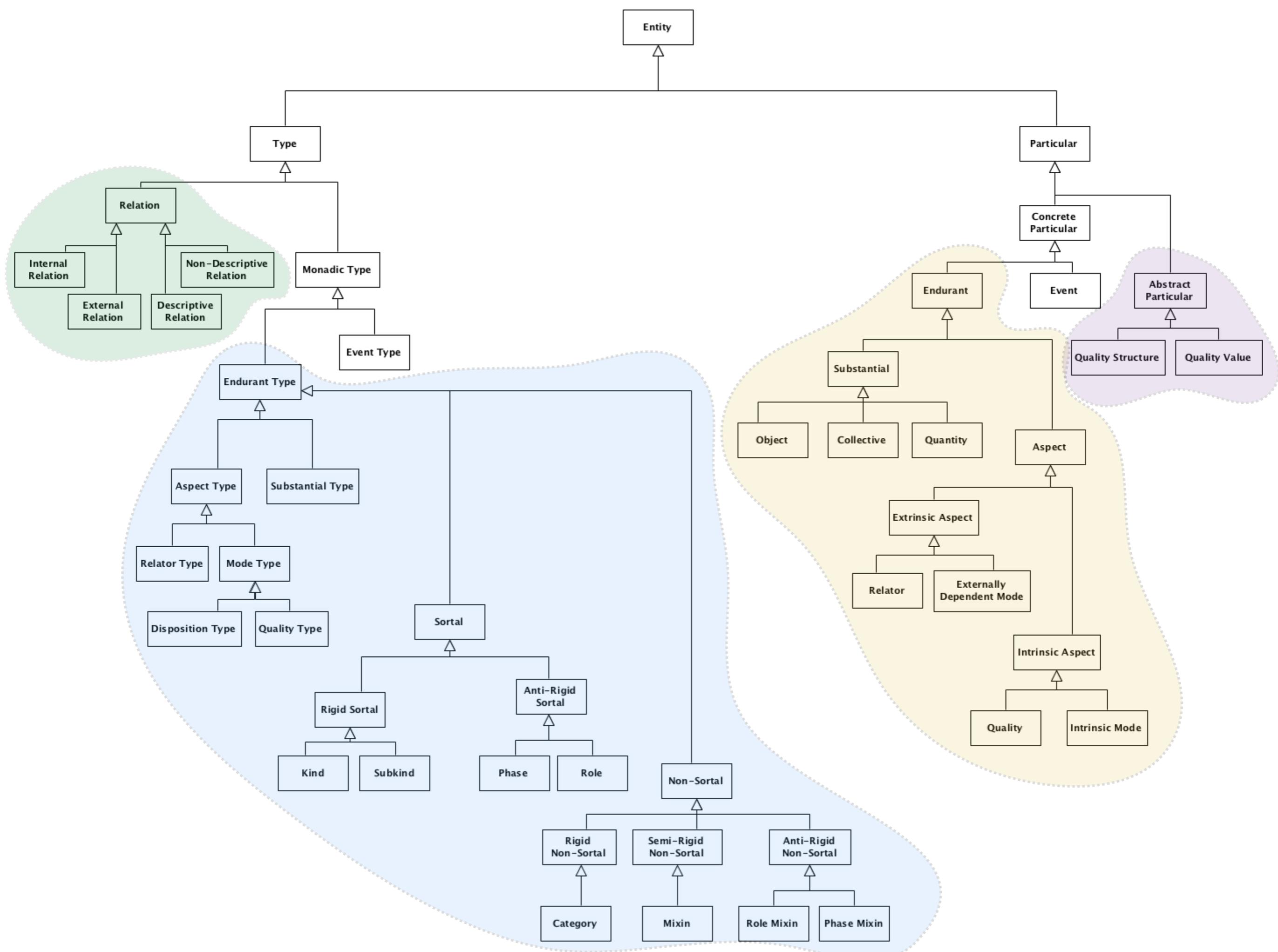
Internal Relation

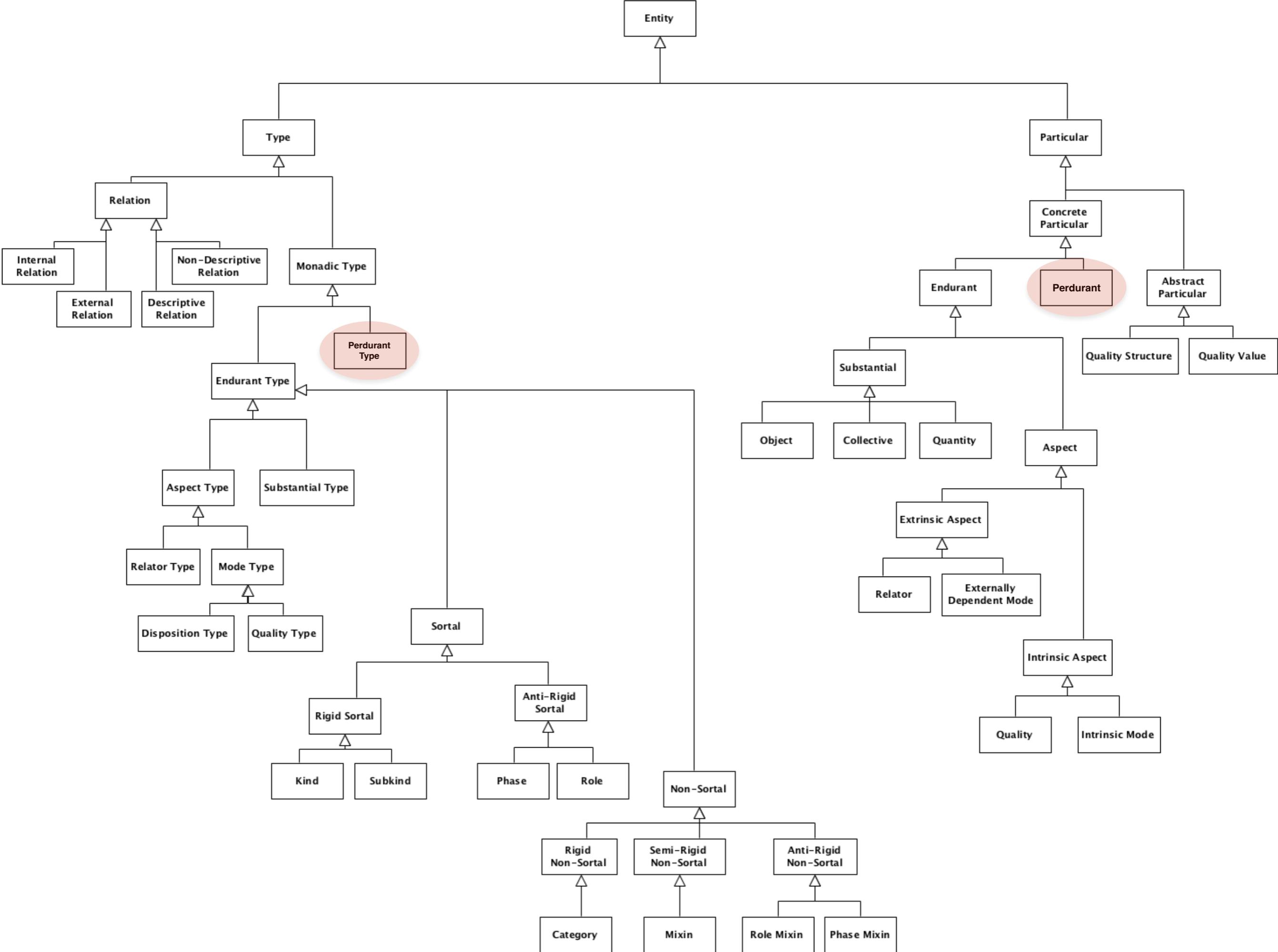
E R

alue











Events, their names, and their synchronic structure

Nicola Guarino, Riccardo Baratella & Giancarlo Guizzardi

Applied ontology 17 (2):249-283 (2022) [Copy](#) [BIBTEX](#)

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Abstract

We present in this paper a novel ontological theory of events whose central tenet is the Aristotelian distinction between the object that changes and the actual subject of change, which is what we call an individual quality. While in the Kimian tradition events are individuated by a triple $\langle o, P, t \rangle$, where o is an object, P a property, and t an interval of time, for us the simplest events are qualitative changes, individuated by a triple $\langle o, q, t \rangle$, where q is an individual quality inhering in o or in one of its parts. Detaching the individuation of events from the property they exemplify results in a fine-grained theory that keeps metaphysics and semantics clearly separate, and lies between the multiplicative and the unitarian approaches. We discuss then the way language refers to events, observing that, in most cases, event descriptions refer to complex, cognitively relevant clusters of co-occurring qualitative changes, which exhibit a synchronic structure depending on the way they are described. Contra Bennett, who famously argued that the semantics of event names ultimately depends on “local context and unprincipled intuitions”, we show how the lexicon provides systematic principles for individuating such clusters and classifying them into kinds. Finally, we address some open challenges in the semantics of locative and manner modifiers.

Representing a Reference Foundational Ontology of Events in $SR\mathcal{O}IQ$

Alessander Botti Benevides ^{a,*}, Jean-Rémi Bourguet ^a, Giancarlo Guizzardi ^{a,b},
Rafael Peñaloza ^b and João Paulo A. Almeida ^a

^a *NEMO, Computer Science Department, Federal University of Espírito Santo, Av. Fernando Ferrari, 514, Goiabeiras/Vitória, Brazil*

E-mails: abbenevides@inf.ufes.br, jean-remi.bourguet@ufes.br, gguizzardi@inf.ufes.br, jpalmeyda@ieee.org

^b *Faculty of Computer Science, Free University of Bozen-Bolzano, Italy*
E-mails: giancarlo.guizzardi@unibz.it, rafael.penaloza@unibz.it

Abstract. In recent years, there has been a growing interest in the application of foundational ontologies, i.e., formal ontological theories in the philosophical sense, to provide a theoretically sound foundation for improving the theory and practice of conceptual modeling and knowledge representation. This paper addresses one particular foundational theory of events termed UFO-B, which has been successfully employed as a reference model for addressing problems from complex media management, enterprise architecture, software engineering, and modeling of events in petroleum exploration. Despite its success, there is still no formalization of UFO-B in a decidable knowledge representation language that could support reasoning about complex events and event relations. We address this gap by proposing a number of alternative translations from UFO-B's original axiomatization (in first-order logic and in the Alloy formal language) to the description logic $SR\mathcal{O}IQ$, which is the formal underpinning of OWL 2 DL. Additionally, to support practical applications, we translated these $SR\mathcal{O}IQ$ theories to OWL 2 DL TBoxes, which were validated by showing that all the intended models of UFO-B (the logical models of the UFO-B specification in Alloy) that we generated are consistent with these UFO-B TBoxes. In a sense, the specification in Alloy *implements* the specification in first-order logic, while the OWL 2 TBoxes implement the $SR\mathcal{O}IQ$ specifications. Incidentally, the methodology that we designed for the translation from UFO-B's original axiomatization in FOL and Alloy to $SR\mathcal{O}IQ$ came to be a key contribution of this work by providing us evidence of the inadequacy of DLs for the specification of comprehensive foundational ontologies.

Keywords: Ontology of Events, Description Logics, $SR\mathcal{O}IQ$, OWL, SAT

Home > Synthese > Article

Processes as variable embodiments

Original Research | Open access | Published: 20 March 2024

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Synthese

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[Nicola Guarino](#) & [Giancarlo Guizzardi](#)

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Abstract

In a number of papers, Kit Fine introduced a theory of embodiment which distinguishes between rigid and variable embodiments, and has been successfully applied to clarify the ontological nature of entities whose parts may or may not vary in time. In particular, he has applied this theory to describe a process such as the erosion of a cliff, which would be a variable embodiment whose manifestations are the different states of erosion of the cliff. We find this theory very powerful, and especially appropriate to capture the intuition that the same process may go on at different times. However, its formal principles have been subject to some criticisms, mainly concerning the mereological structure of a variable embodiment. Moreover, since the notion of variable embodiment is very general, simply saying that processes are variable embodiments is not enough to understand their ontological nature. To address these concerns, in this paper we proceed in two phases: first, we propose a revised version of Fine’s original theory adapted to the case of processes, which adopts a classical mereology instead of Fine’s hylomorphic mereology, and a temporalized constitution relation in place of Fine’s function of variable embodiment; second, we go deeper into the ontological nature of processes by revisiting the notions of homogeneity, intentionality, and telicity discussed in the literature, and propose an account based on ontological principles and not on semantic properties of predicates. This allows us to organize processes into a novel taxonomy based exclusively on their unity and individuation principles.

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Sections Figures References

- [Abstract](#)
- [Introduction](#)
- [The distinction between processes and events](#)
- [The relationship between processes and events](#)
- [Basic distinctions within processes](#)
- [Basic kinds of process](#)
- [Conclusions](#)
- [Notes](#)
- [References](#)
- [Acknowledgements](#)
- [Funding](#)
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UFO-A (Endurants)

UFO-B (Events)

FOL-RU, Sortal
Modal Logic,
Alloy*, SROIQ*,
TPTP

Alloy, SROIQ

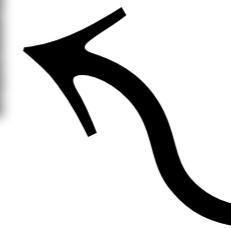


UFO-A (Endurants)

UFO-B (Events)

Formalization

**Event Mereology, Processual Roles,
Event Predication, Temporal
Ordering, Causation, Situations,
Events and Dispositions**



UFO-A (Endurants)

UFO-B (Events)

UFO-C (Social Reality)

UFO-A (Endurants)

UFO-B (Events)

**UFO-S
(Services)**

**UFO-L
(Legal Relations)**

UFO-C (Social Reality)

UFO-A (Endurants)

UFO-B (Events)

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COVR

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**UFO-S
(Services)**

**UFO-L
(Legal Relations)**

UFO-C (Social Reality)

UFO-A (Endurants)

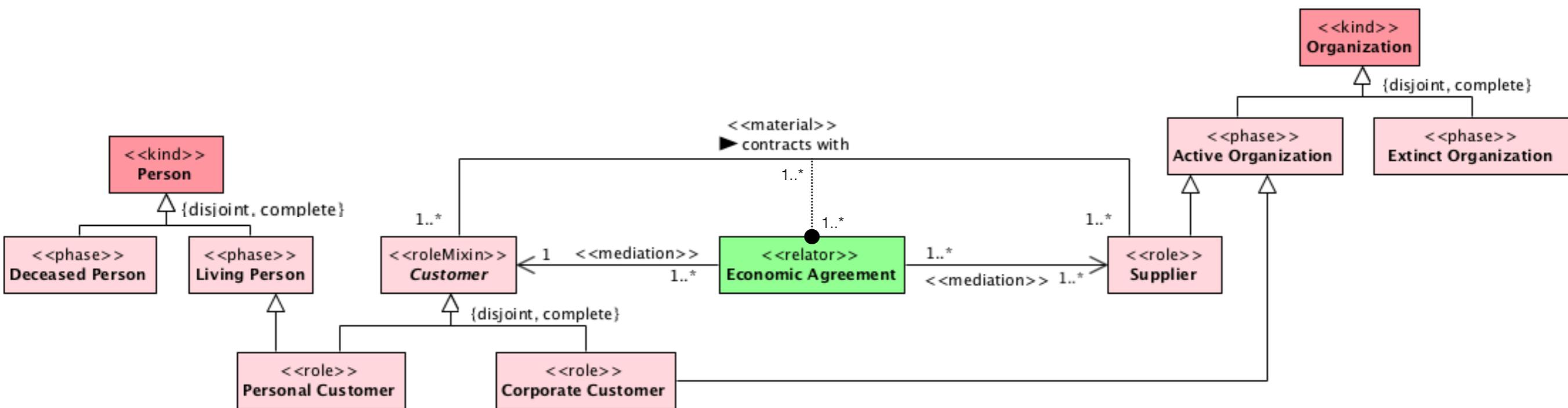
UFO-B (Events)



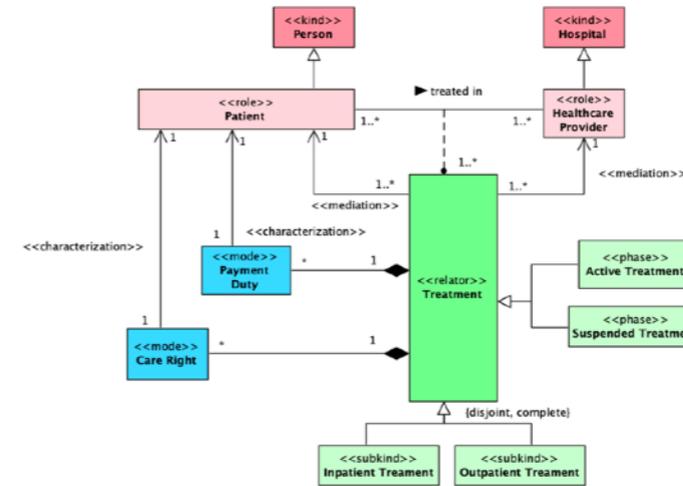
Unified Foundational
Ontology



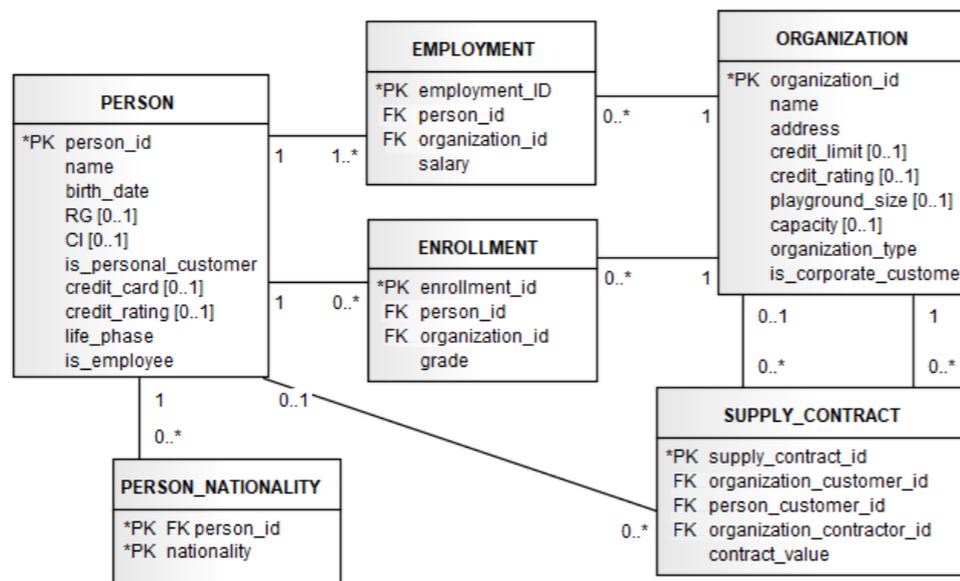
1. **Primitives** reflecting ontological **distinctions**
2. **Grammar** reflecting ontological **axiomatization**
3. **Patterns** reflecting ontological **micro-theories**

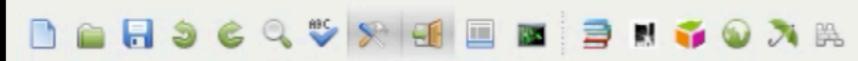


Ontological



Design + Implementation

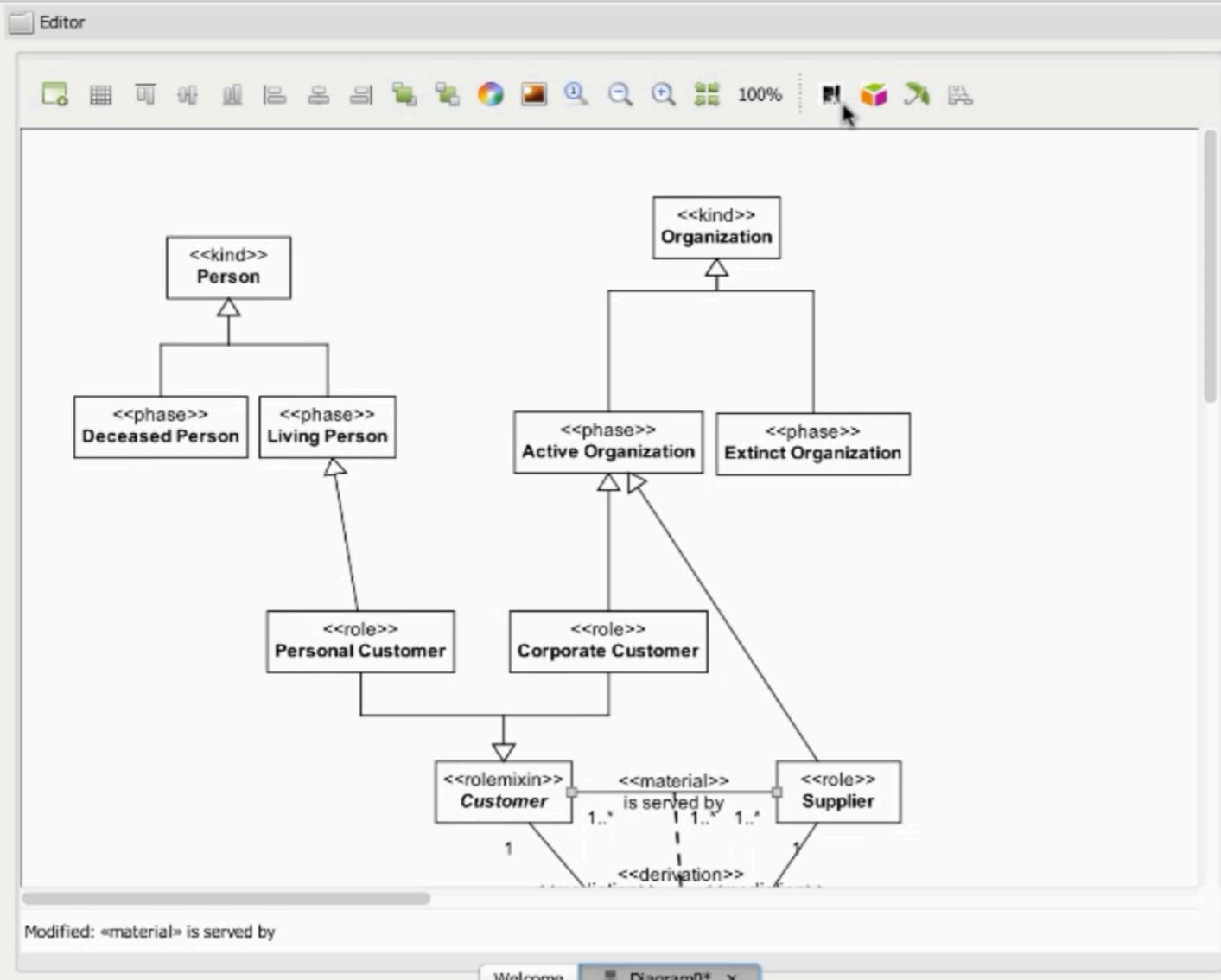




Toolbox

- Elements
- Patterns**
 - Pointer
 - Principle of Identity
 - Relator
 - RoleMixin

Derived Patterns



Project Browser

- OLED Project
 - Diagrams
 - Constraints
 - Model
 - «Phase» Living Person
 - Generalization Person
 - «Phase» Deceased Person
 - Generalization Person
 - «Kind» Person
 - GeneralizationSet partition1 { Dece
 - «Phase» Extinct Organization
 - Generalization Organization
 - «Phase» Active Organization
 - Generalization Organization
 - «Kind» Organization
 - GeneralizationSet partition2 { Activ
 - «RoleMixin» Customer
 - «Relator» Service Contract
 - «Role» Supplier
 - Generalization Active Organizat
 - «Role» Corporate Customer
 - Generalization Active Organizat
 - Generalization Customer
 - «Role» Personal Customer
 - Generalization Living Person
 - Generalization Customer
 - «Material» is served by
 - «Mediation»
 - «Mediation»
 - «Derivation»
 - GeneralizationSet roleMixinGS3 { Pe



criminalInvestigation (http://www.semanticweb.org/ontologies/2014/10/criminalInvestigation.owl) : [C:\Users\Fredd_000\Desktop\criminalInvestigation.owl]

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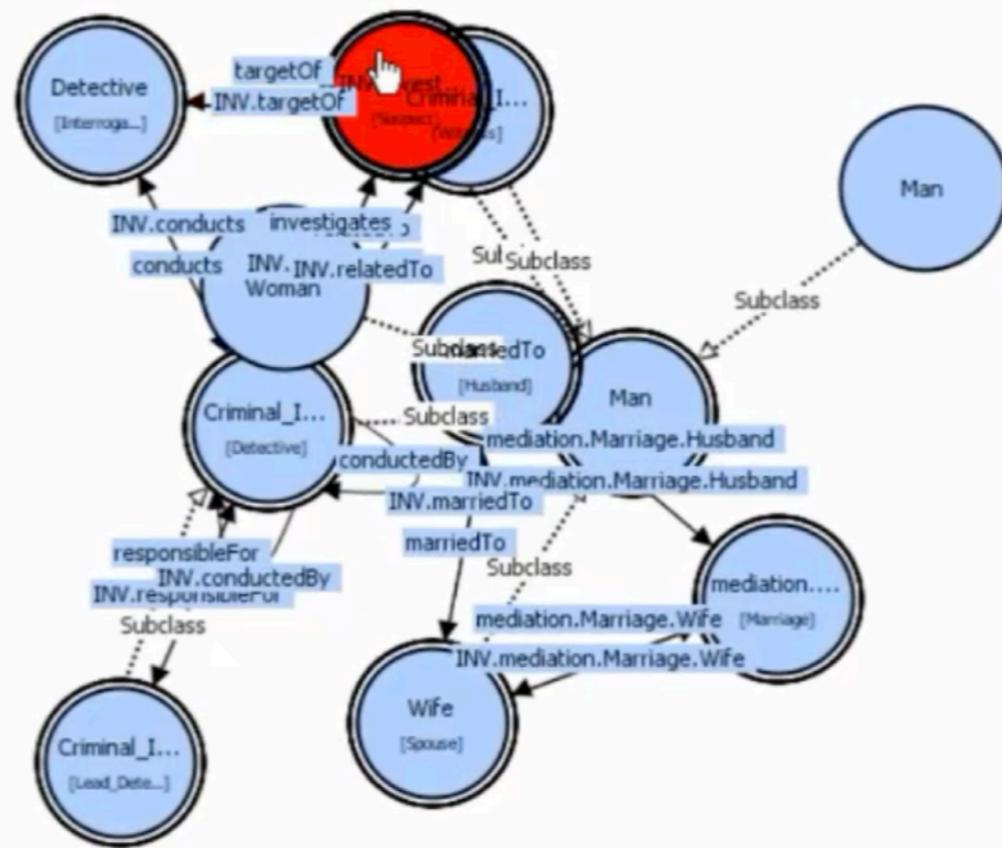
criminalInvestigation (http://www.semanticweb.org/ontologies/2014/10/criminalInvestigation.owl) Search for entity

Active Ontology Entities Classes Object Properties Data Properties Annotation Properties Individuals OWLViz DL Query OntoGraf VOWL SPARQL Query Ontology Differences SWRL

Rules

```
Husband(?x), Marriage(?z), Wife(?y), mediation.Marriage.Husband(?z, ?x), mediation.Marriage.Wife(?z, ?y), DifferentFrom (?x, ?y), DifferentFrom (?x, ?z), DifferentFrom (?y, ?z) -> marriedTo(?x, ?y)
conductedBy(?Lead_Detective.investigation, ?Lead_Detective), conductedBy(?Lead_Detective2.investigation2, ?Lead_Detective2), SameAs (?Lead_Detective.investigation, ?Lead_Detective2.investigation2), DifferentFrom (?Lead_Detective, ?Lead_Detective2) ->
(not (Lead_Detective))(?Lead_Detective)
```

To use the reasoner click Reasoner->Start reasoner Show Inferences





Unified Foundational
Ontology

gUFO: A Lightweight Implementation of the Unified Foundational Ontology (UFO)

IRI

<http://purl.org/nemo/gufo#>

Creator(s)

Almeida, João Paulo A.
Falbo, Ricardo A.
Guizzardi, Giancarlo
Sales, Tiago P.

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Ontology Source

[RDF \(Turtle\)](#)

Description

The objective of gUFO is to provide a lightweight implementation of the Unified Foundational Ontology (UFO) [1-5] suitable for Semantic Web OWL 2 DL applications.

Intended users are those implementing UFO-based lightweight ontologies that reuse gUFO by specializing and instantiating its elements.

There are three implications of the use of the term lightweight. First of all, we have employed little expressive means in an effort to retain computational properties for the resulting OWL ontology. Second, we have selected a subset of UFO-A [1, 2] and UFO-B [3] to include here. In particular, there is minimalistic support for UFO-B (only that which is necessary to establish the participation of objects in events and to capture historical dependence between events). Third, a lightweight ontology, differently from a reference ontology, is designed with the purpose of providing an implementation artifact to structure a knowledge base (or knowledge graph). This has driven a number of pragmatic

2

Types and Taxonomic Structures







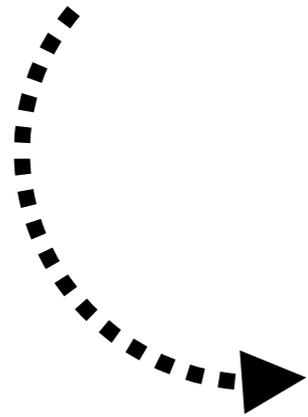




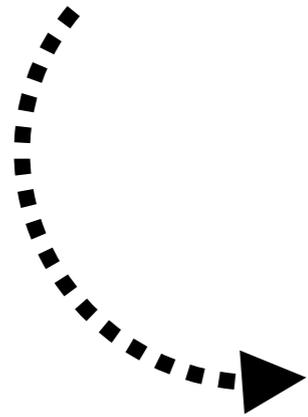


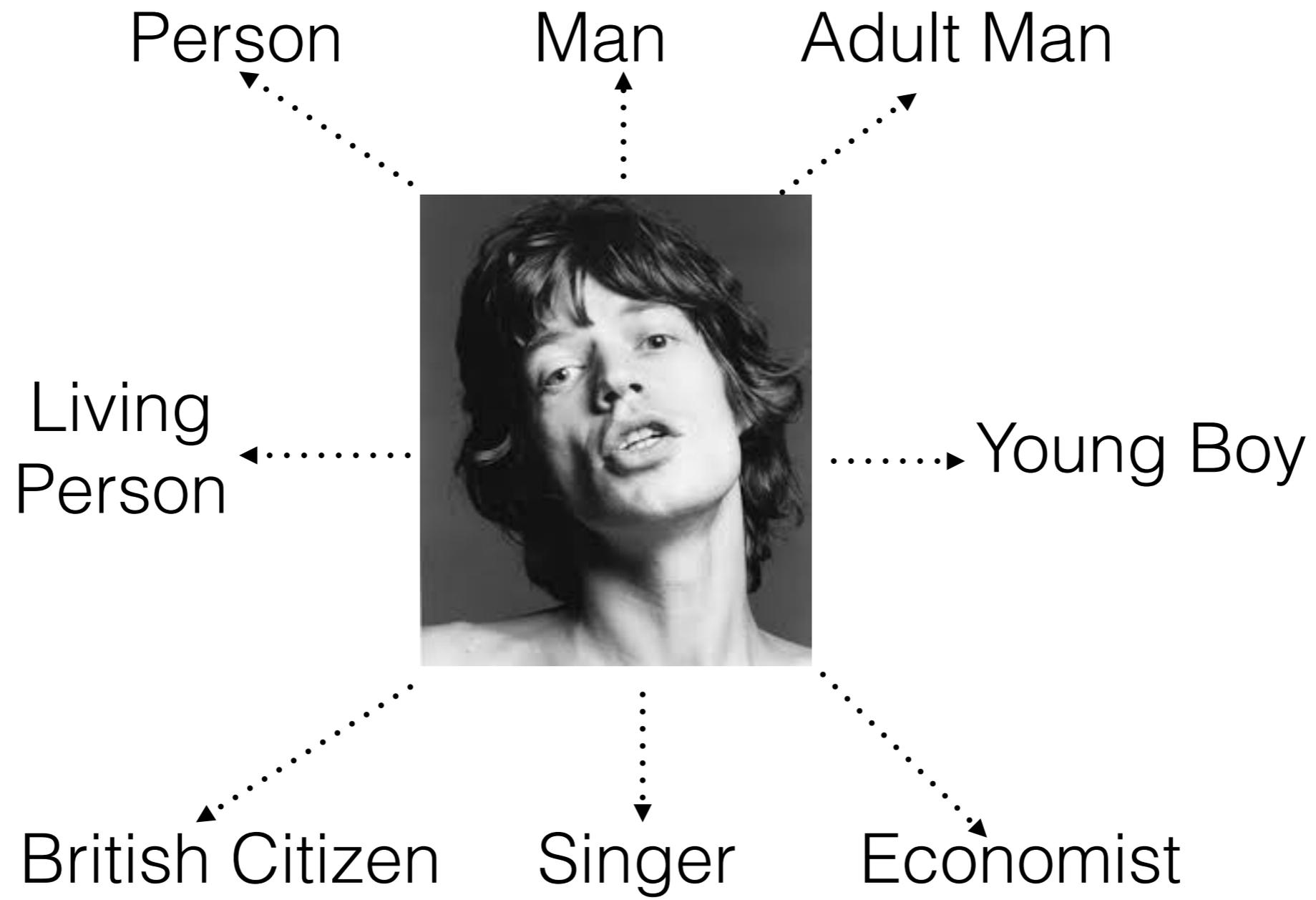


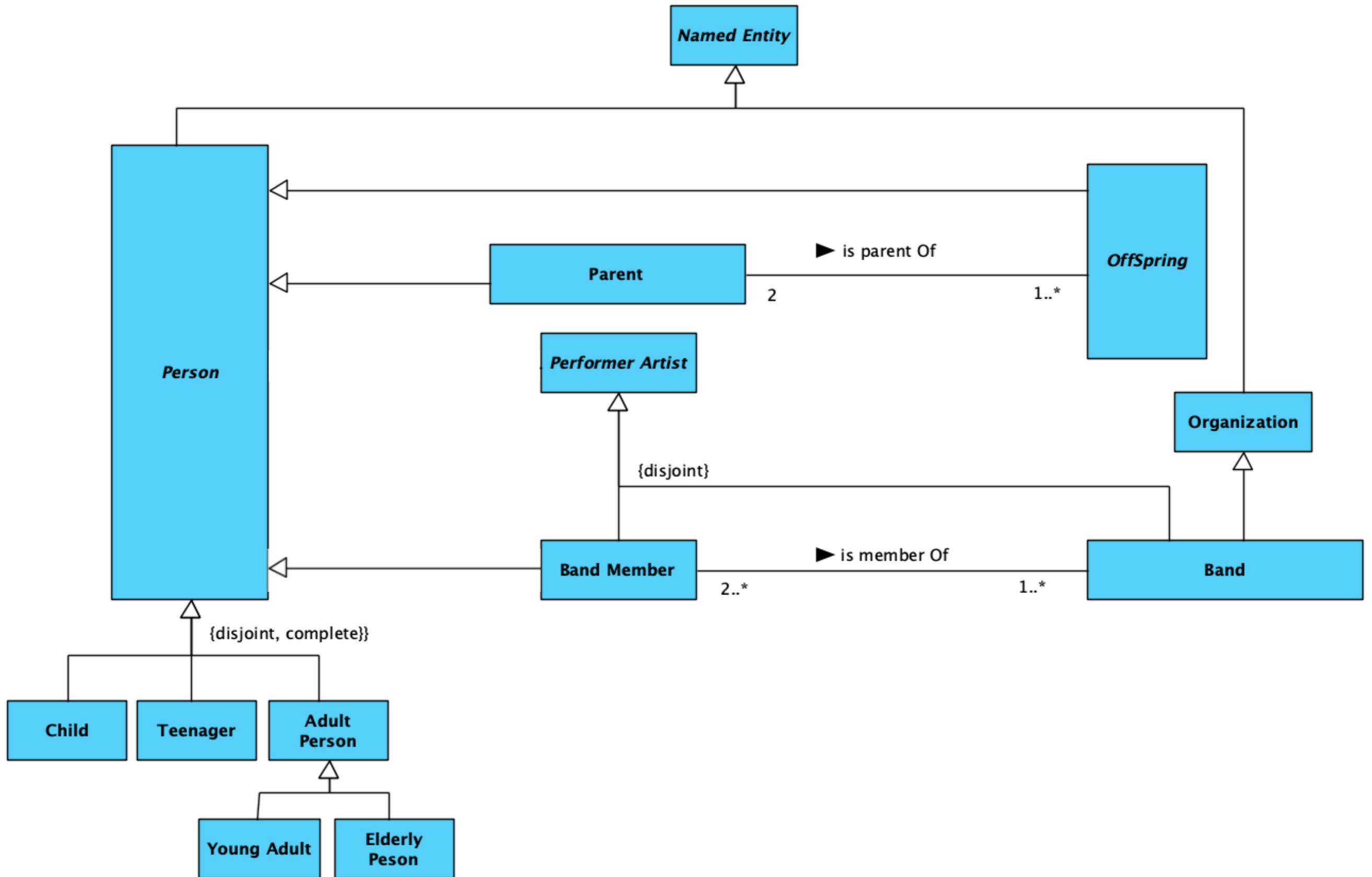


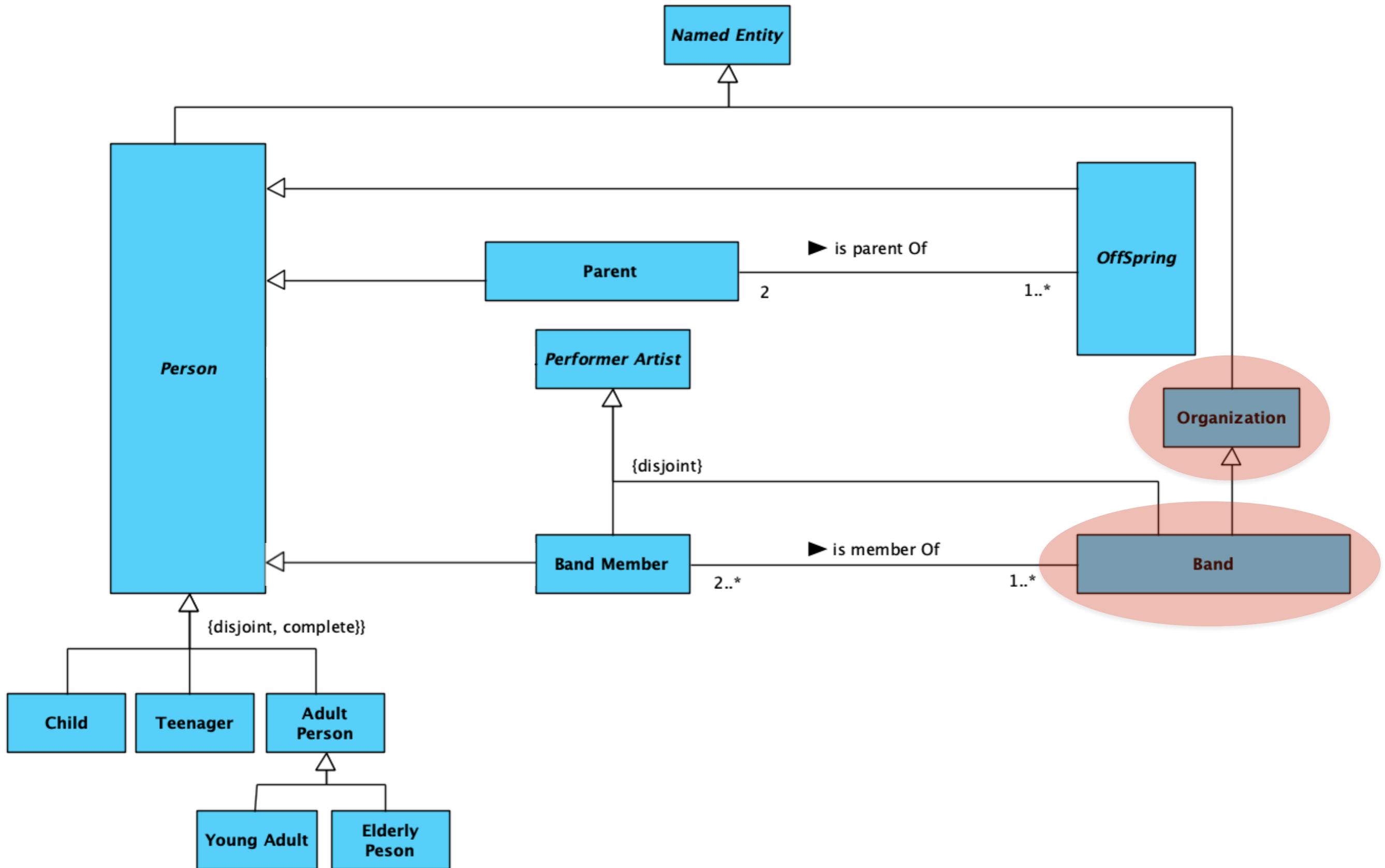


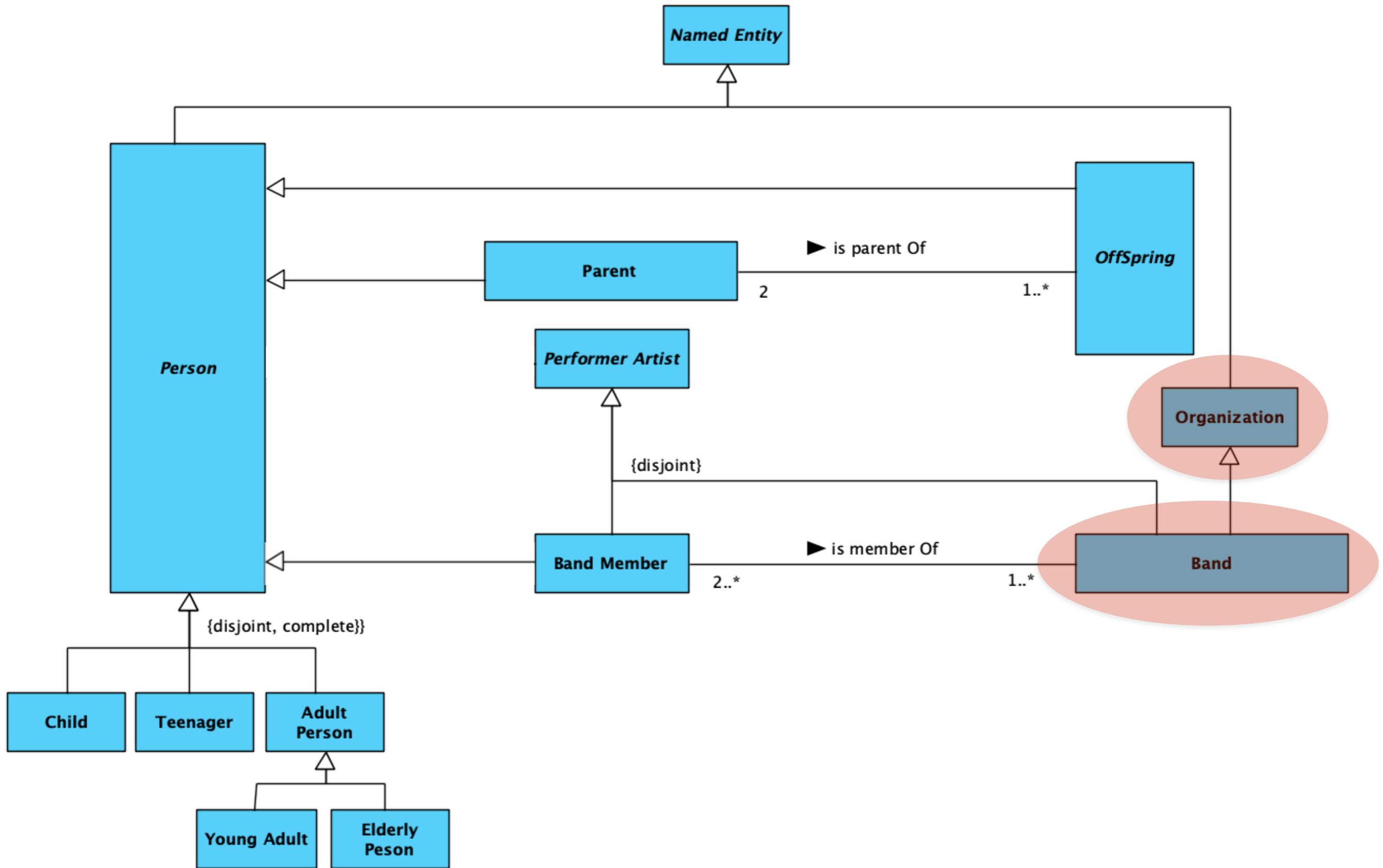


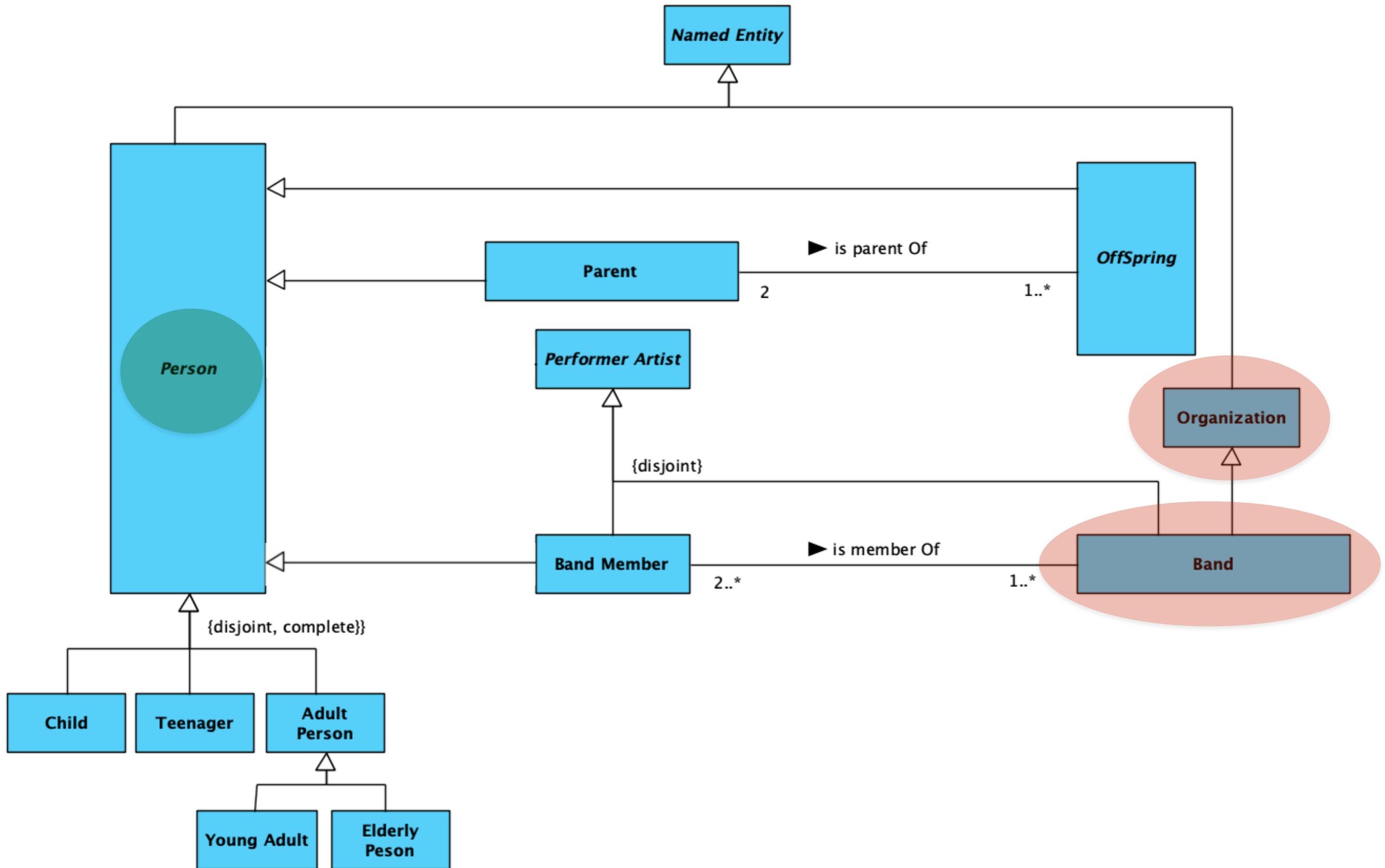


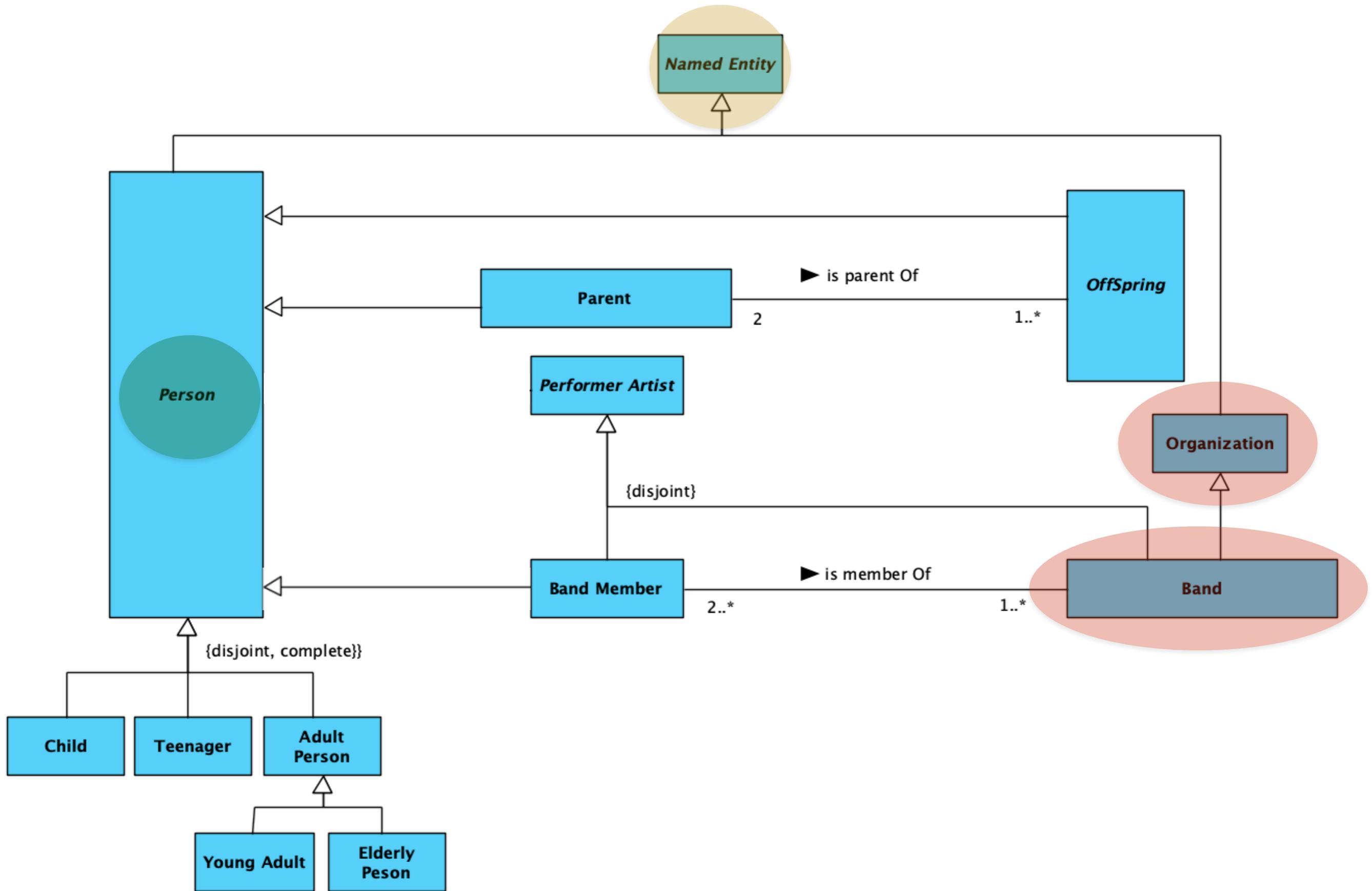


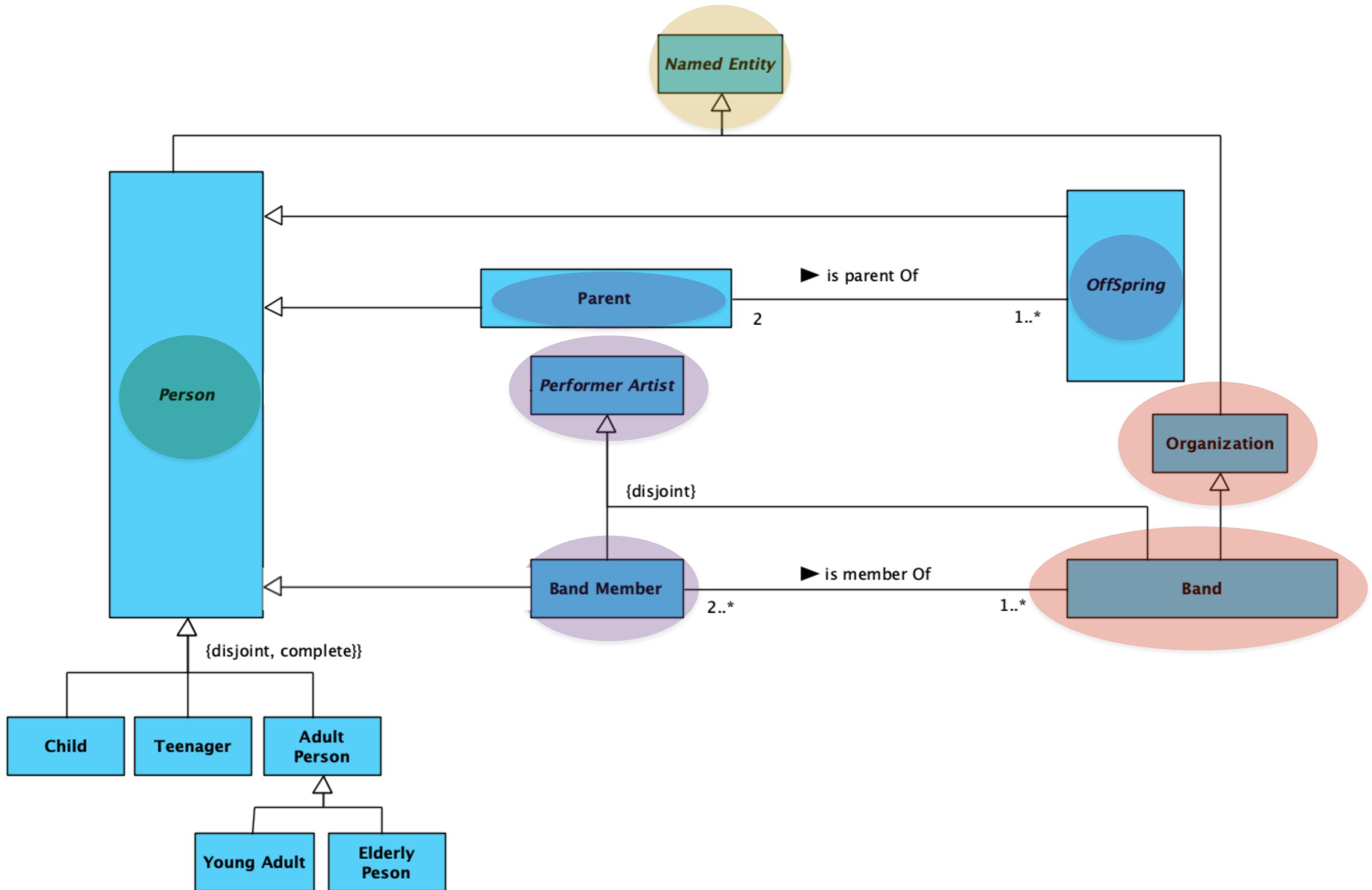


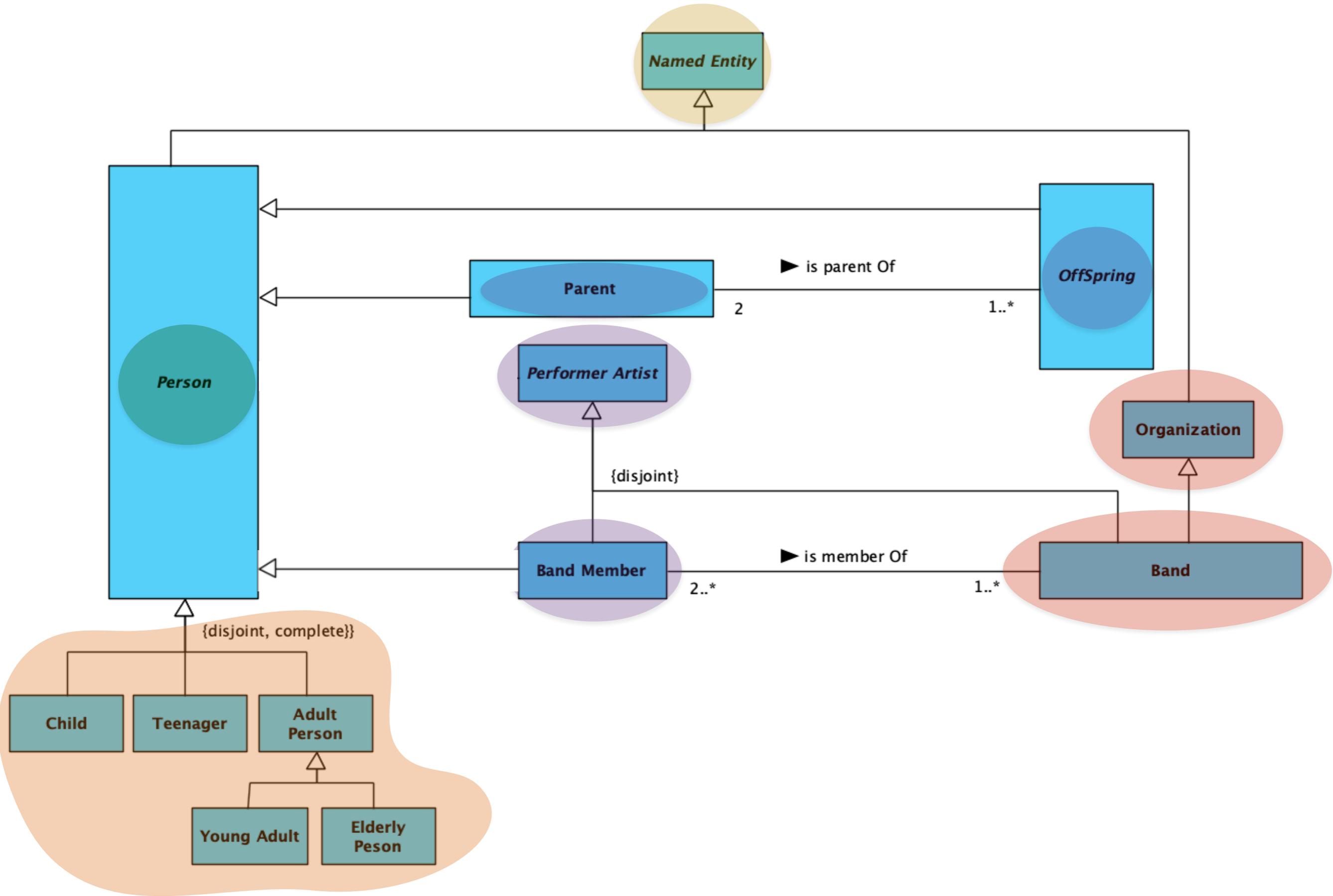






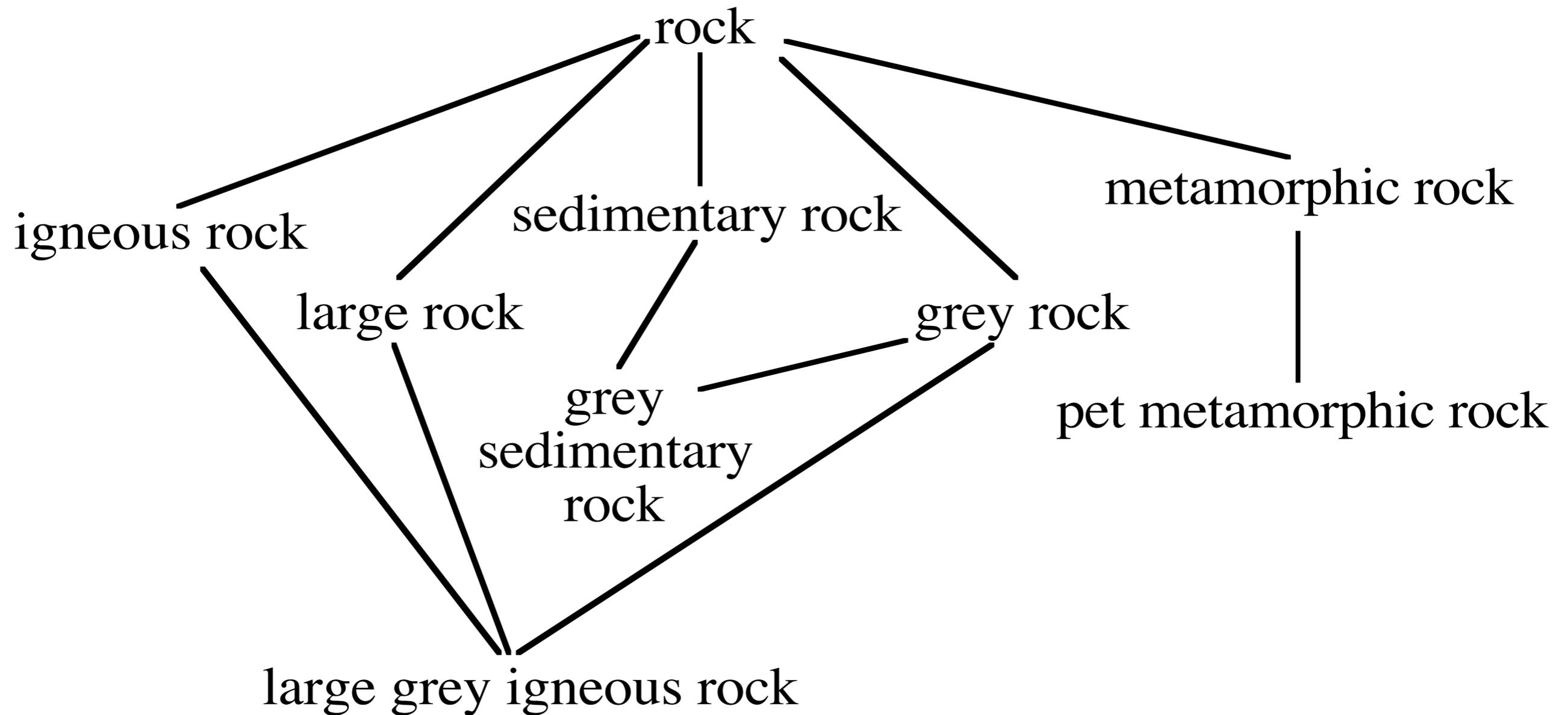






Categories of Object types

How many kinds of rock?



General Terms and Common Nouns

- (i) exactly five mice were in the kitchen last night
- (ii) the mouse which has eaten the cheese, has been in turn eaten by the cat

General Terms and Common Nouns

- (i) exactly five X ...
- (ii) the Y which is Z...

General Terms and Common Nouns

- (i) exactly five *reds* were in the kitchen last night
- (ii) the *red* which has ..., has been in turn ...

General Terms and Common Nouns

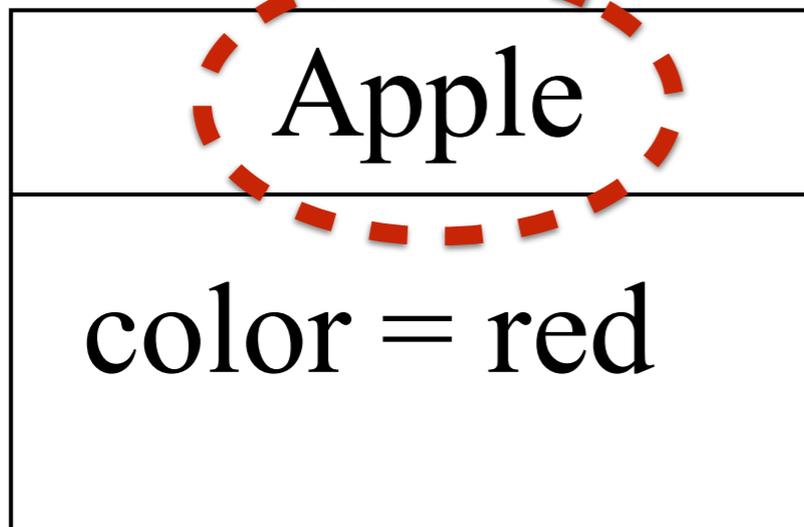
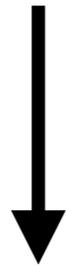
Both **reference** and **quantification** require that the thing (or things) which are referred to or which form the domain of quantification are **determinate individuals**, i.e. their conditions for **individuation** and **numerical identity** must be determinate

Sortal and Characterising Types (or Non-sortals)

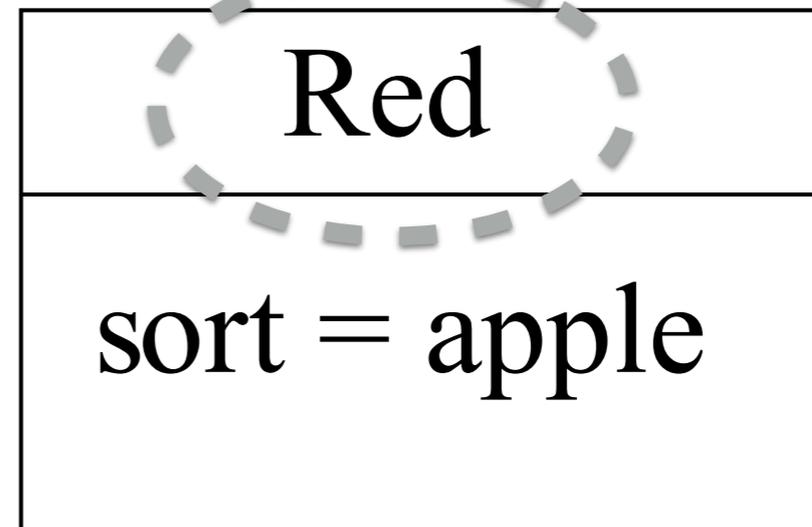
Whilst the **characterizing types** supply only a **principle of application** for the individuals they collect, **sortal types** supply both a principle of application and a **principle of identity**

The Ontological Level

SORTAL



NON-SORTAL



Foundations

- (1) We can only make identity and identification statements with the support of a Sortal, i.e., the identity of an individual can only be traced in connection with a Sortal type, which provides a principle of individuation and identity to the particulars it collects

Every Object in a conceptual model (CM) of the domain must be an instance of a class representing a sortal type

Foundations

Moreover, since Non-Sortals cannot supply a principle of identity for its instances, we have that, all Non-Sortal Types in the model must be represented as *Abstract Classes*

Unique principle of Identity



X



Y

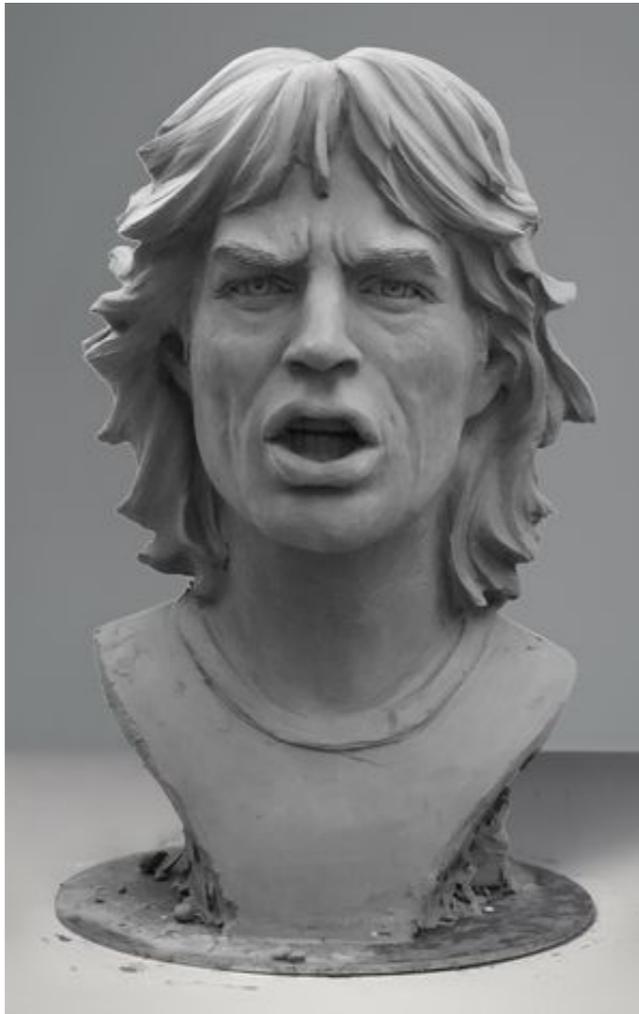
Unique principle of Identity



$X = Y ?$



Unique principle of Identity

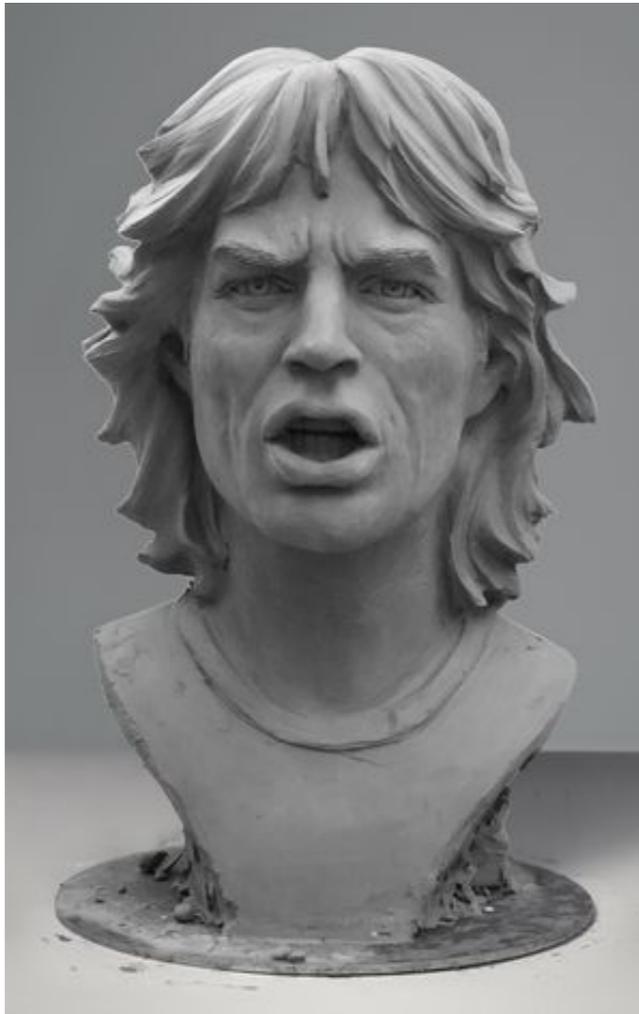


X



Y

Unique principle of Identity



$X = Y ?$



Software?

Software?

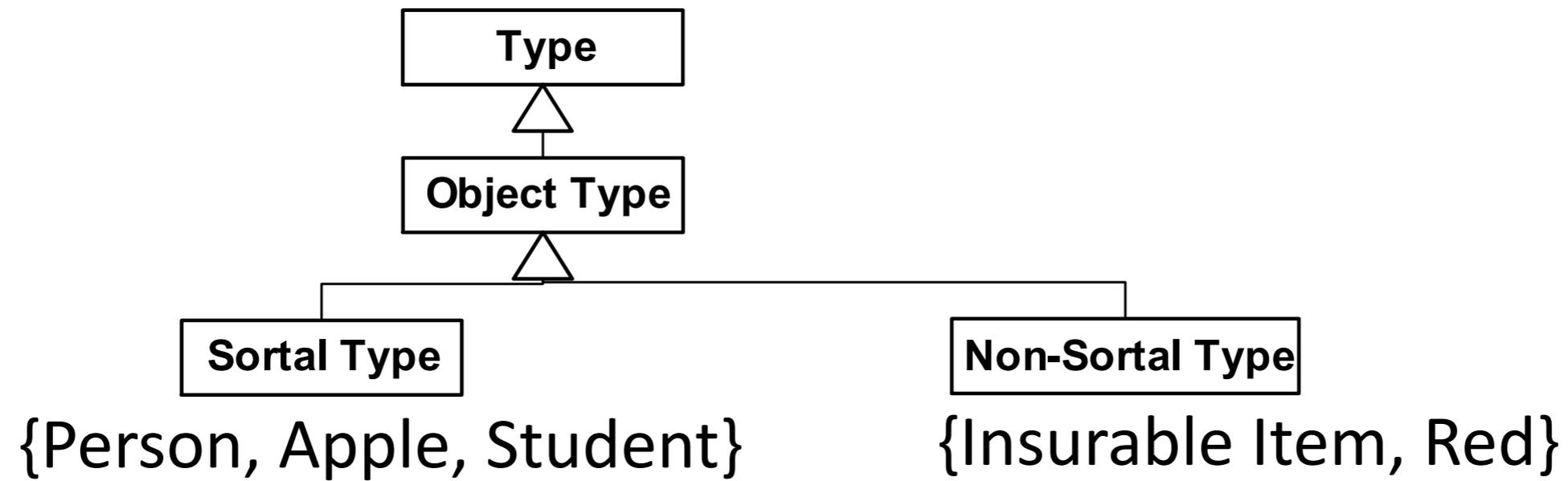
- Software Code?
- Software Program?
- Software System?
- Software Product?

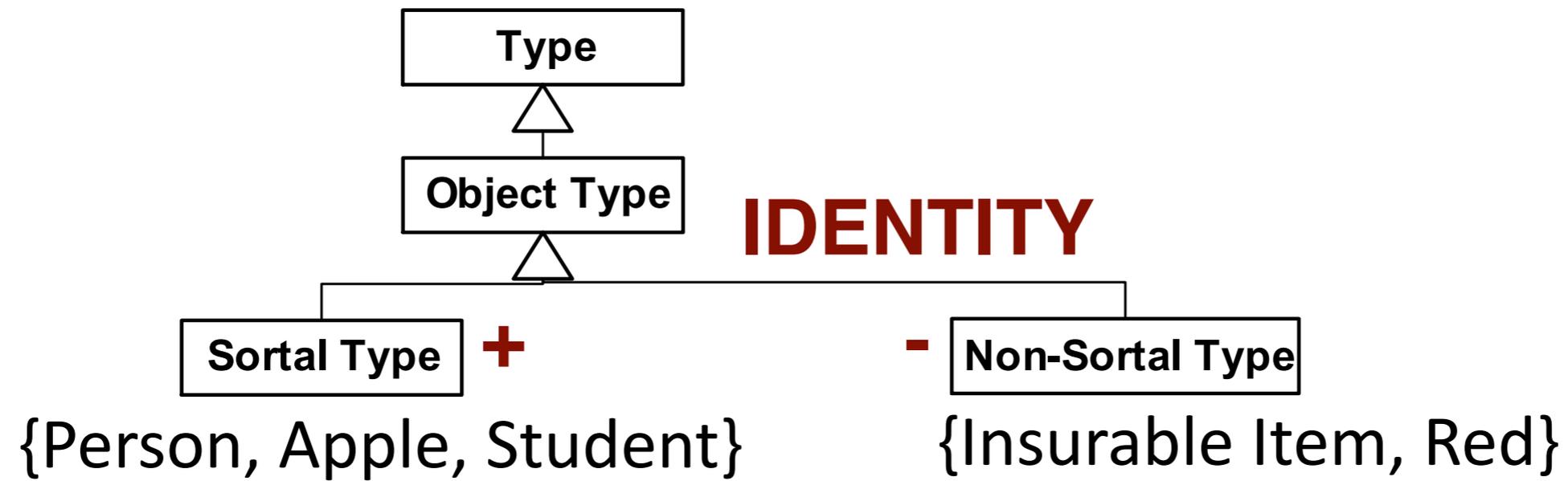
Software?

- Software Code? **IDENTITY = SYNTACTICAL FORM**
- Software Program? **IDENTITY = EXECUTION CLASS**
- Software System? **IDENTITY = REQUIREMENTS**
- Software Product? **IDENTITY = PRODUCT AGREEMENT**

Foundations

- (2) An individual cannot obey incompatible principles of identity





Rigidity

A type T is rigid if for every instance x of T , x is **necessarily** an instance of T :

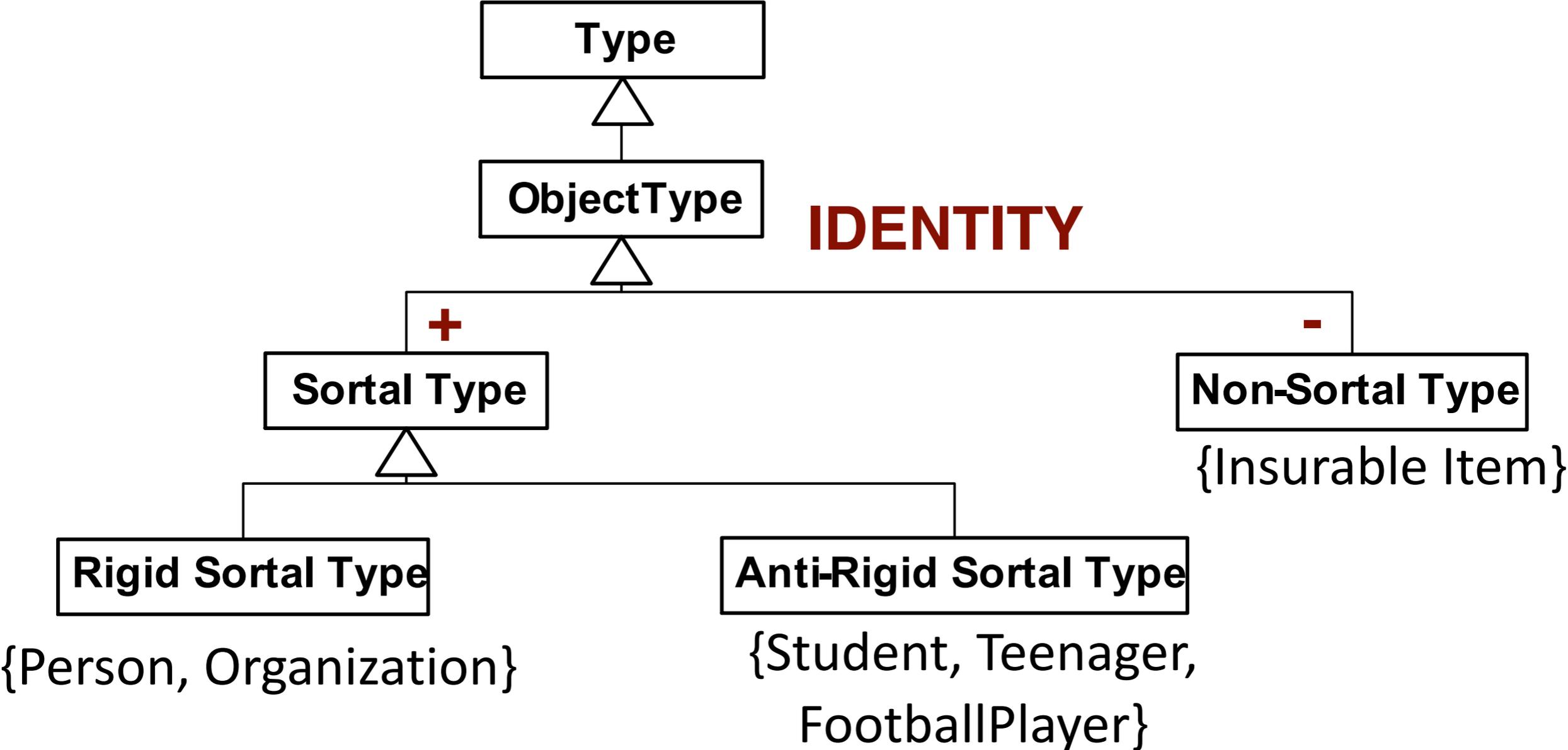
$$\forall x . T(x) \rightarrow \Box T(x)$$

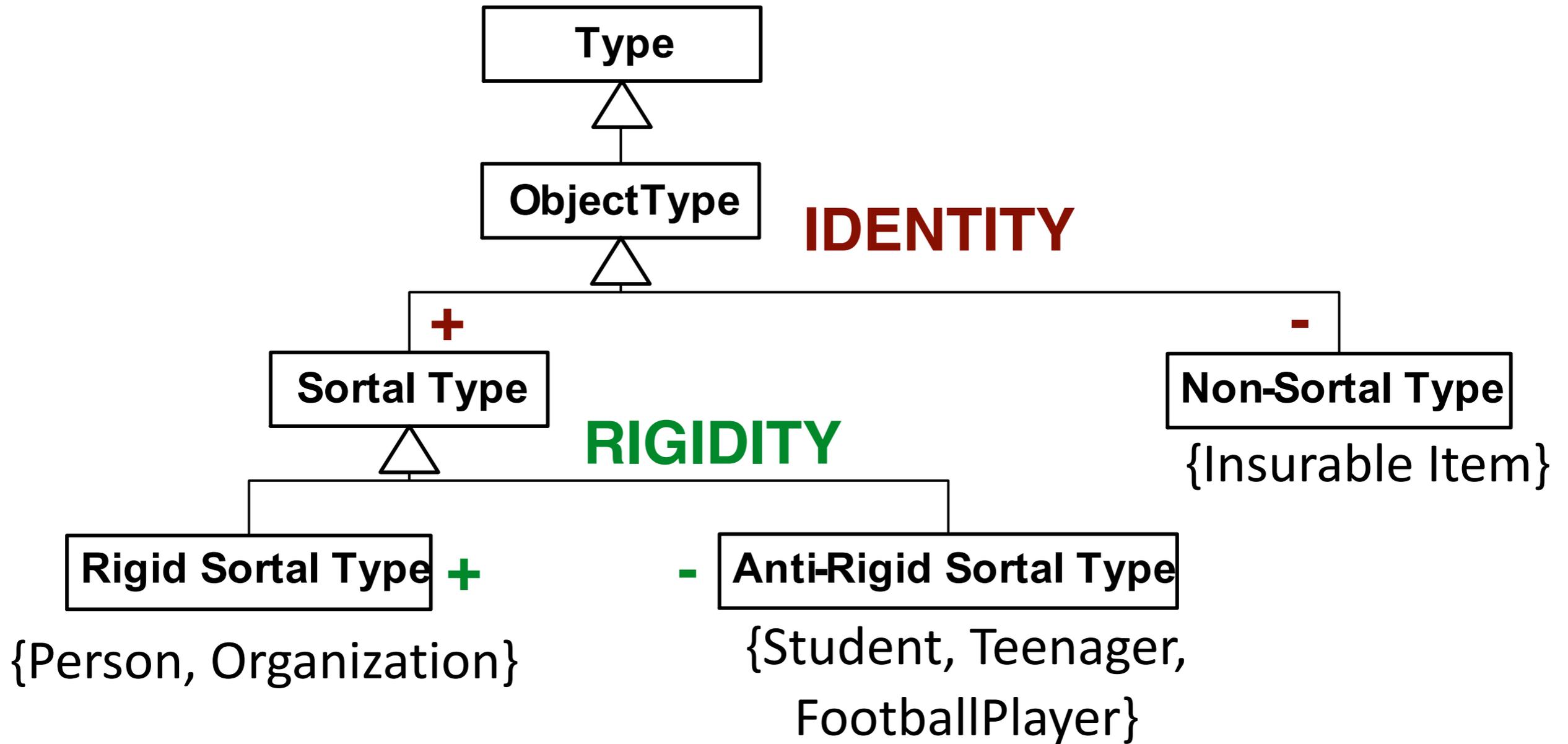
Anti-Rigidity

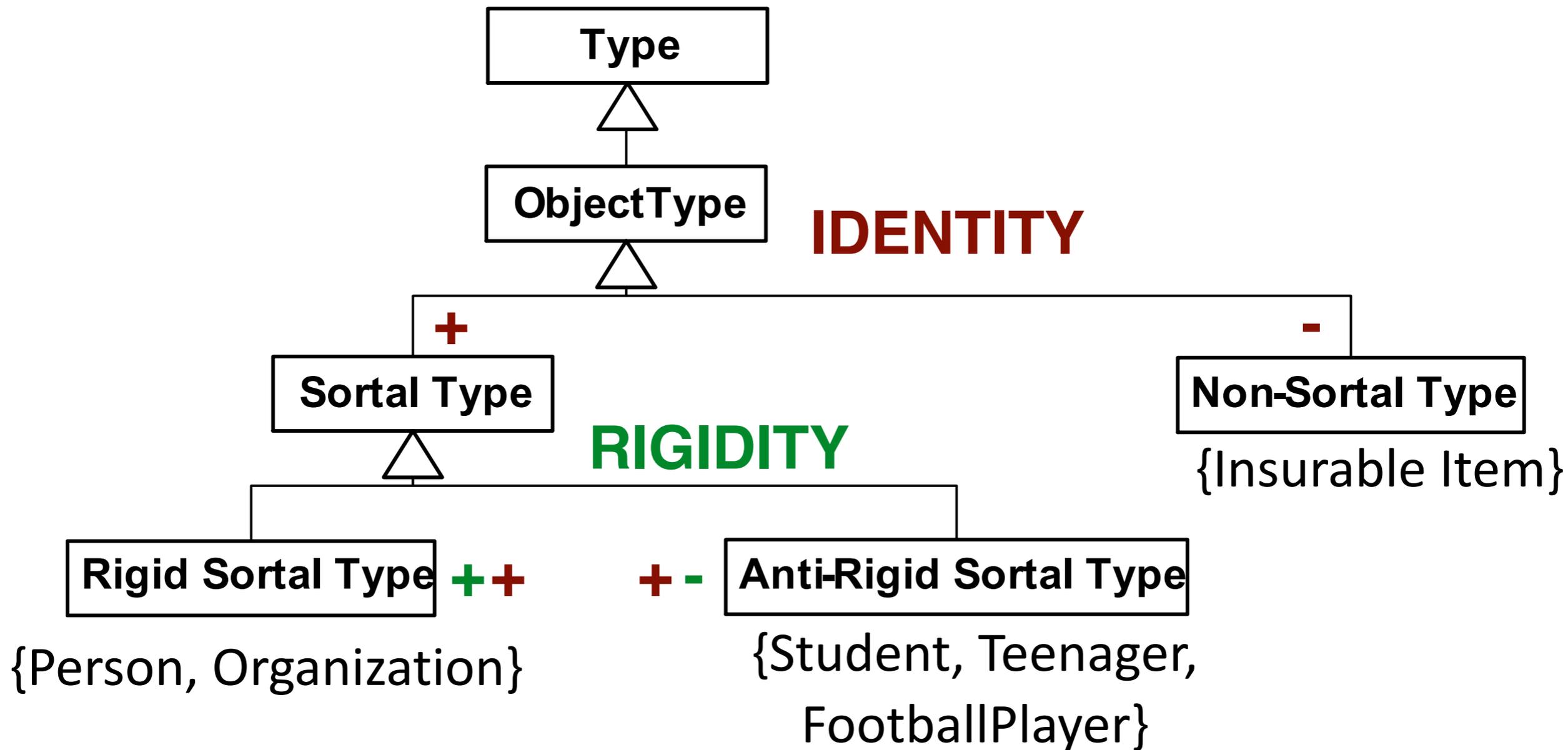
A type T is anti-rigid if for every instance x of T , x is **possibly** not an instance of T :

$$\forall x . T(x) \rightarrow \Diamond \neg T(x)$$

IDENTITY









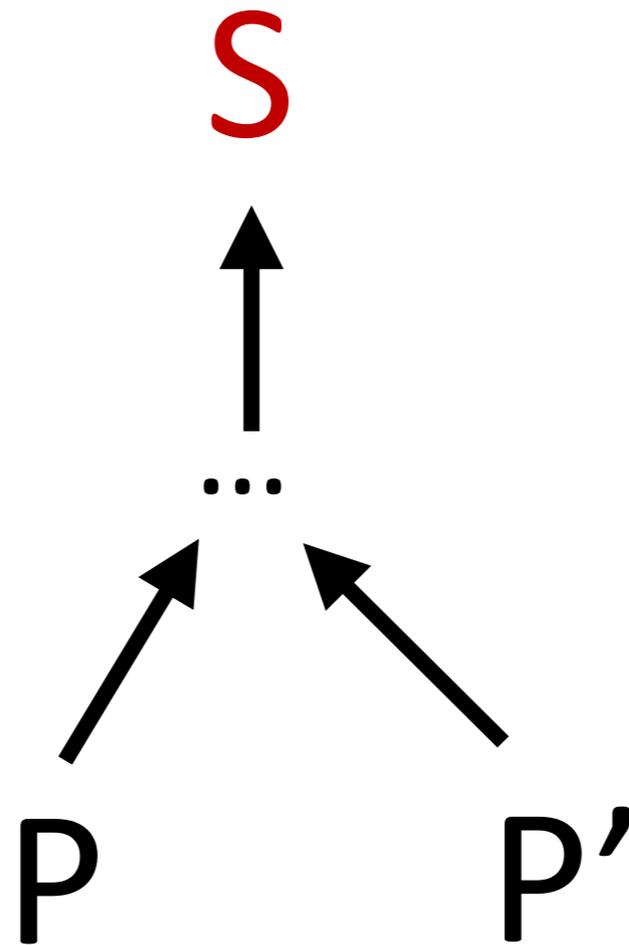


A principle of identity cannot be supplied by either of these two anti-rigid types, since it should be used to identify individuals in every possible situations!

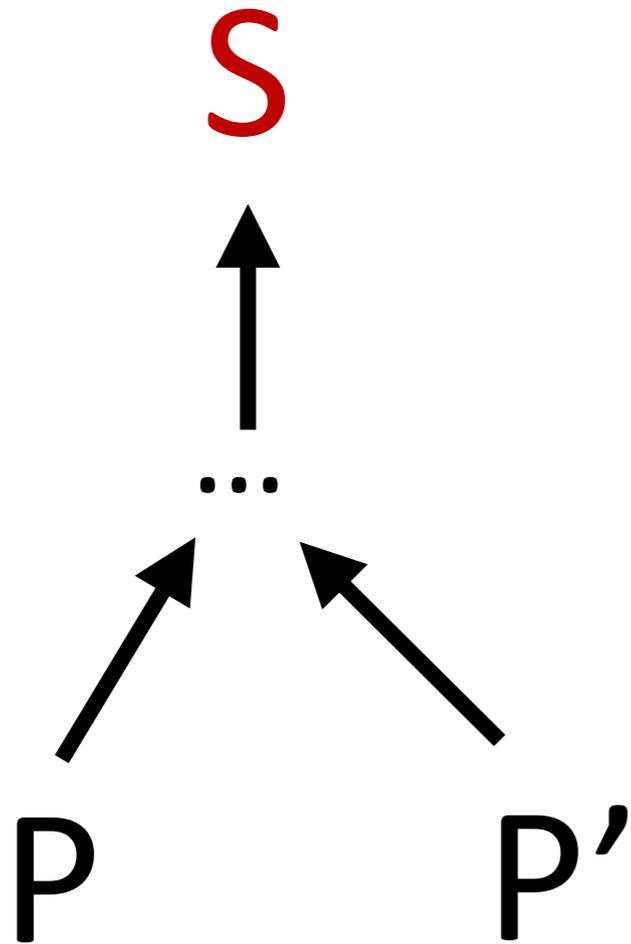


Foundations

If an individual falls under two sortals in the course of its history there must be exactly one **ultimate rigid sortal** of which both sortals are subtypes and from which **they inherit a principle of identity**

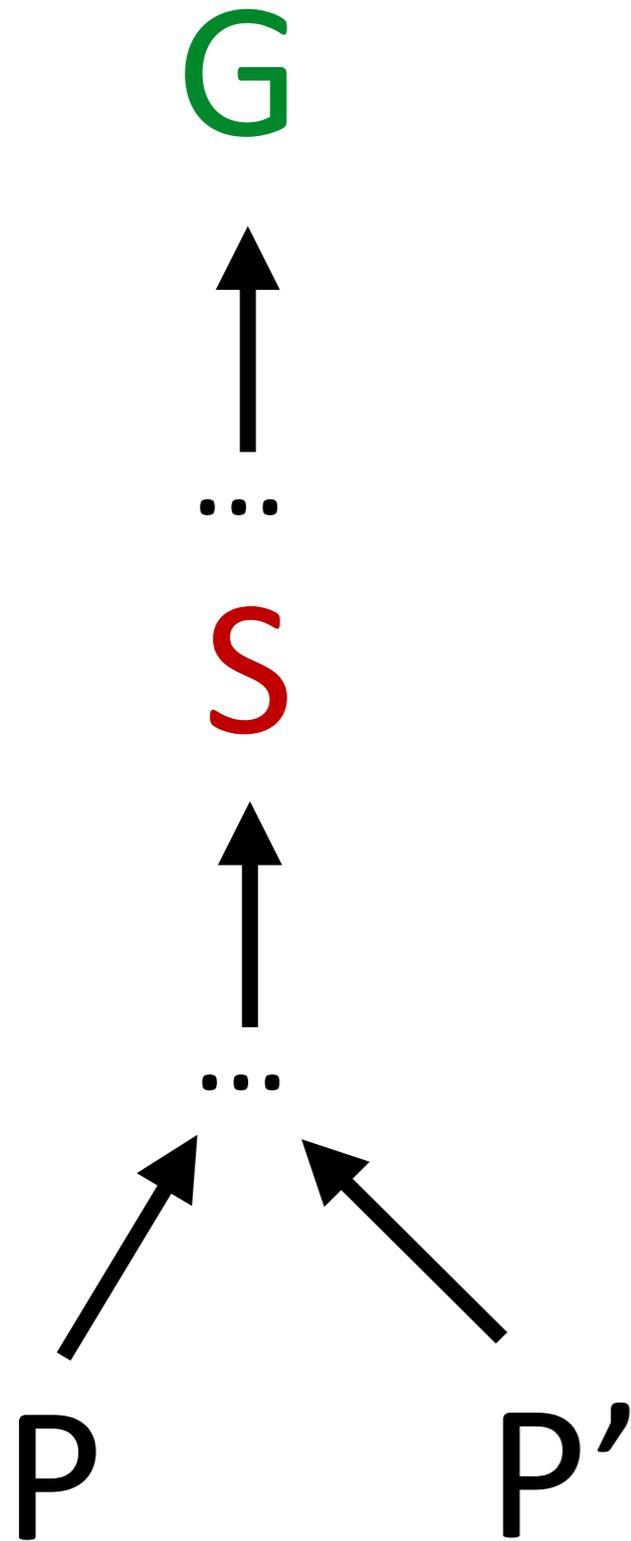


Restriction Principle

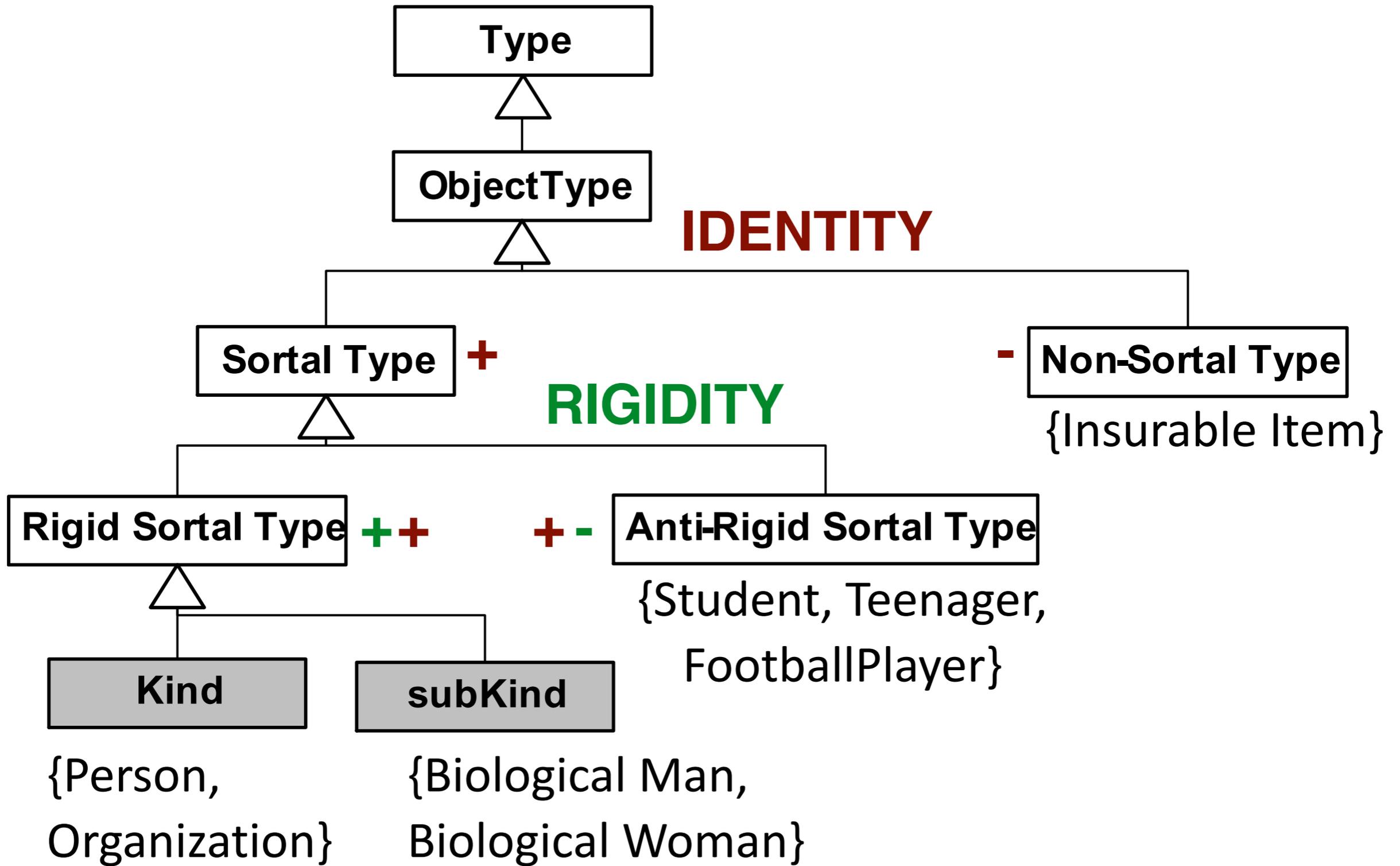


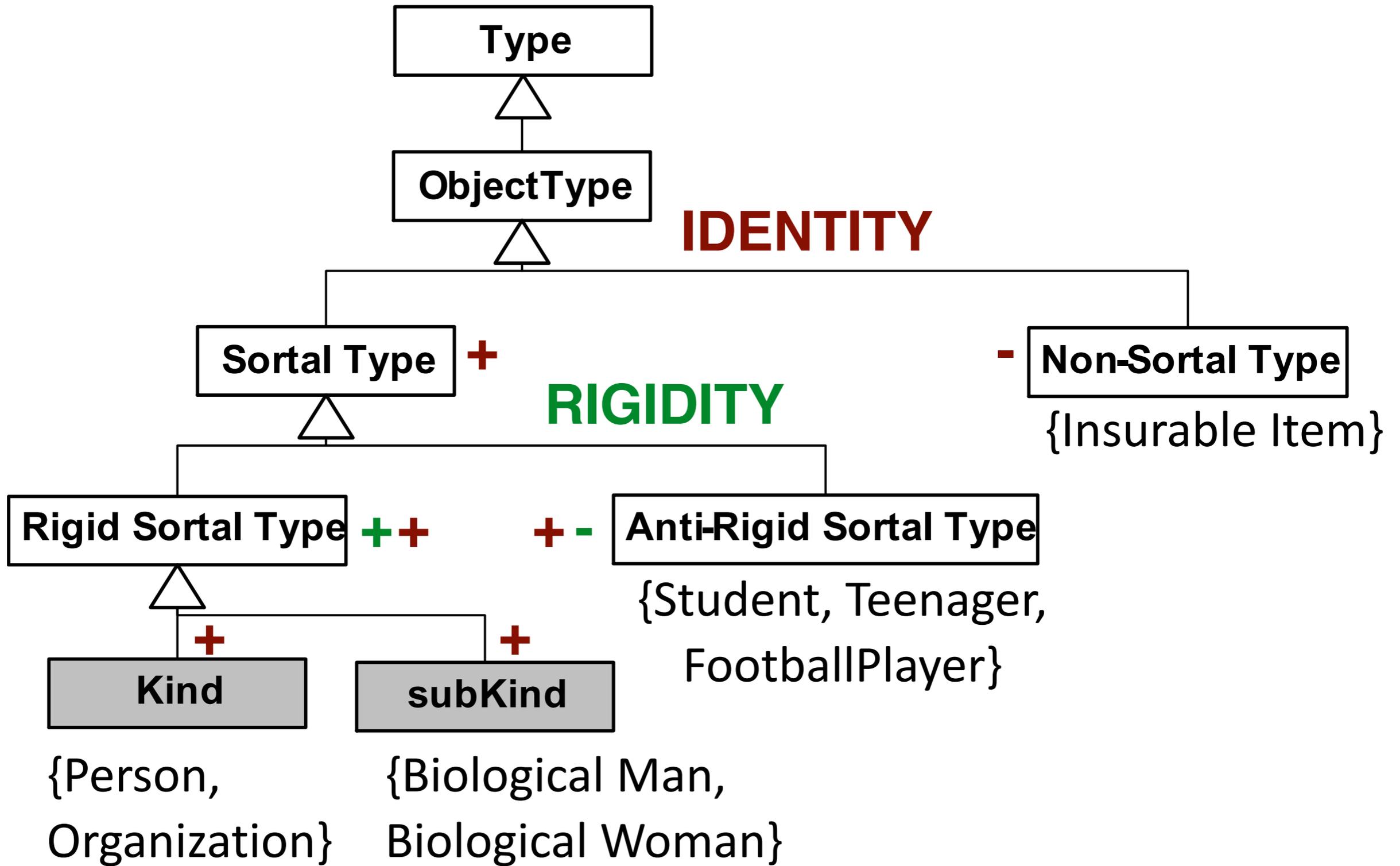
- Instances of P and P' must:
 - obey a principle of identity
 - the same principle of identity
 - which they cannot supply themselves

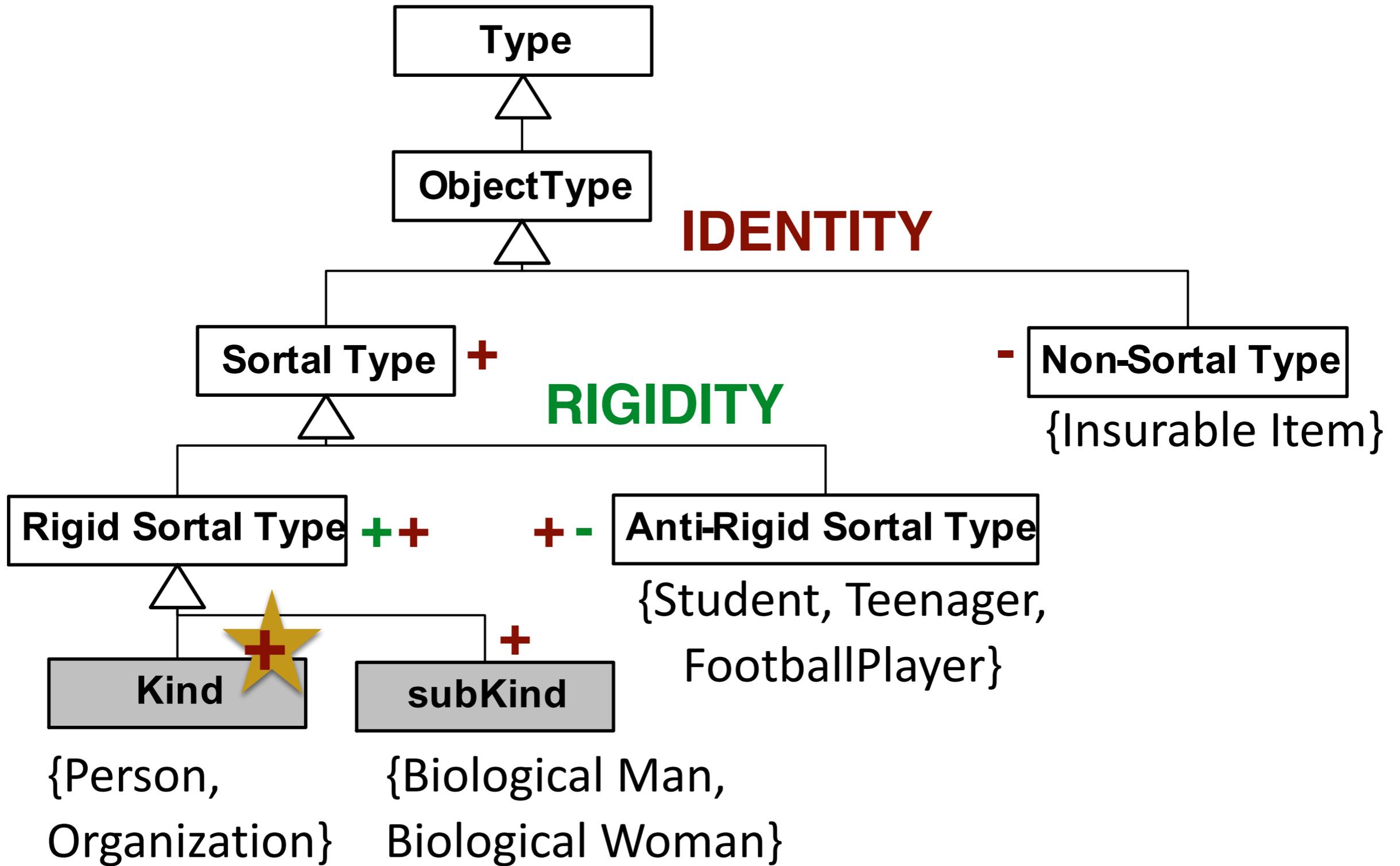
Uniqueness Principle



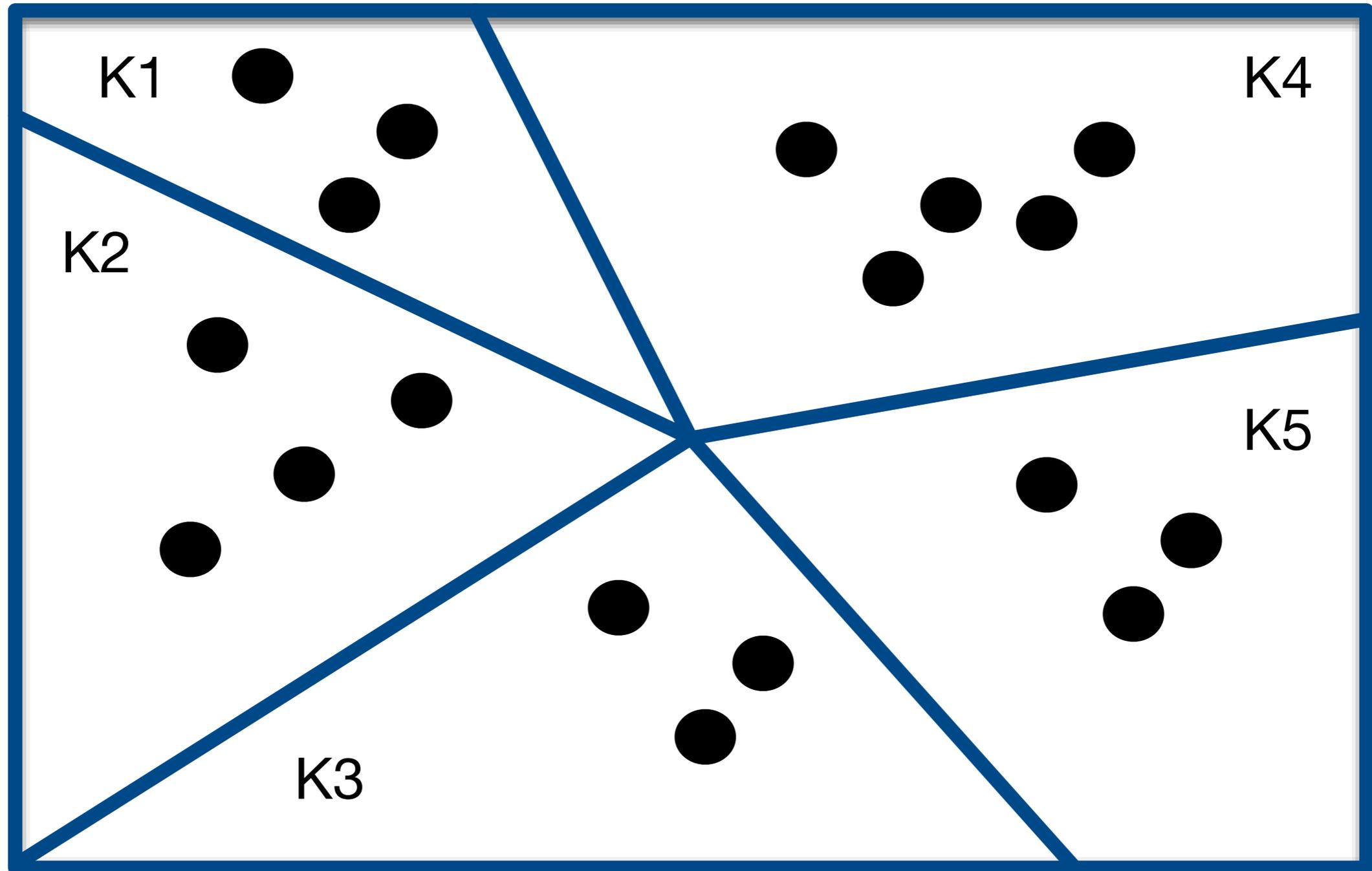
- Suppose S is not ultimate then for any G that supertypes S:
 - G cannot provide a another principle
 - Either G is a Non-Sortal
 - Or G is the **ultimate sortal**



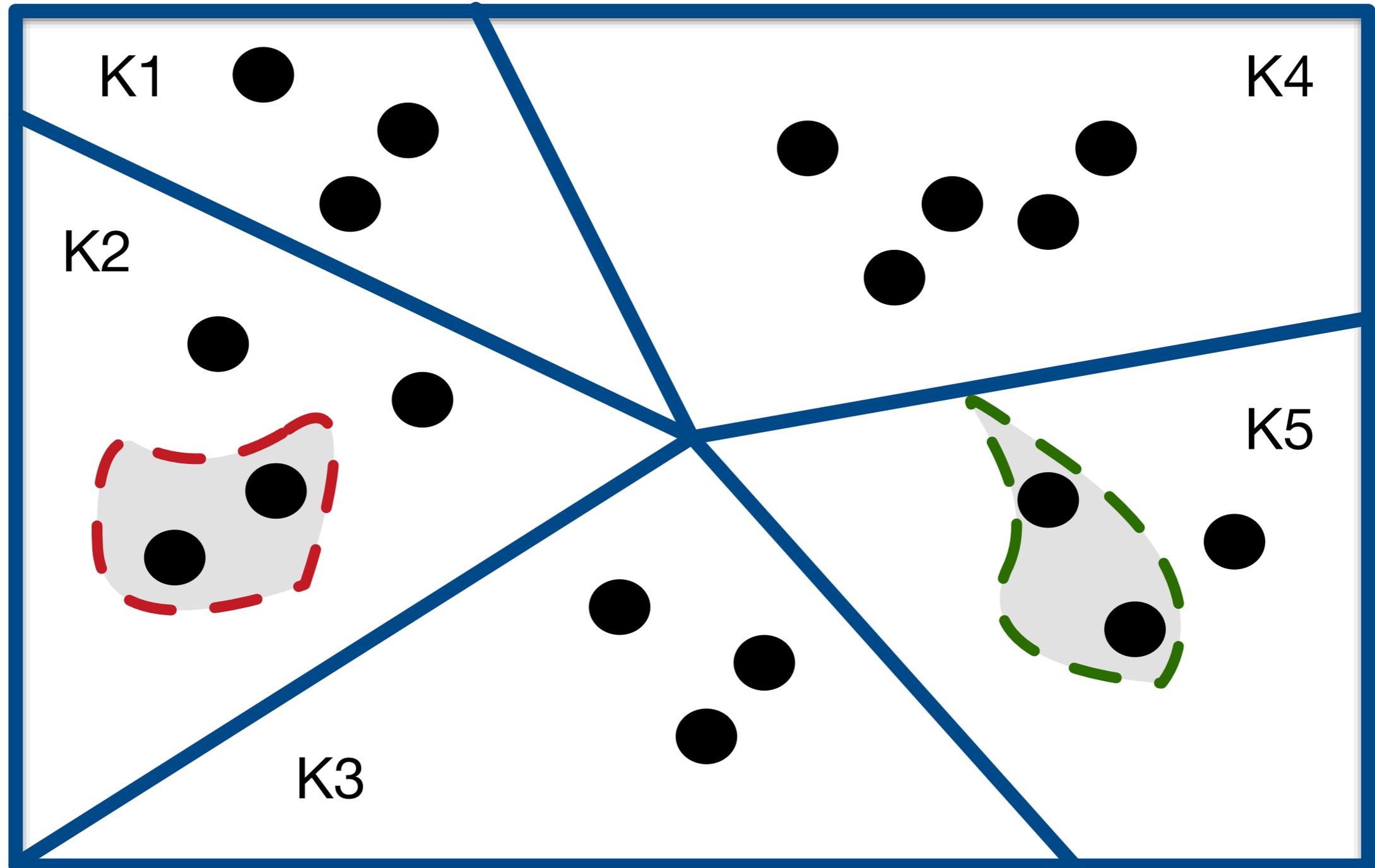




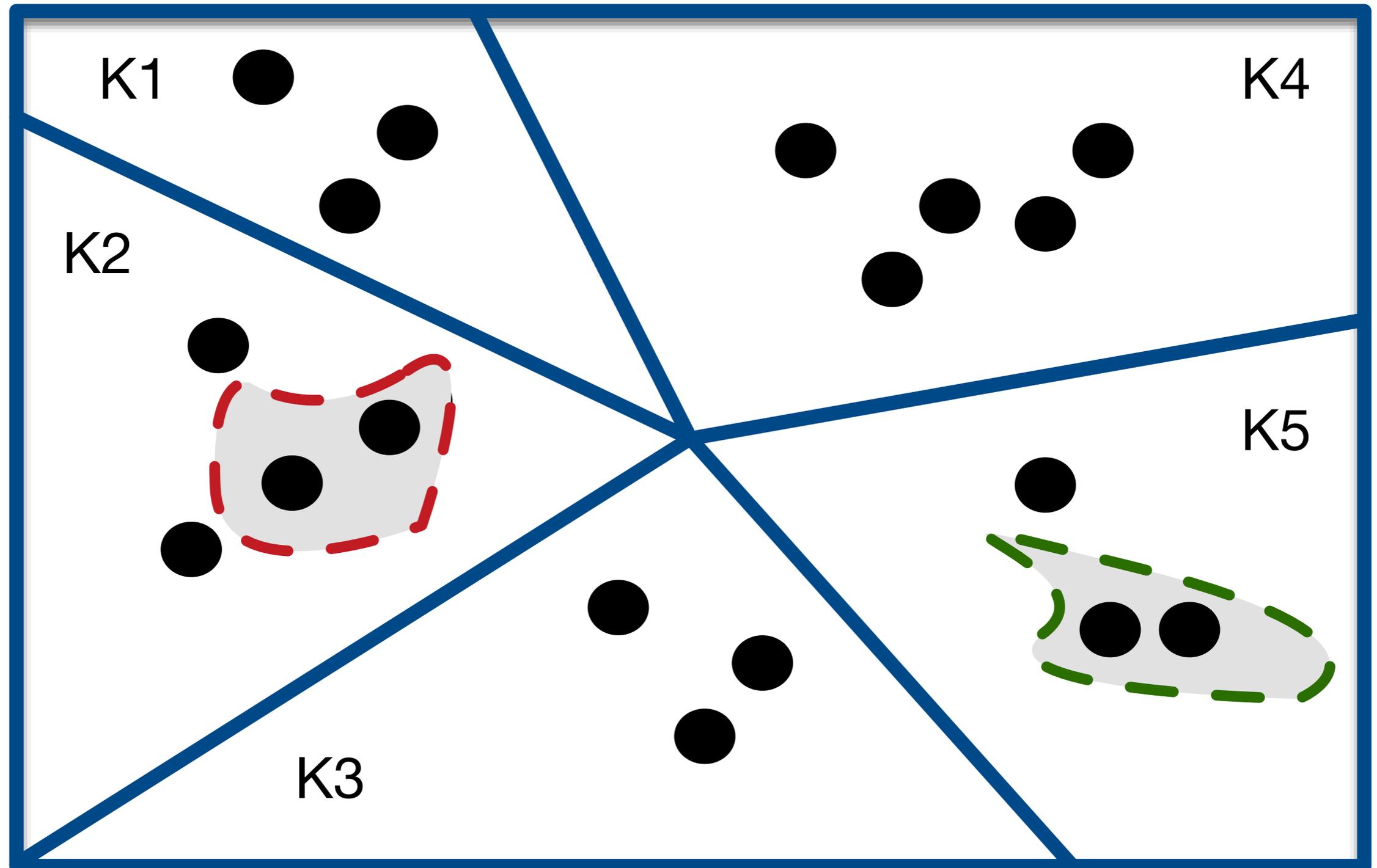
Kinds



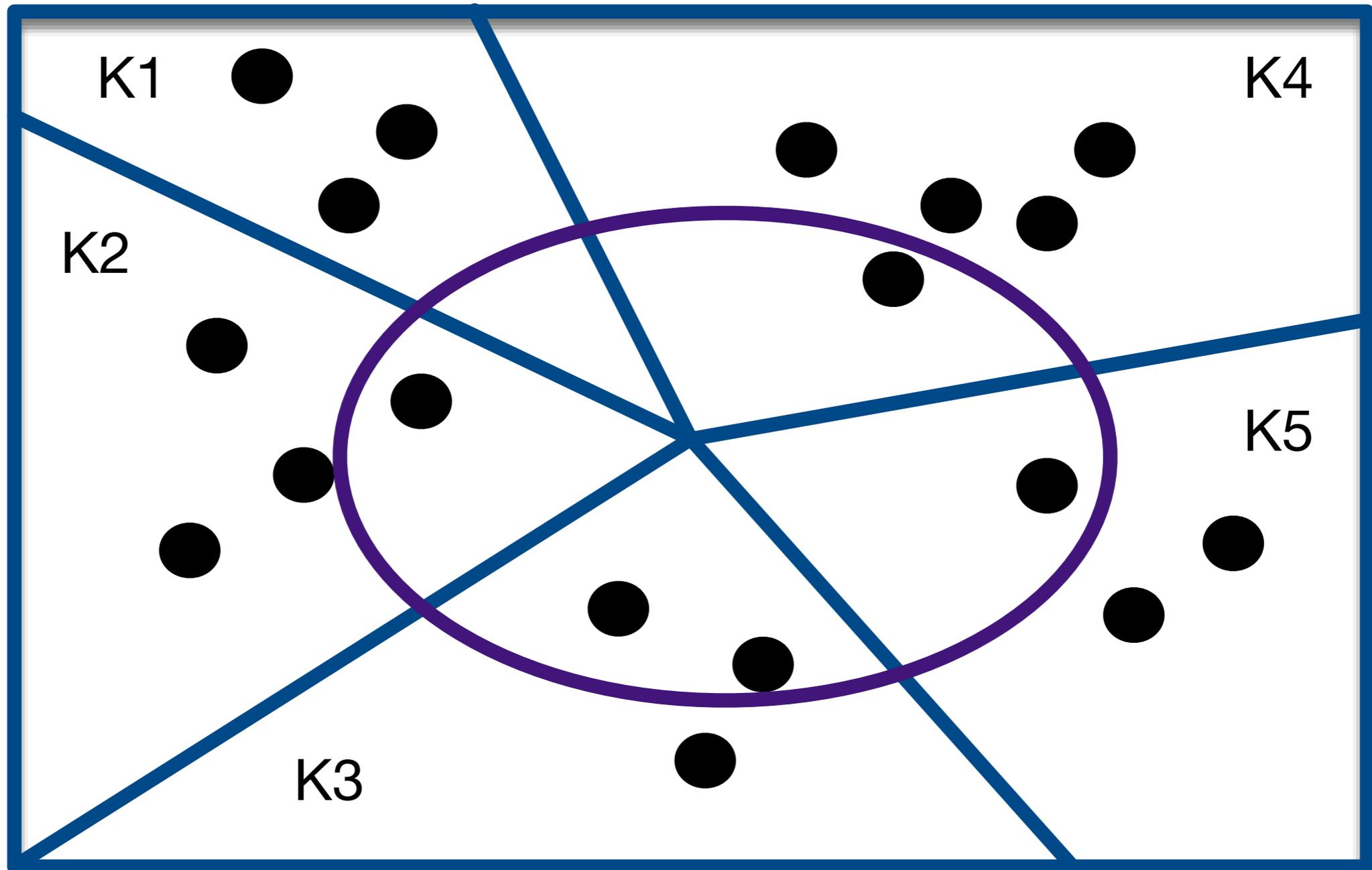
Anti-Rigid Sortals



Anti-Rigid Sortals



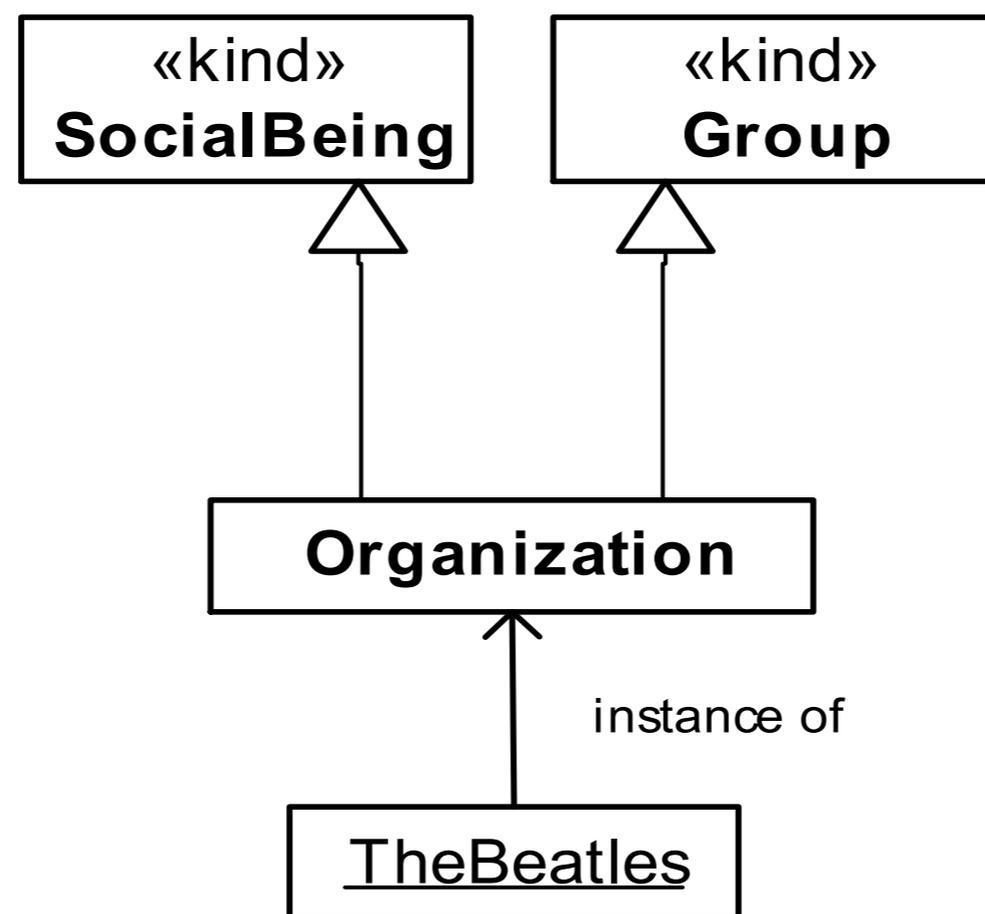
Non-Sortals

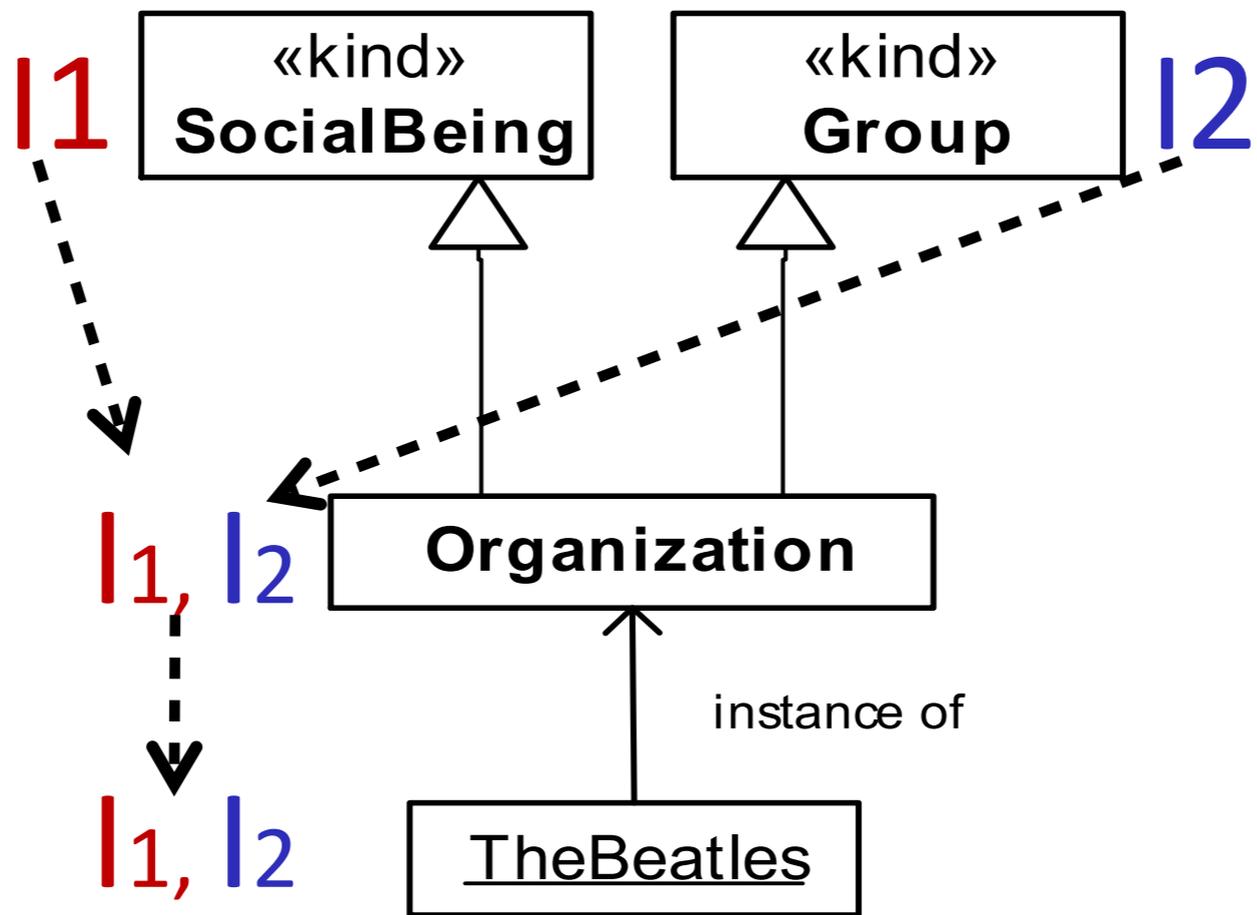


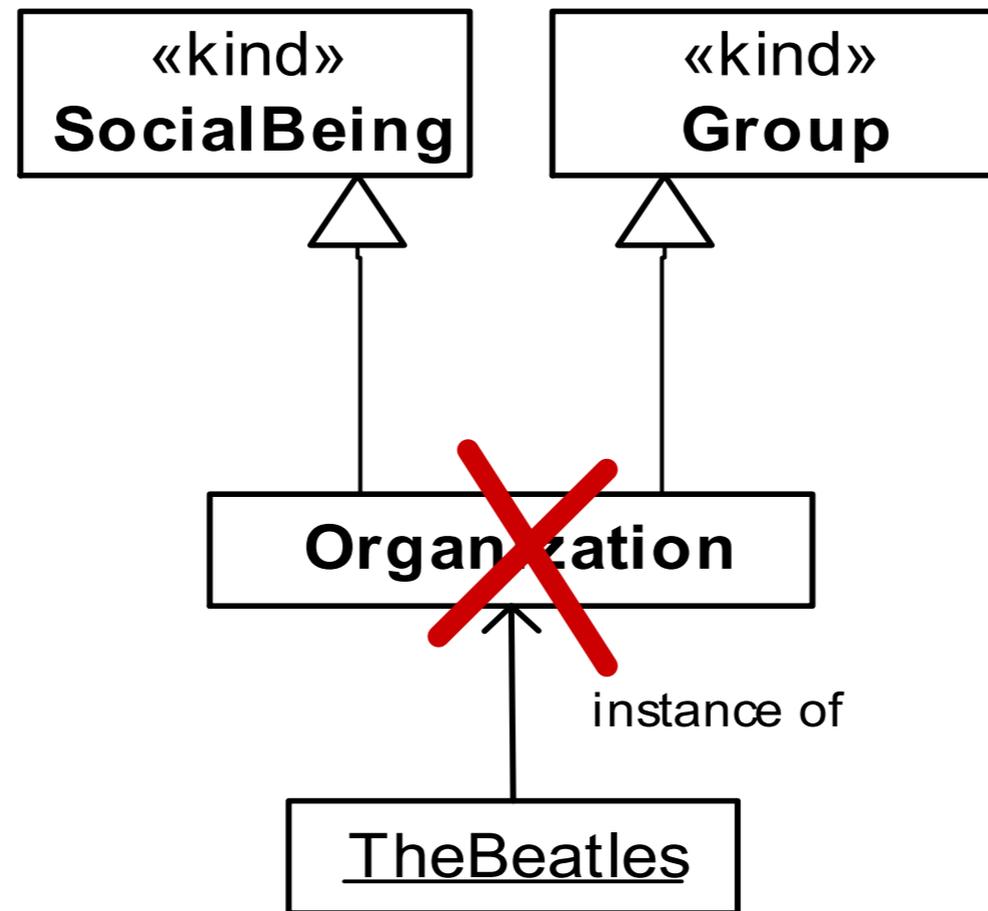
Foundations

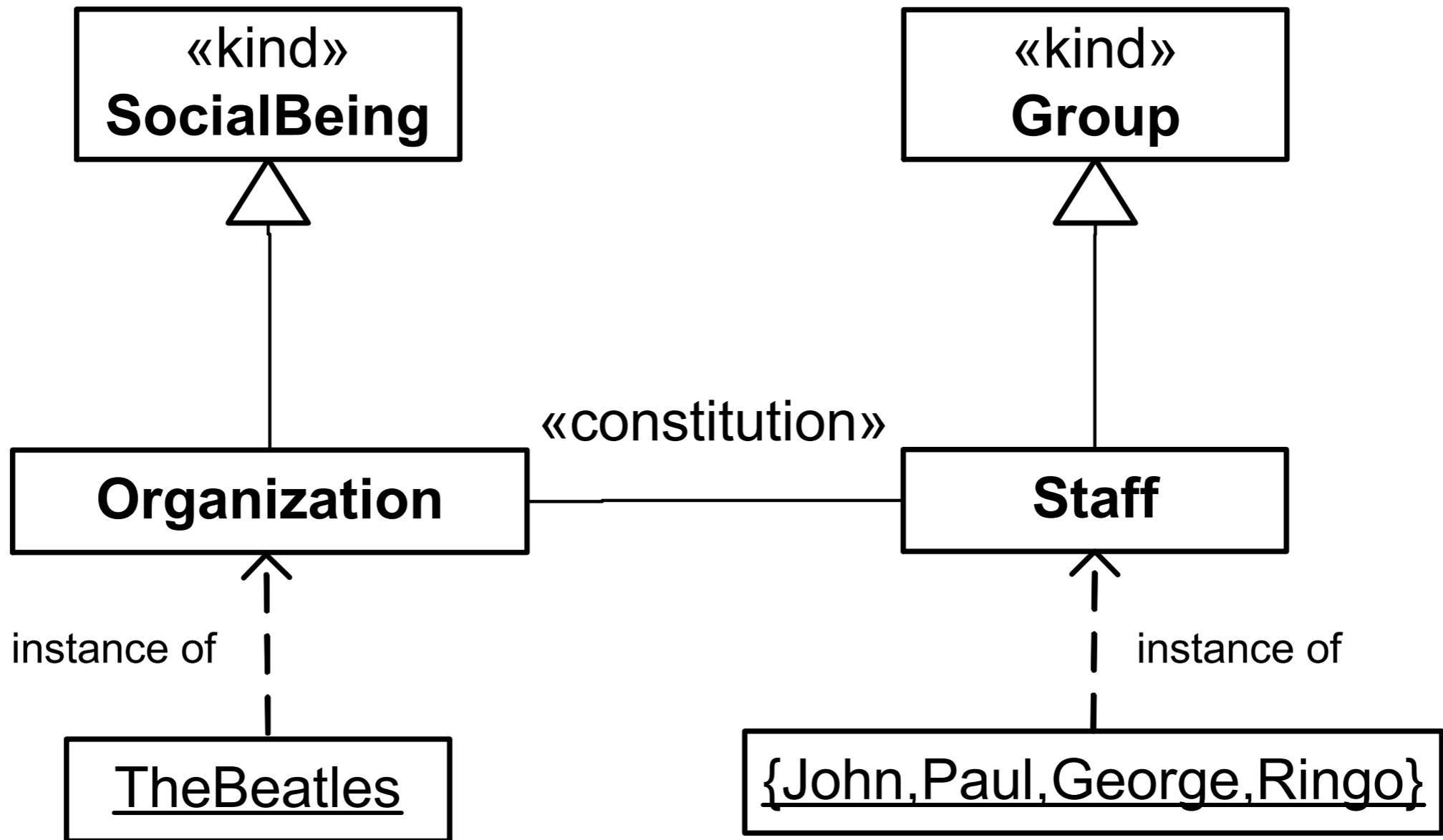
Since the unique principle of identity supplied by a Kind is inherited by its subclasses, we have that:

An Object in a conceptual model of the domain cannot instantiate more than one ultimate **Kind**



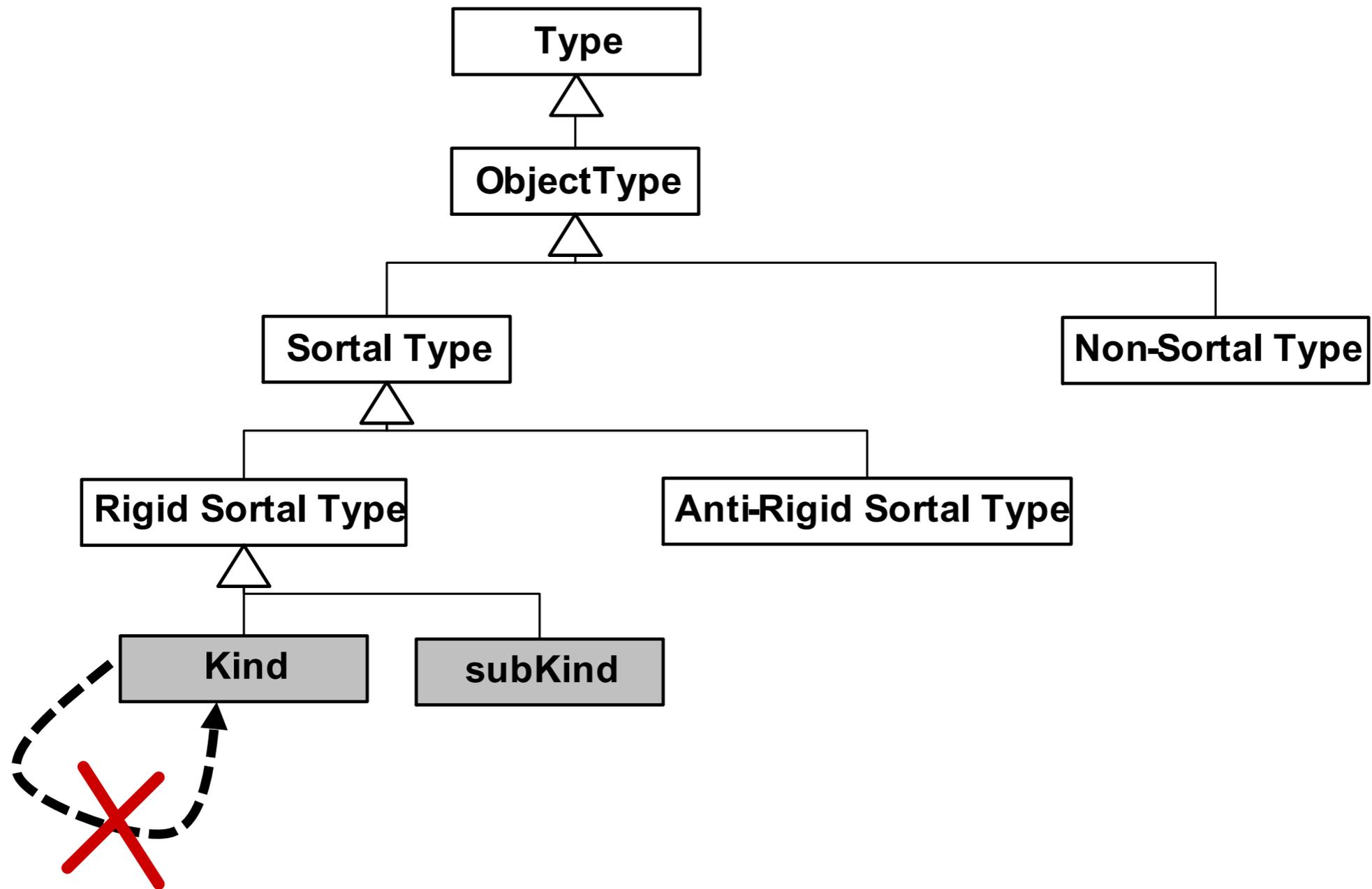




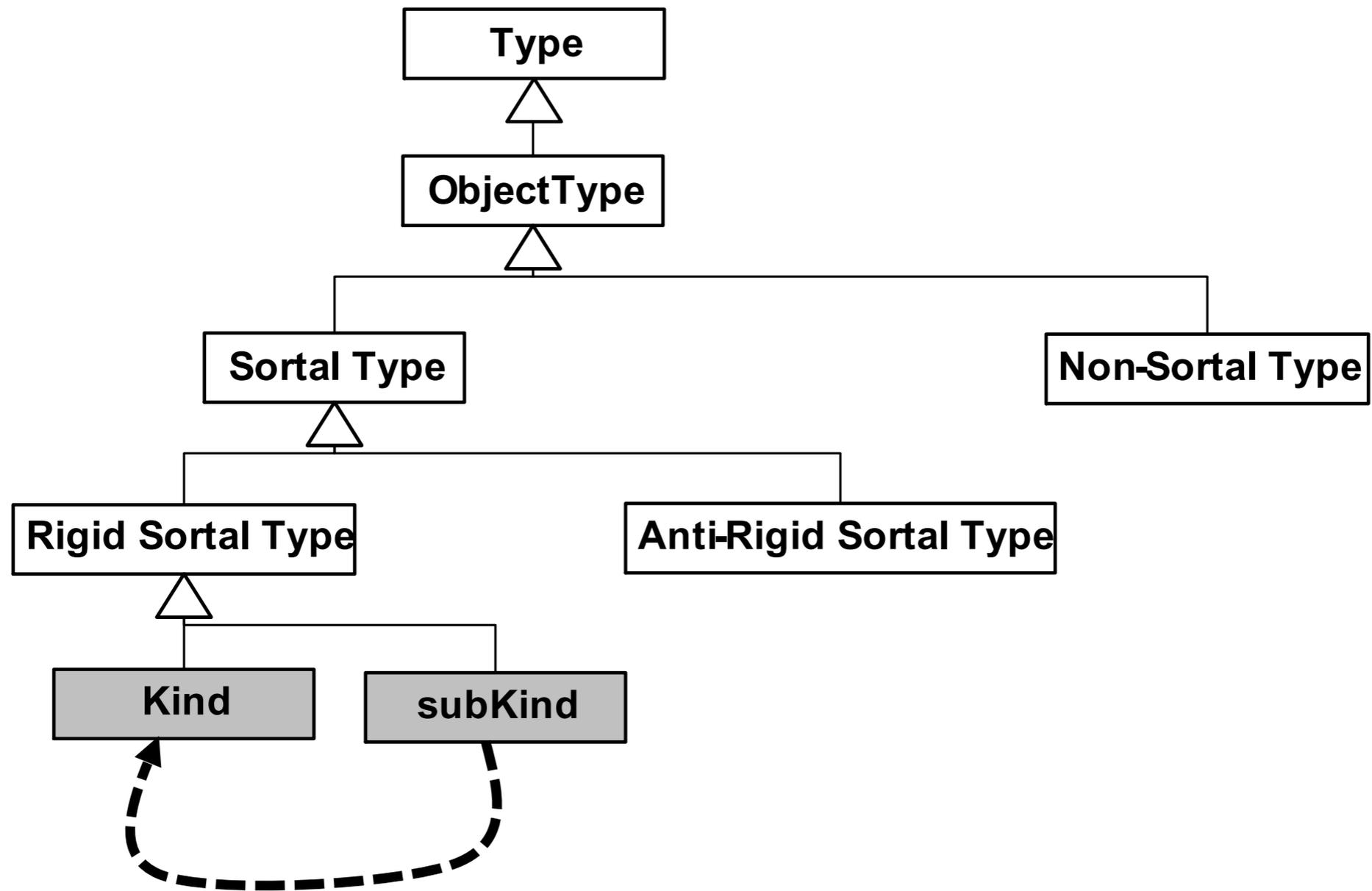


Foundations

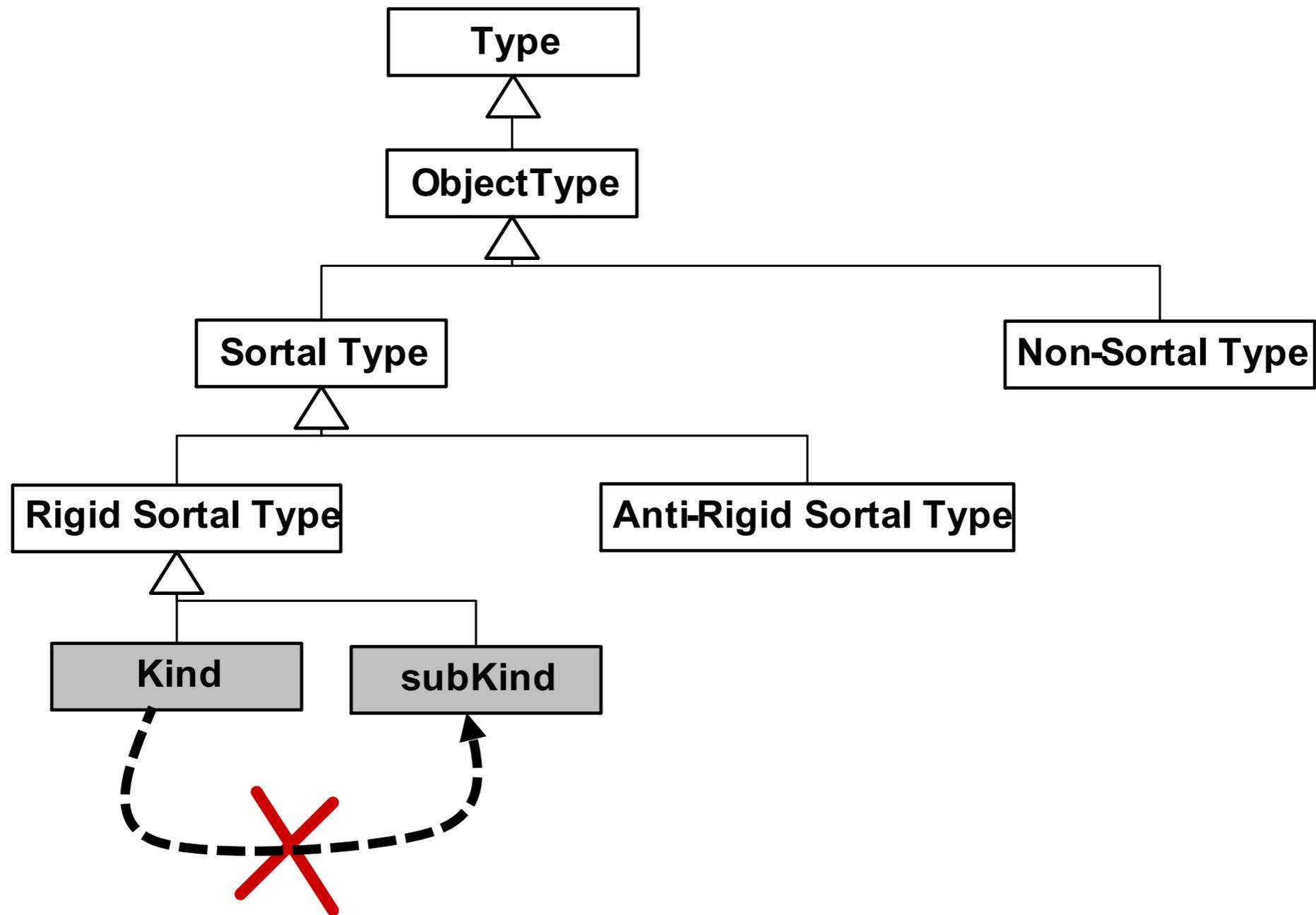
It is not the case that we cannot have multiple supertypes for a given type. Only that a type **cannot** have **multiple kinds as supertypes!**



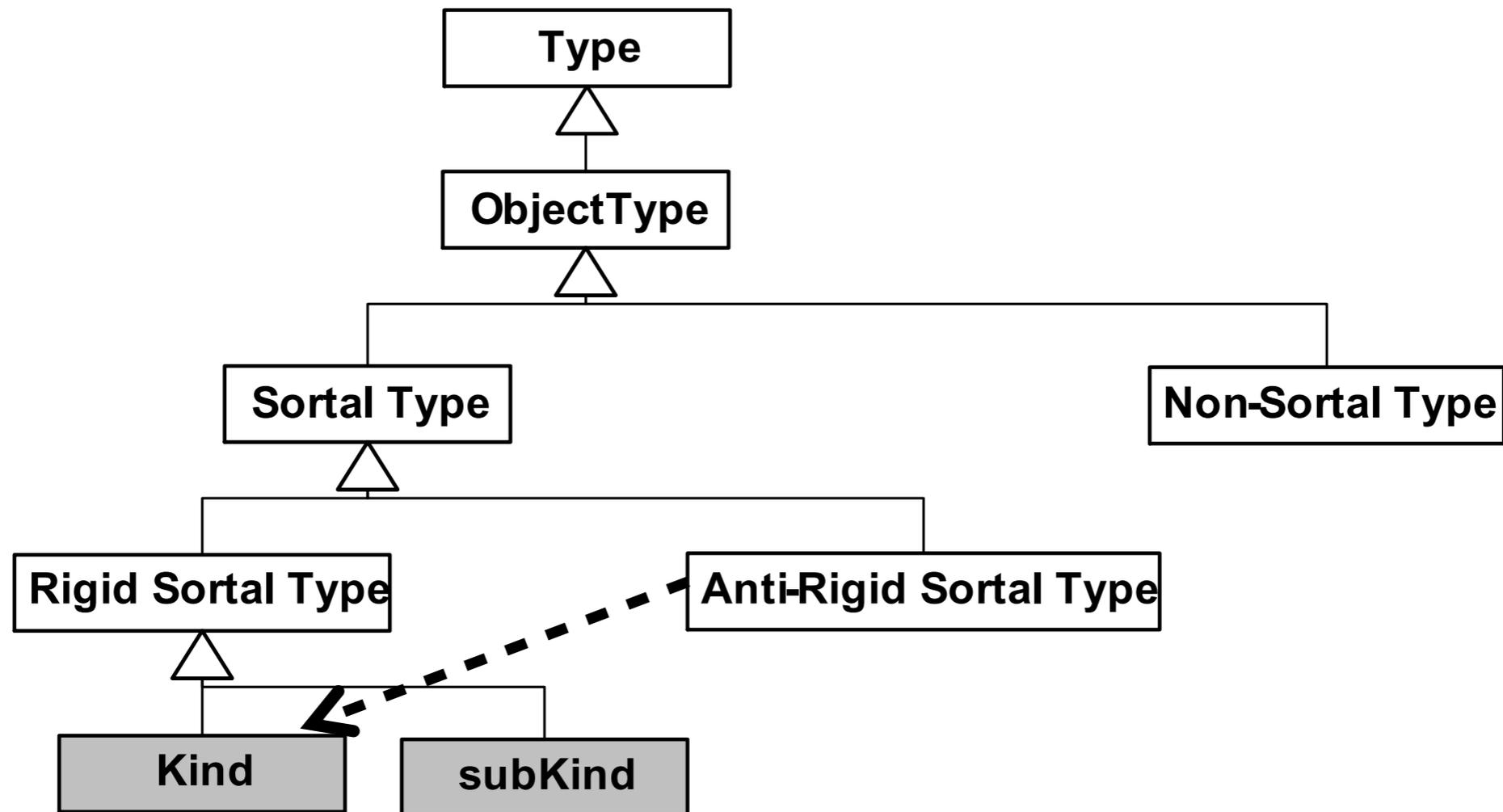
A Kind cannot be a supertype of another Kind



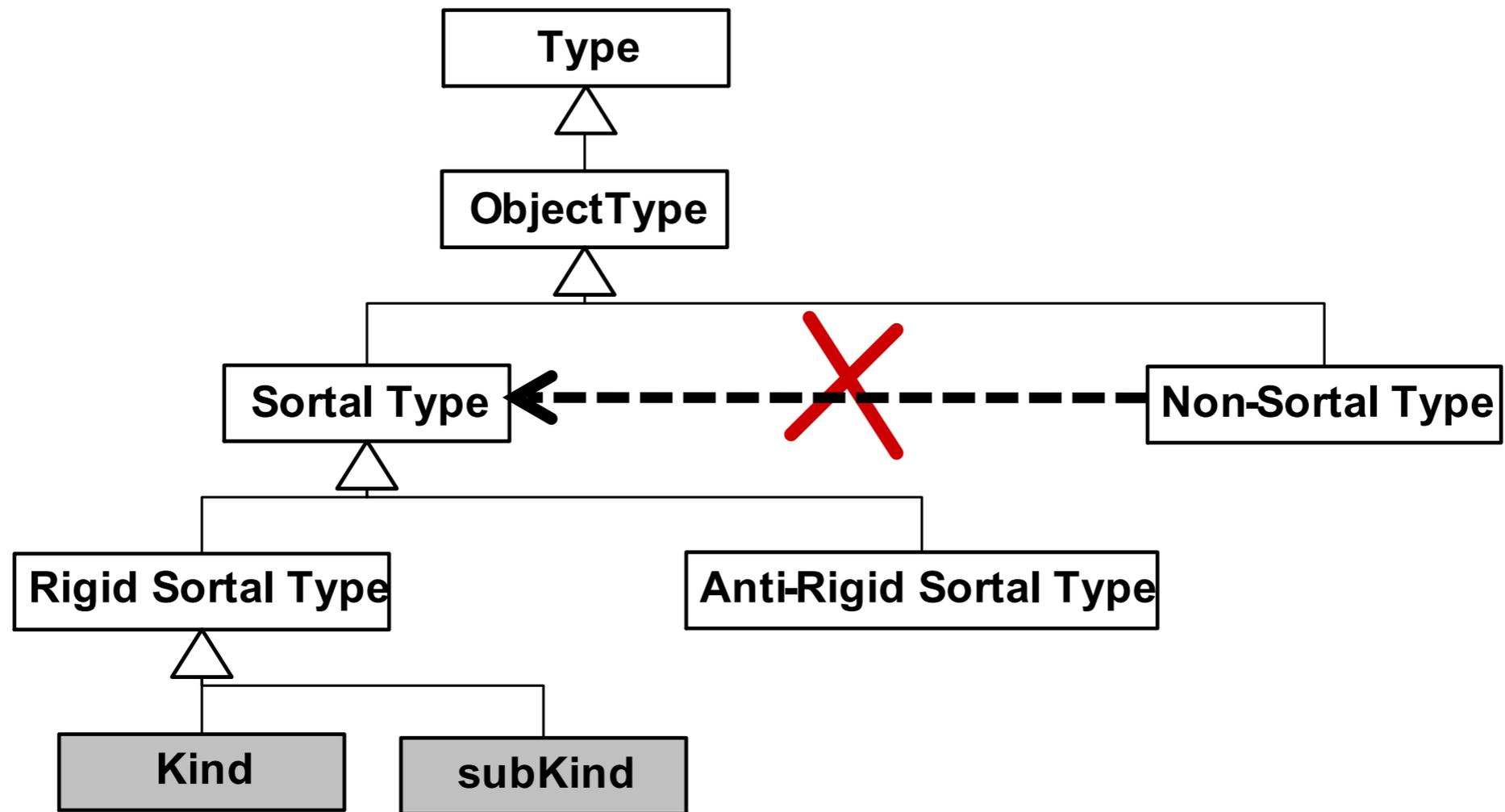
A subKind type **MUST** have as a supertype
a (unique) Kind



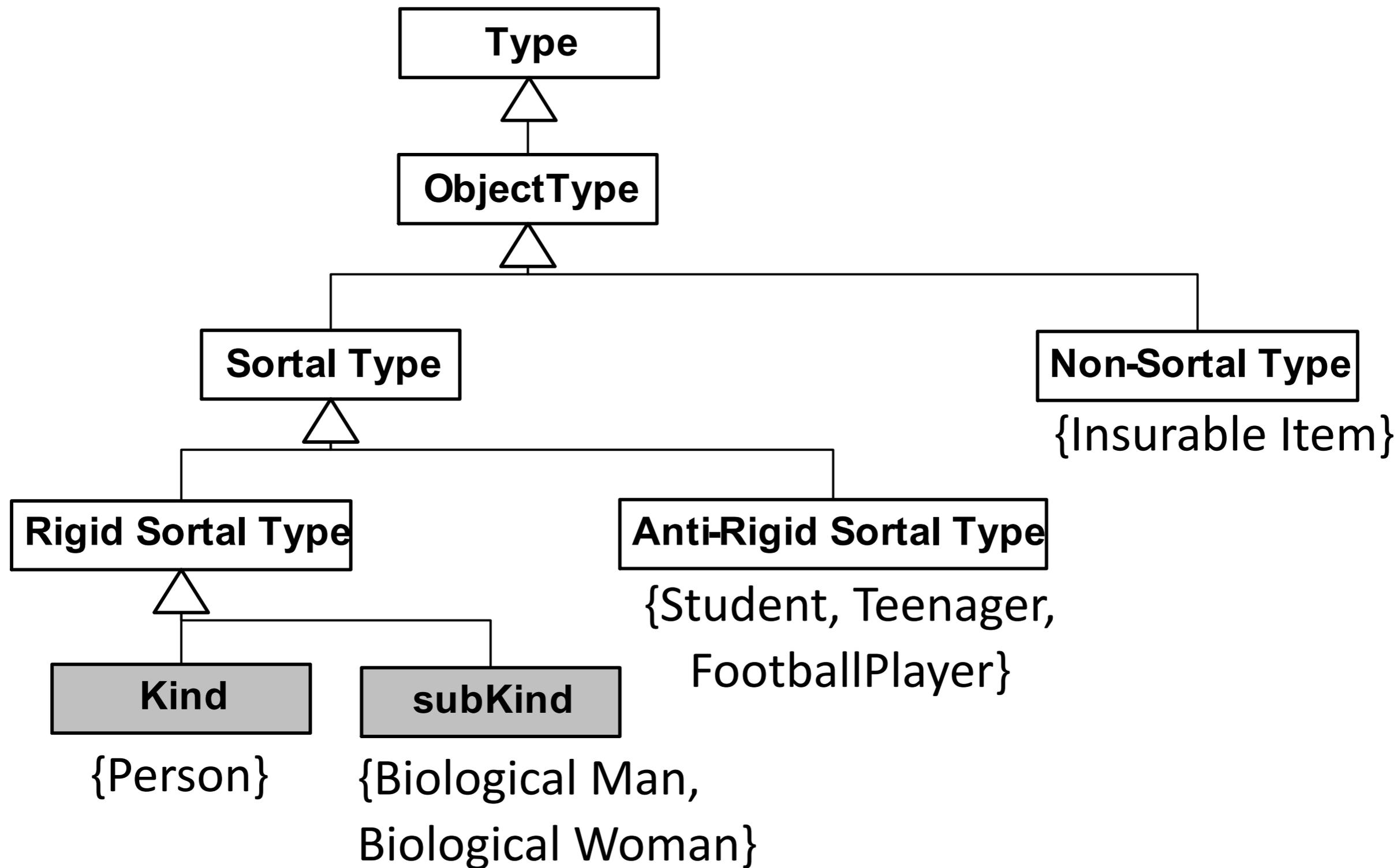
A subKind cannot be a supertype of a kind



An Anti-Rigid type **MUST** have as a supertype
a (unique) Kind



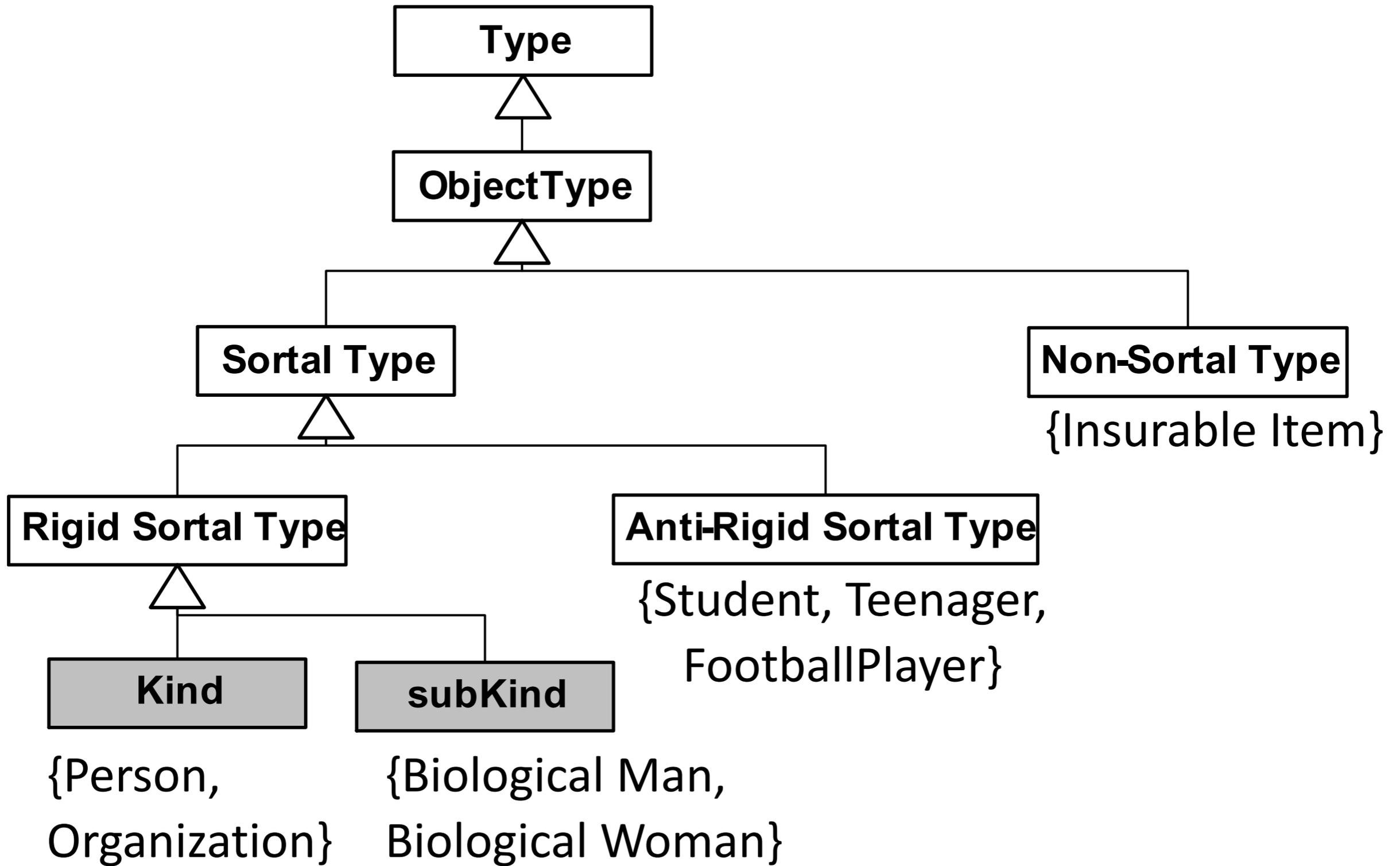
A Sortal Type cannot be a supertype of a Non-Sortal Type

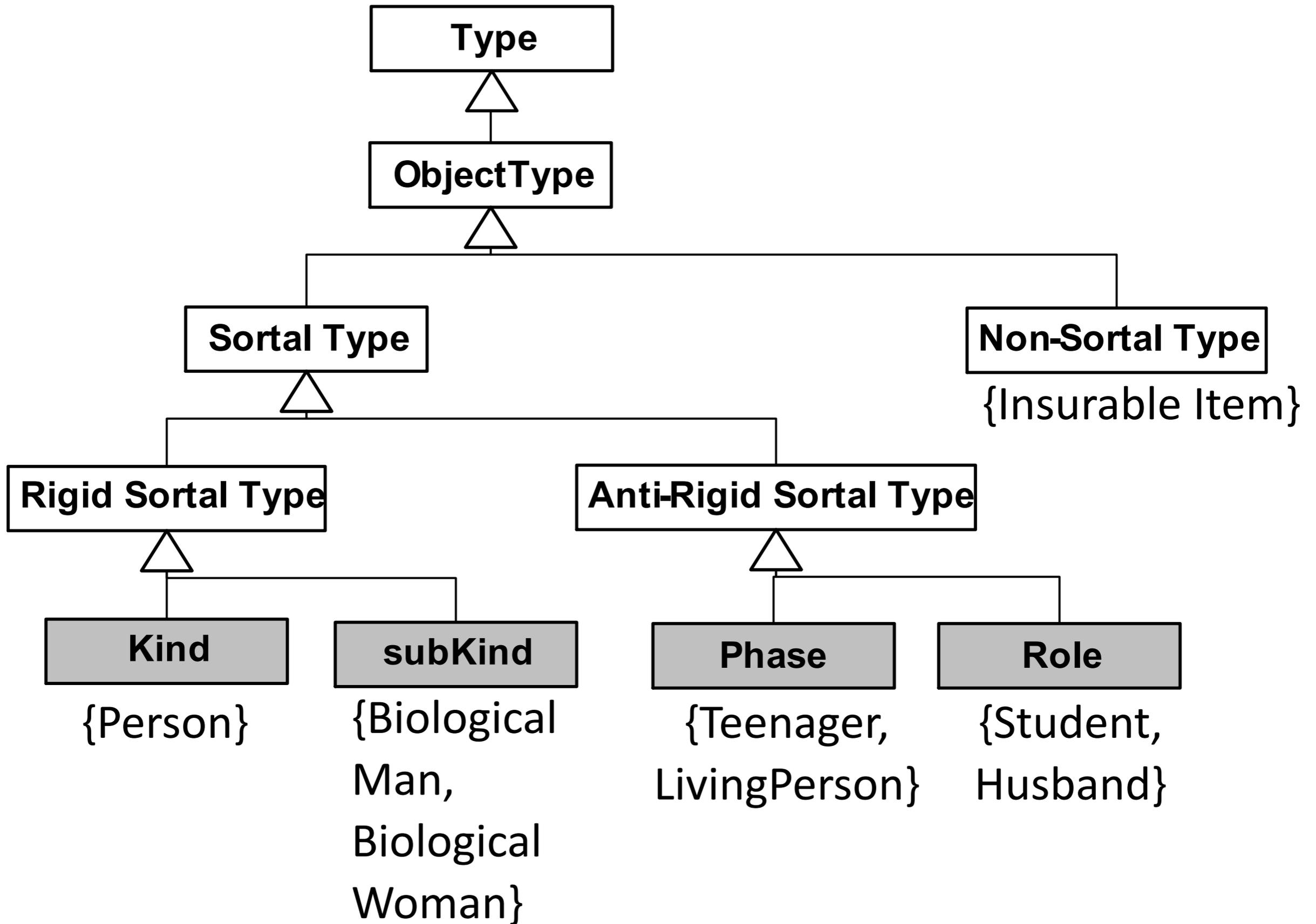


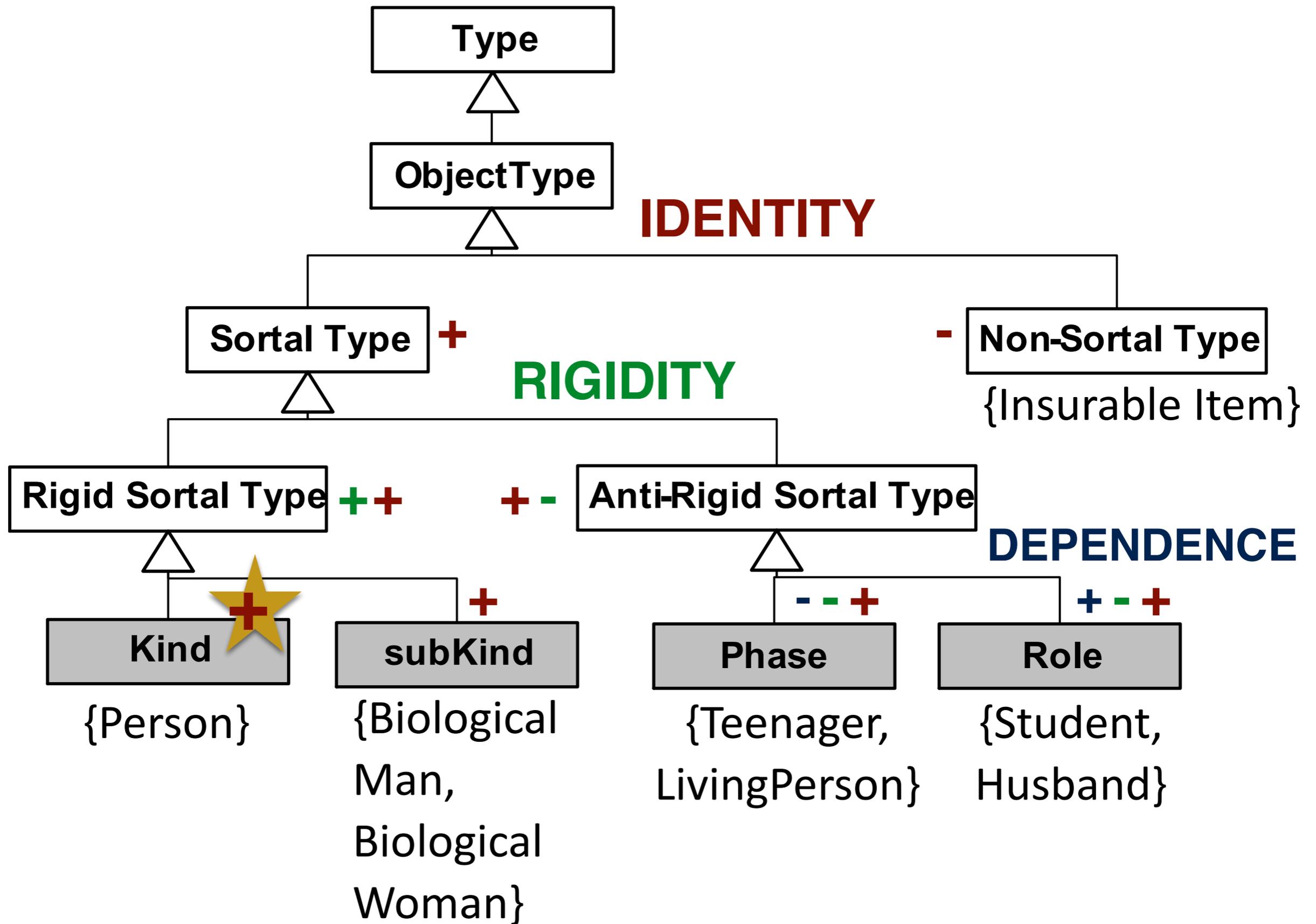
Relational Dependence

A type T is relationally dependent on another type P via relation R iff for every instance x of T there is an instance y of P such that x and y are related via R :

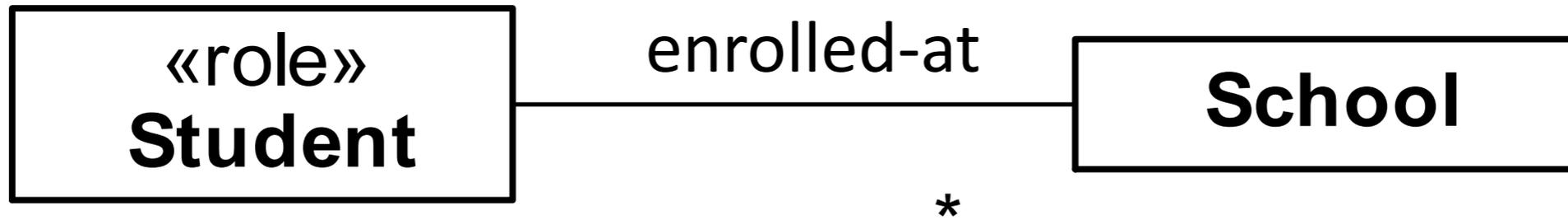
$$\square (Vx . T(x) \rightarrow \exists y . P(y) \wedge R(x, y))$$



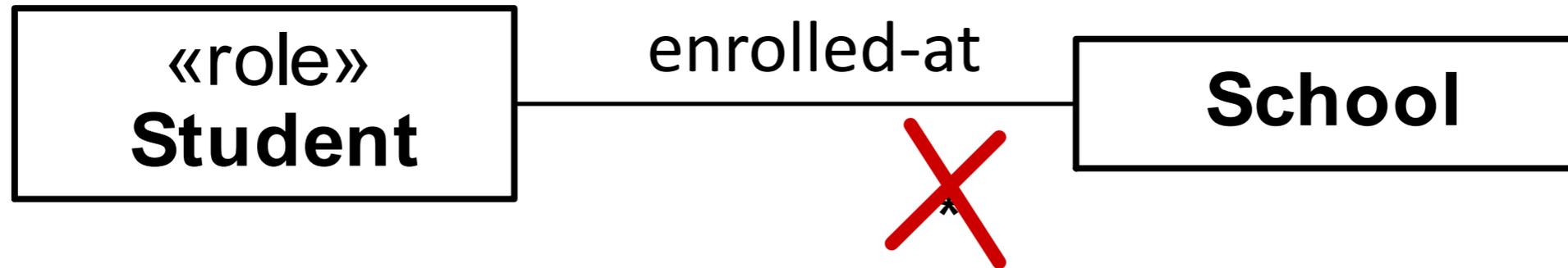




Roles



Roles

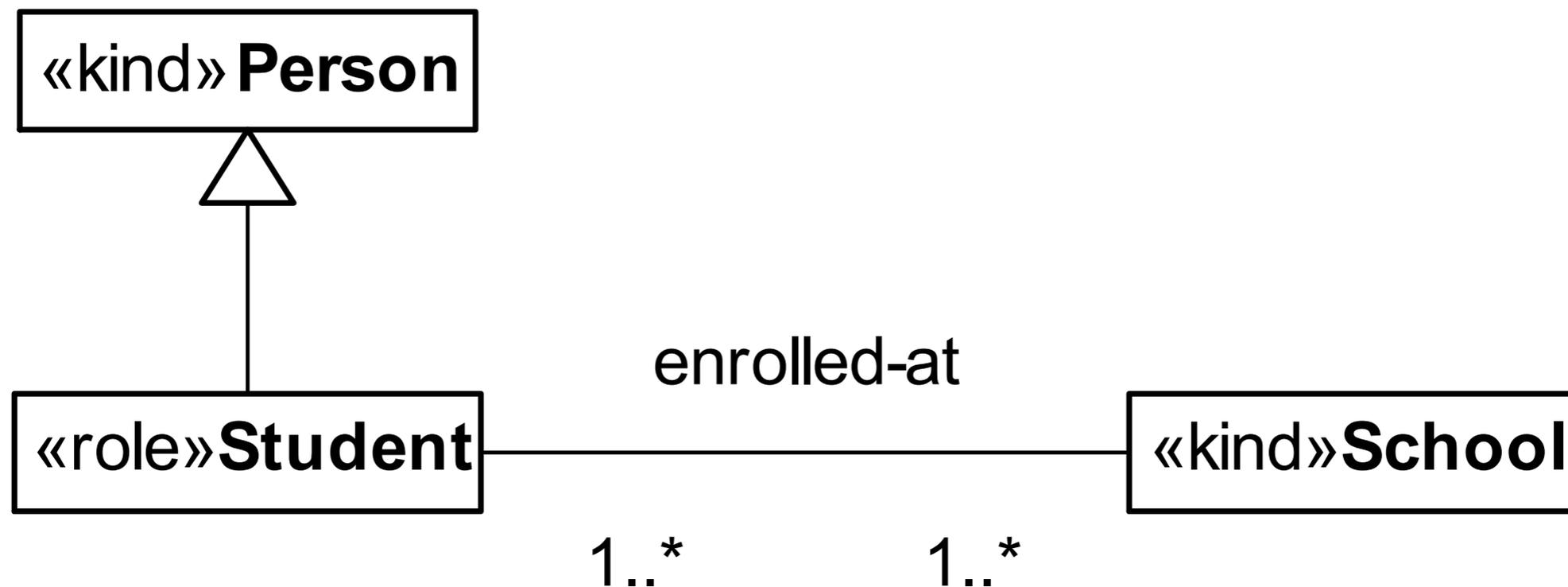


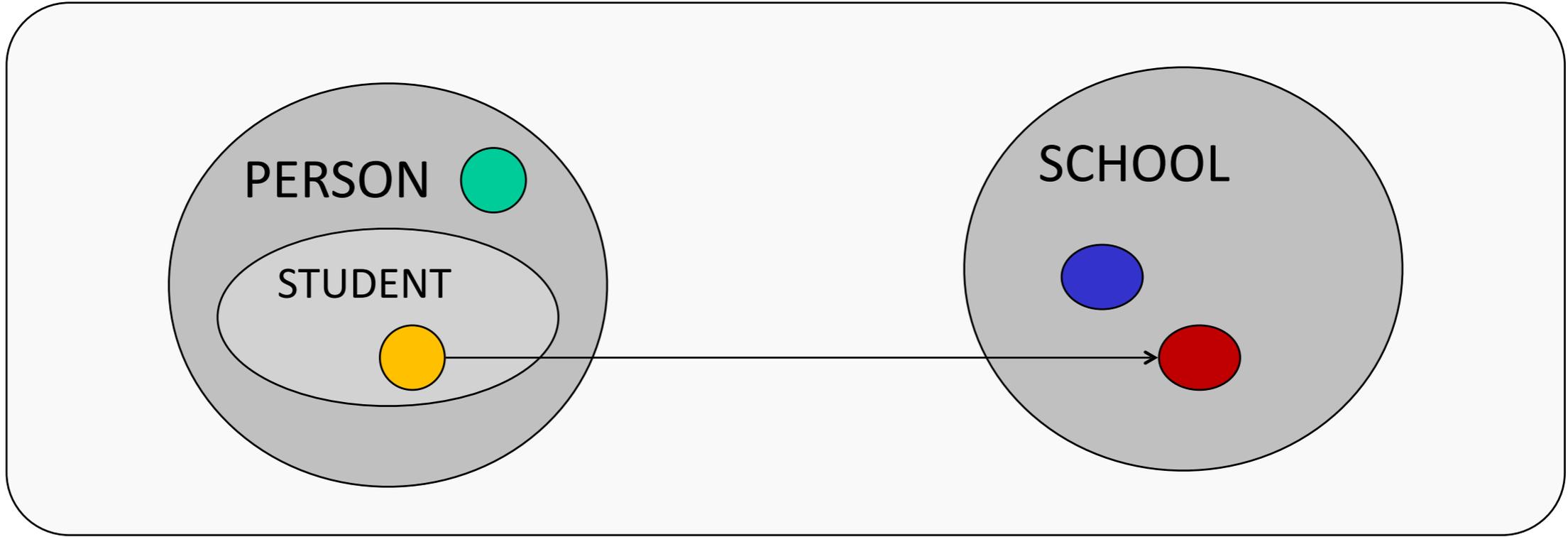
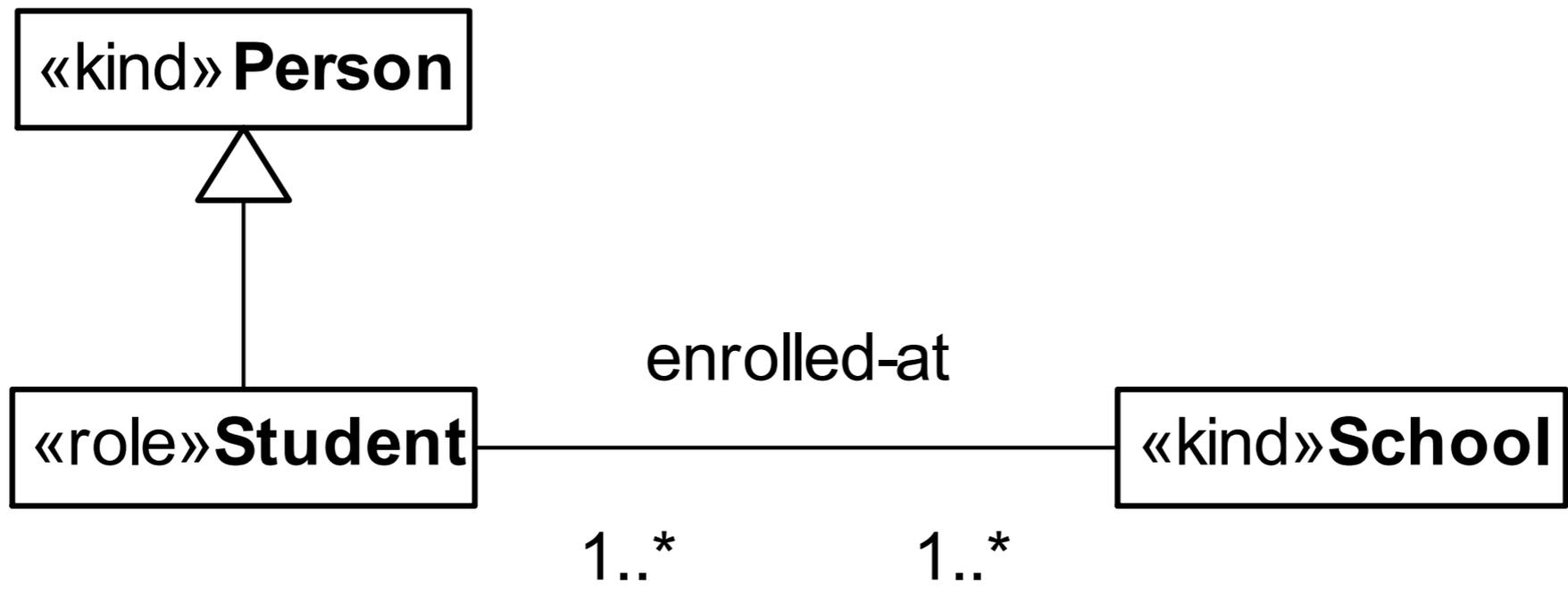
The Relational property in this case is part of the very definition of the Role:

$$\text{Student}(x) =_{\text{def}} \text{Person}(x) \wedge \exists y \text{ School}(y) \wedge \text{enrolled-at}(x,y)$$

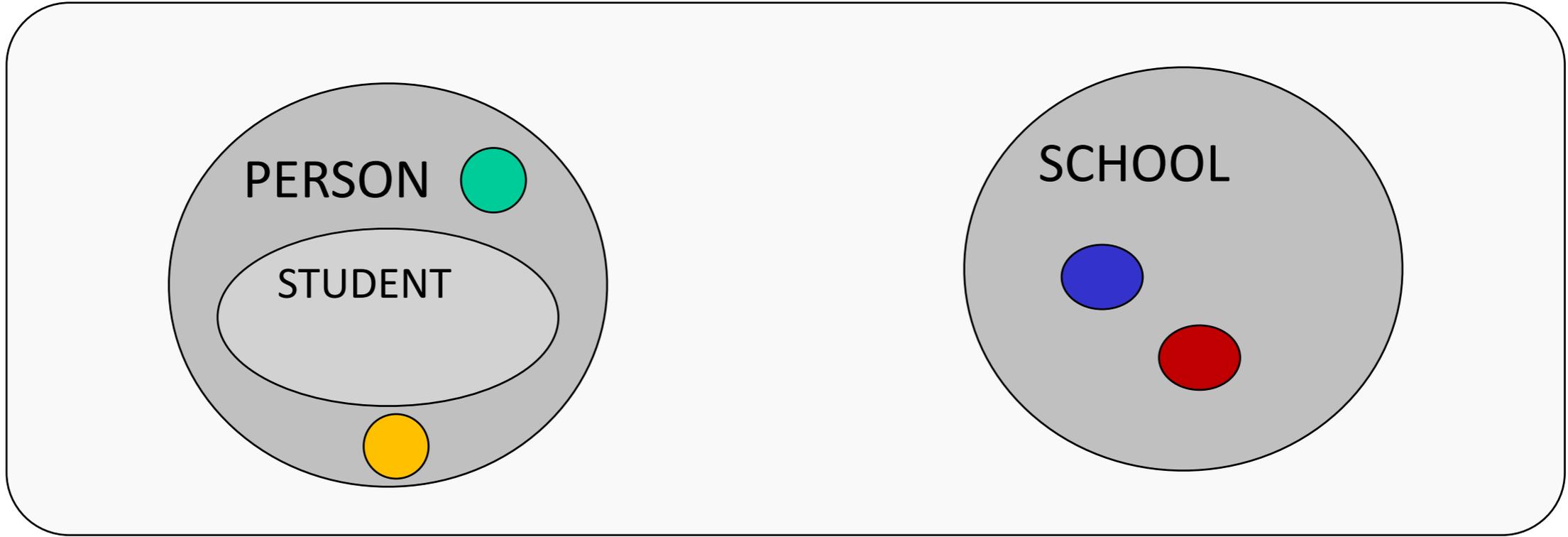
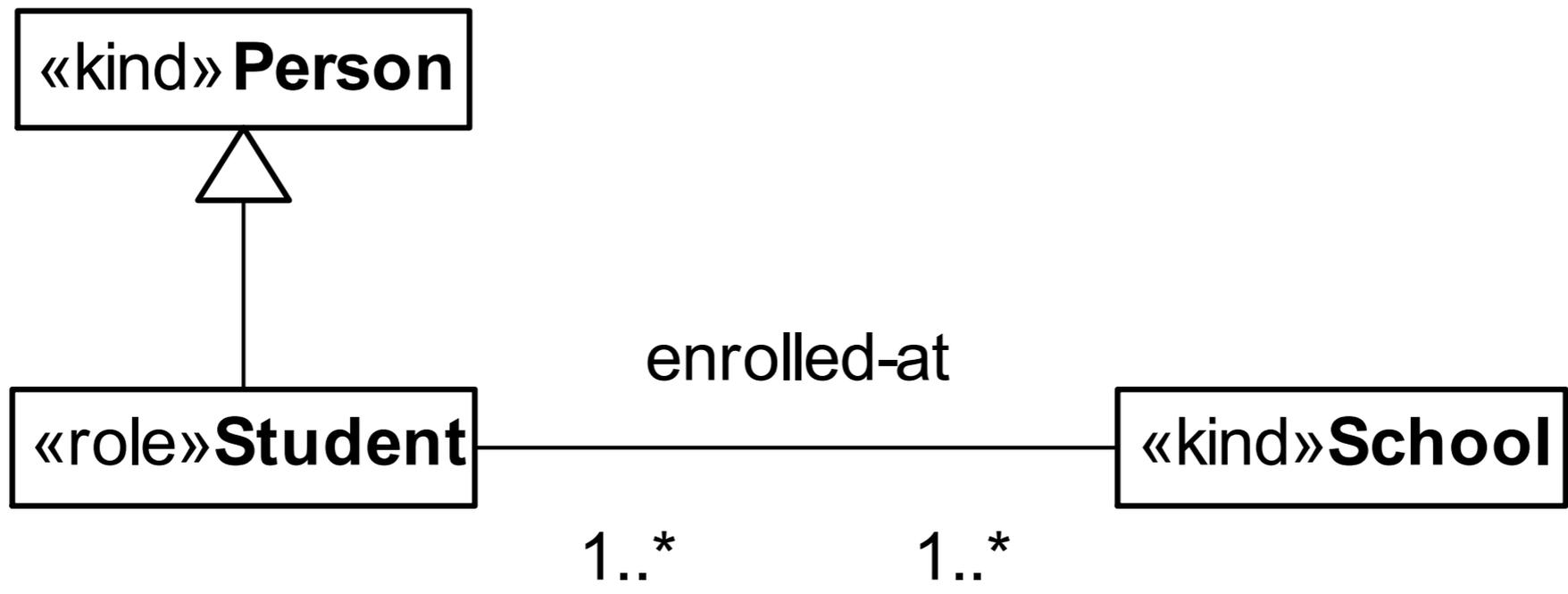
Roles

Defined as a (anti-rigid) specialization of a kind such that the specialization condition is a relational one (correlated with derivation by participation)

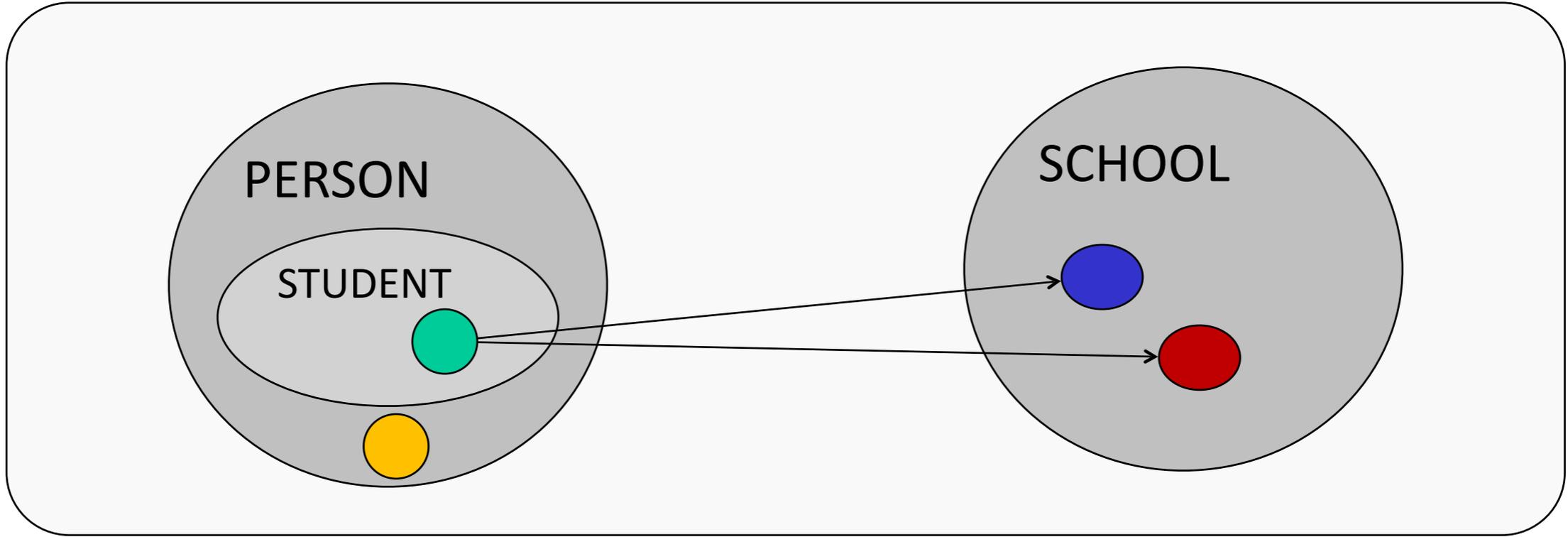
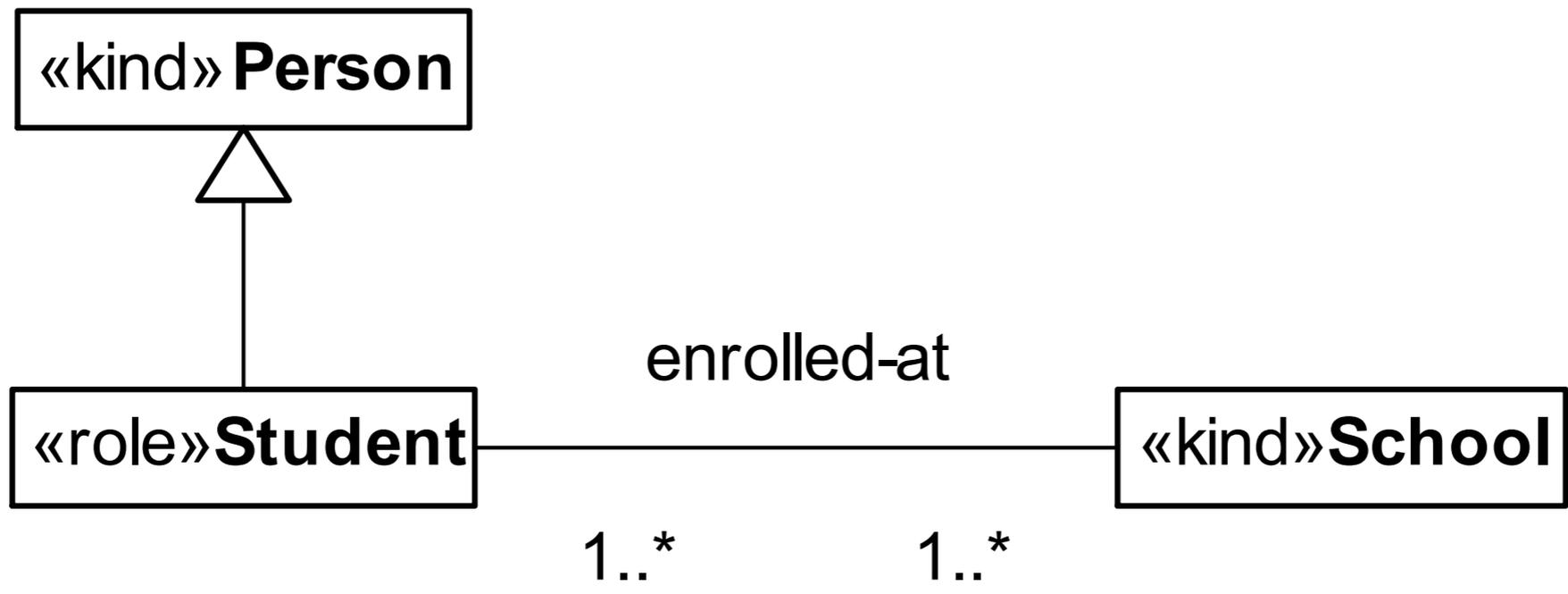




WORLD W

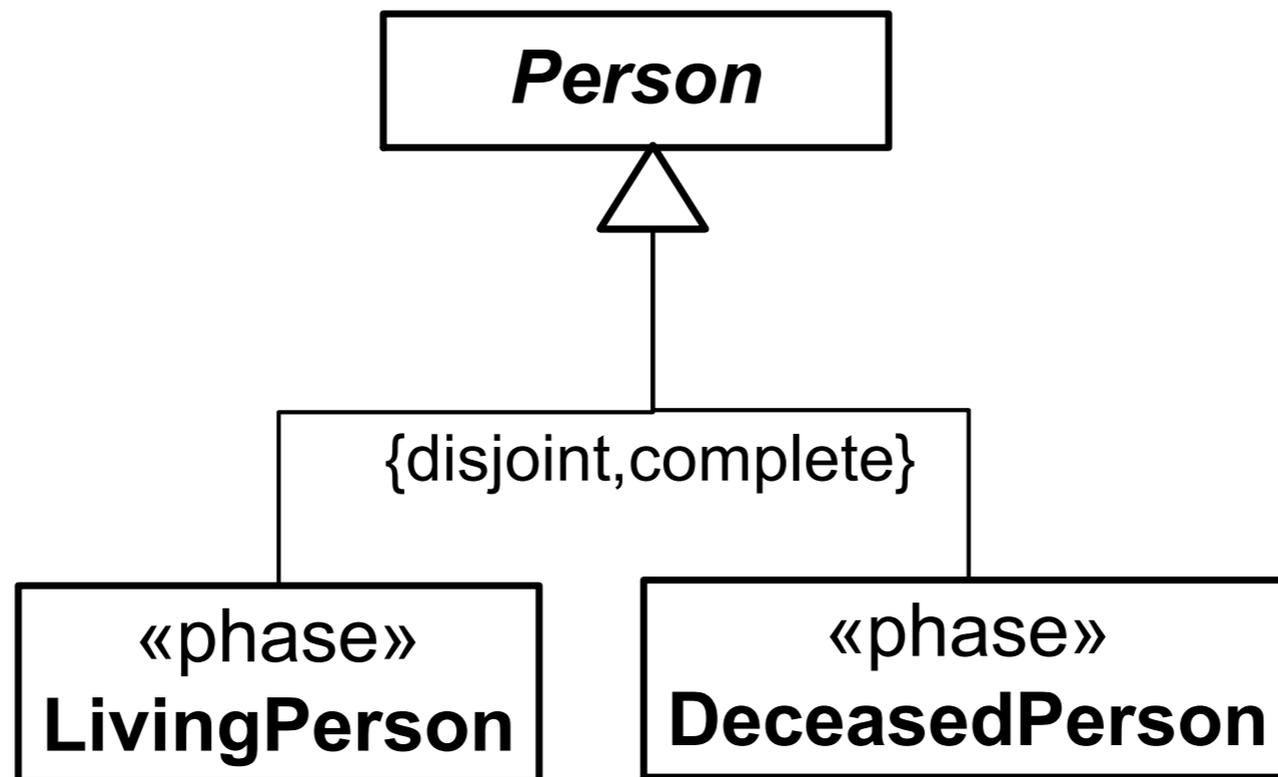


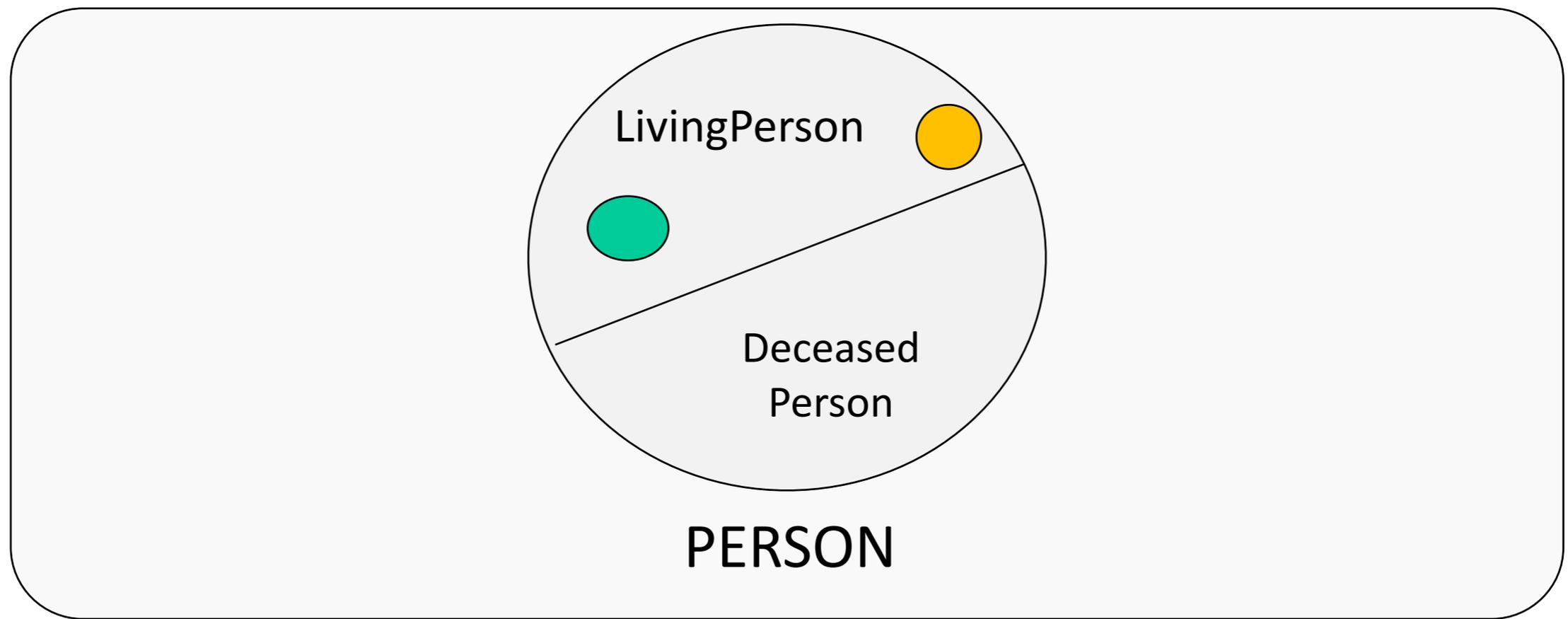
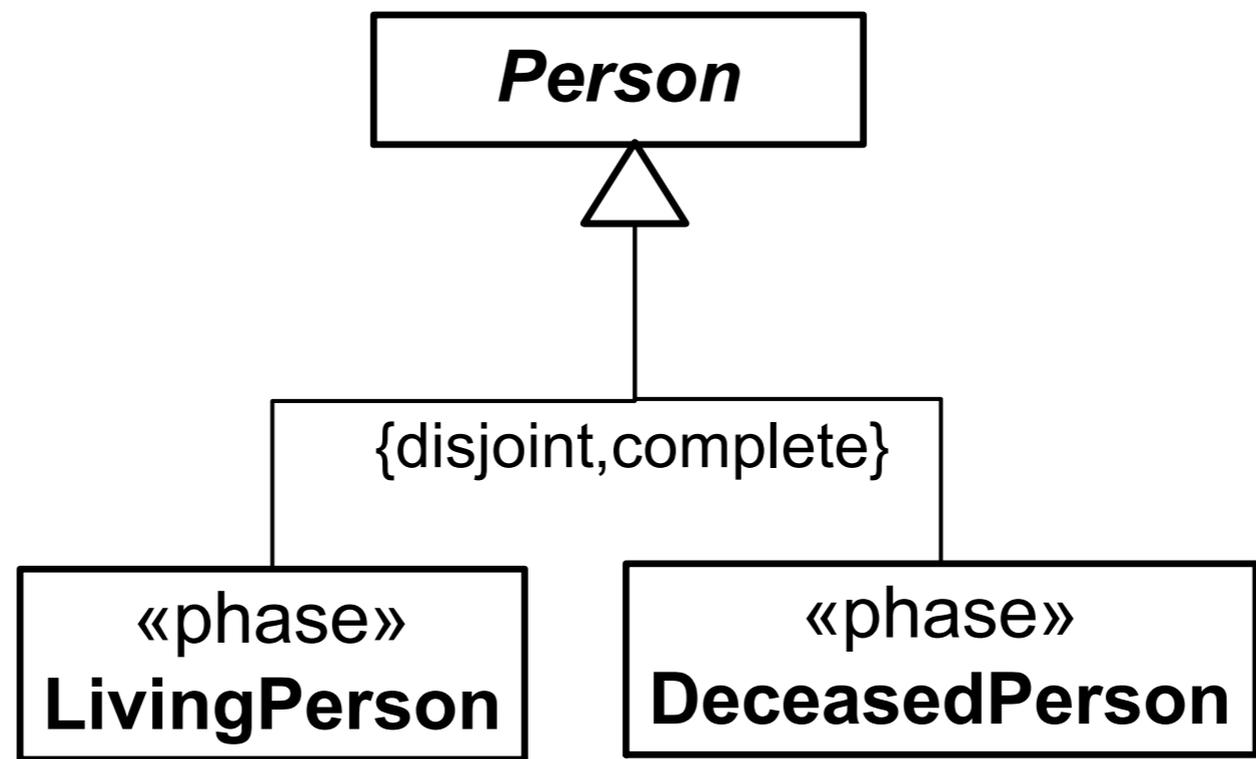
WORLD W'



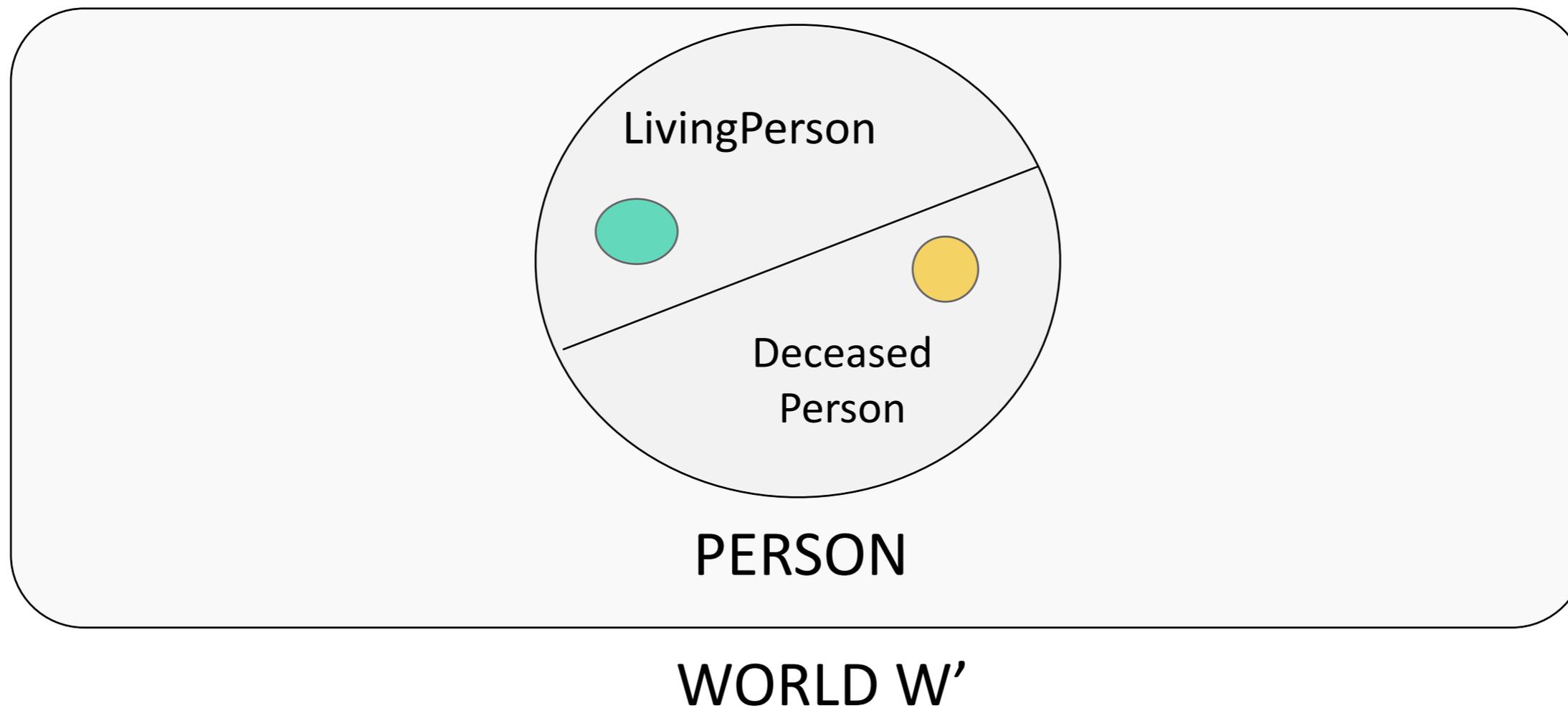
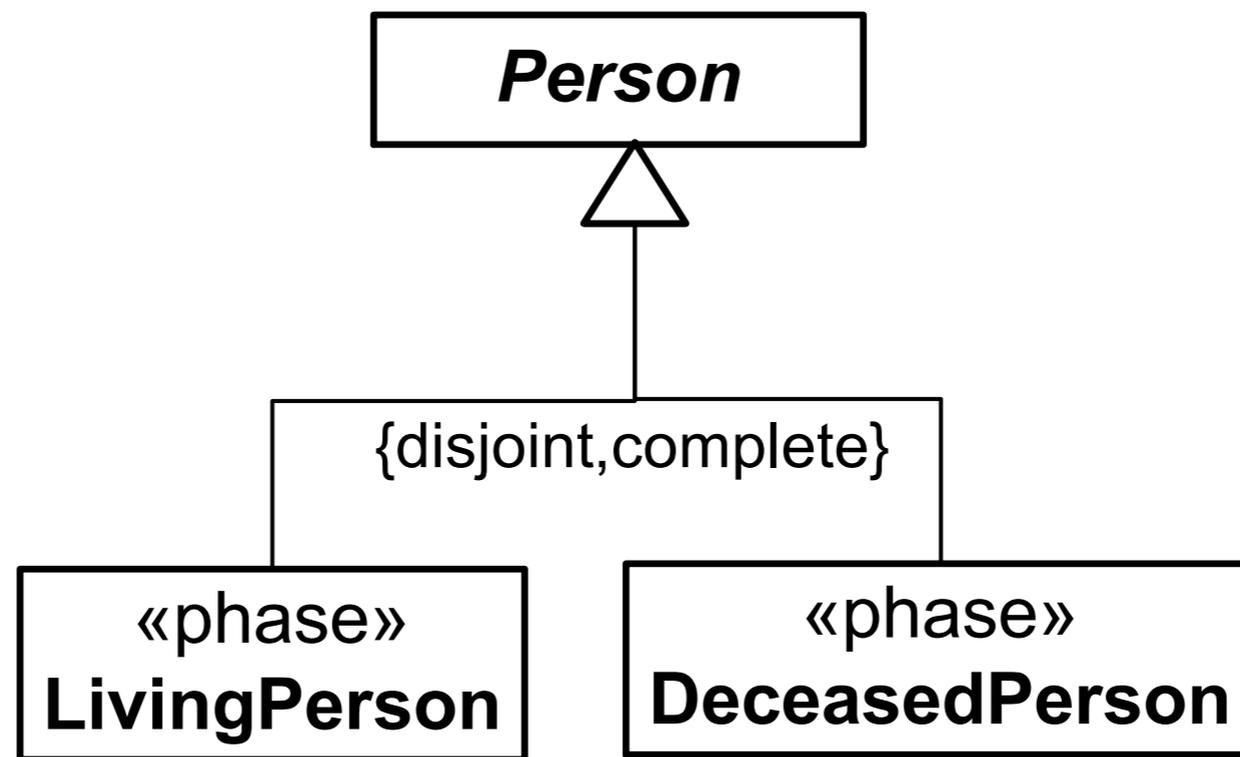
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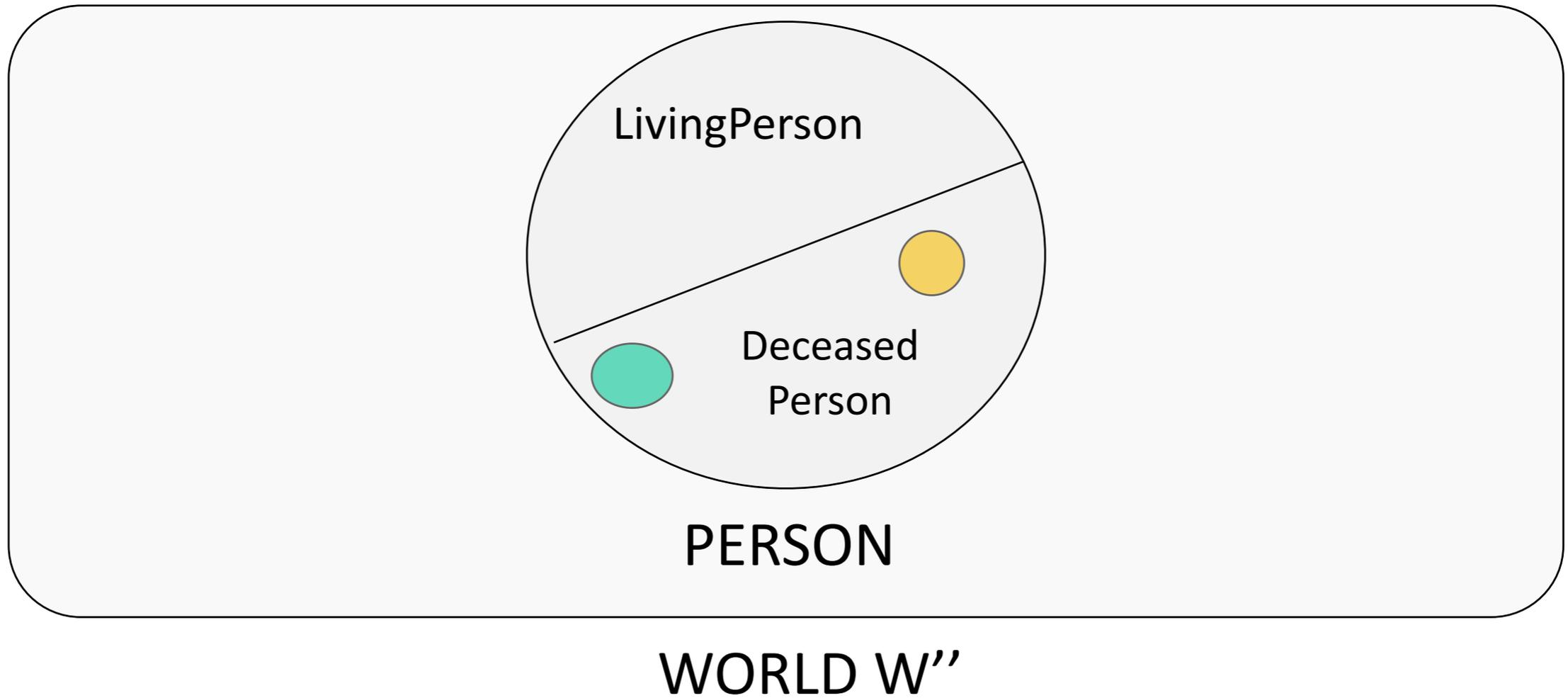
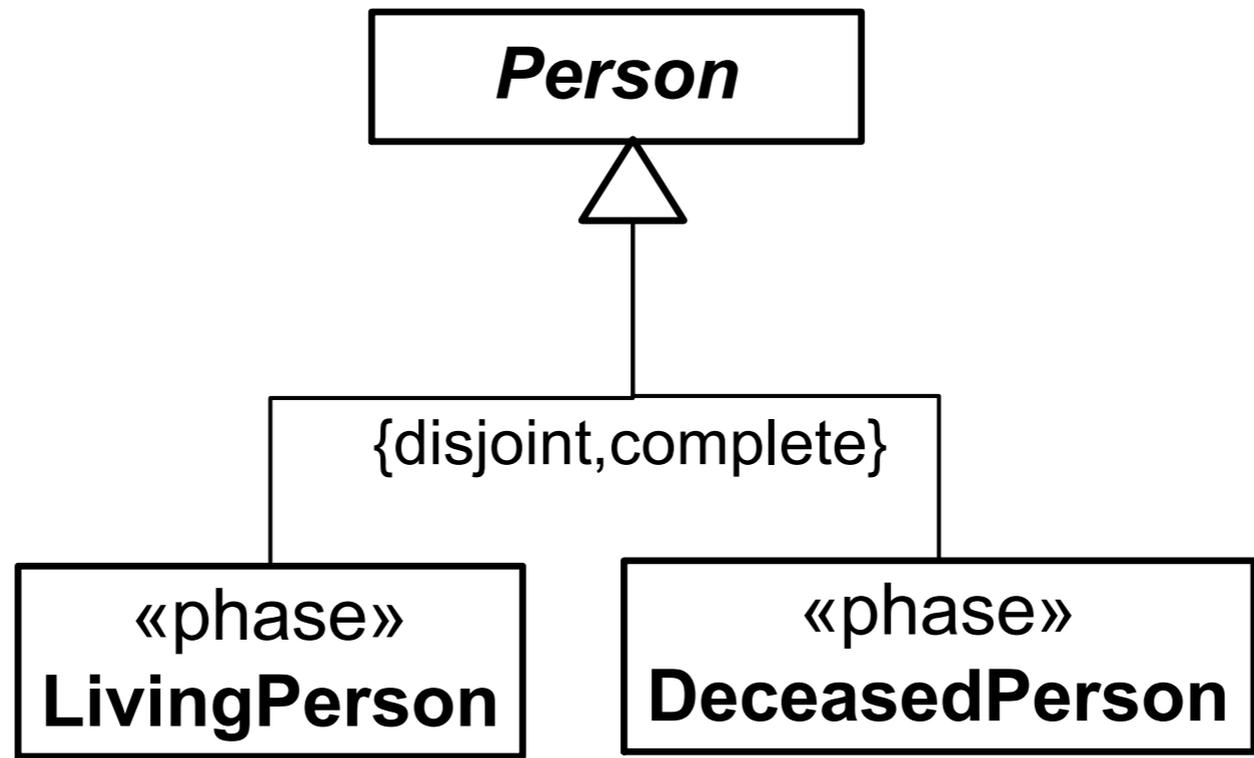
Phases

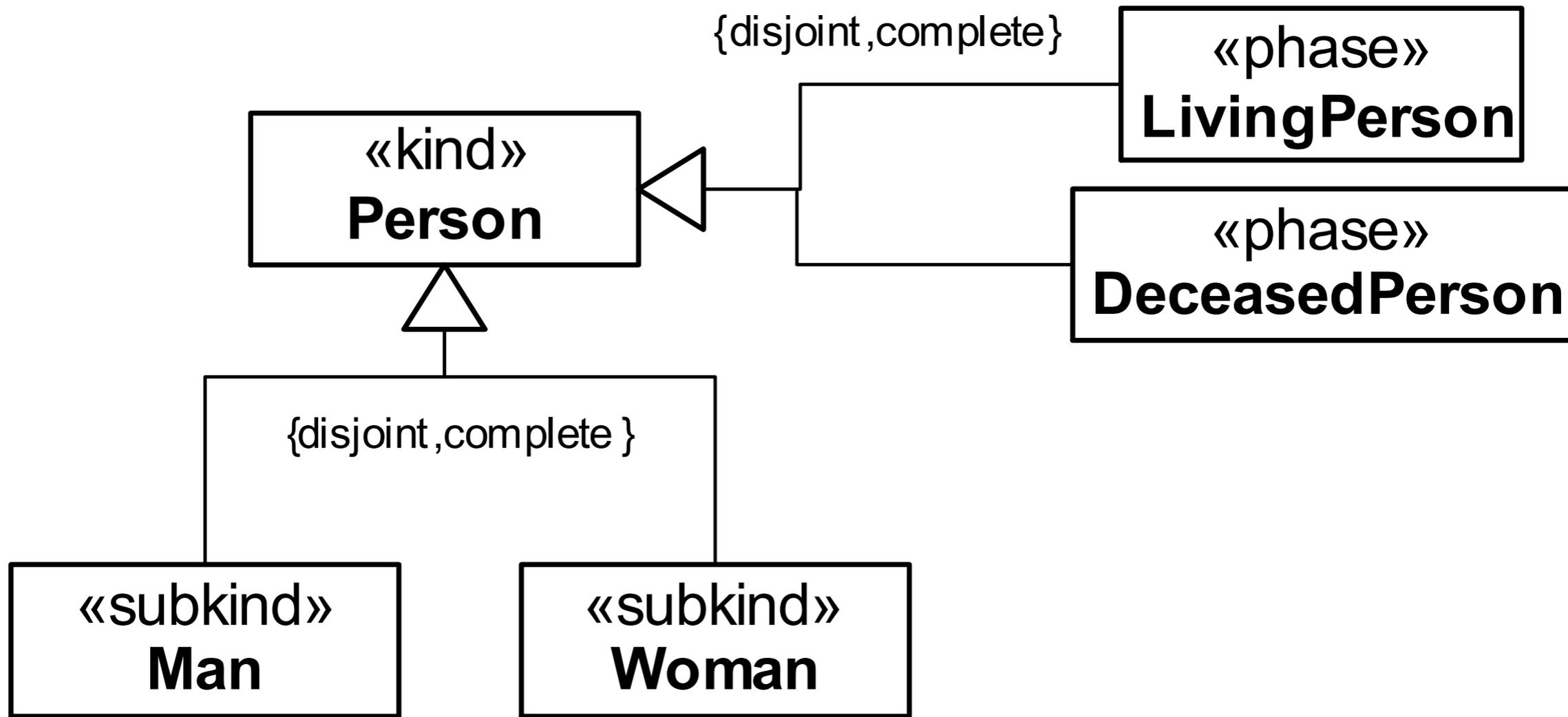


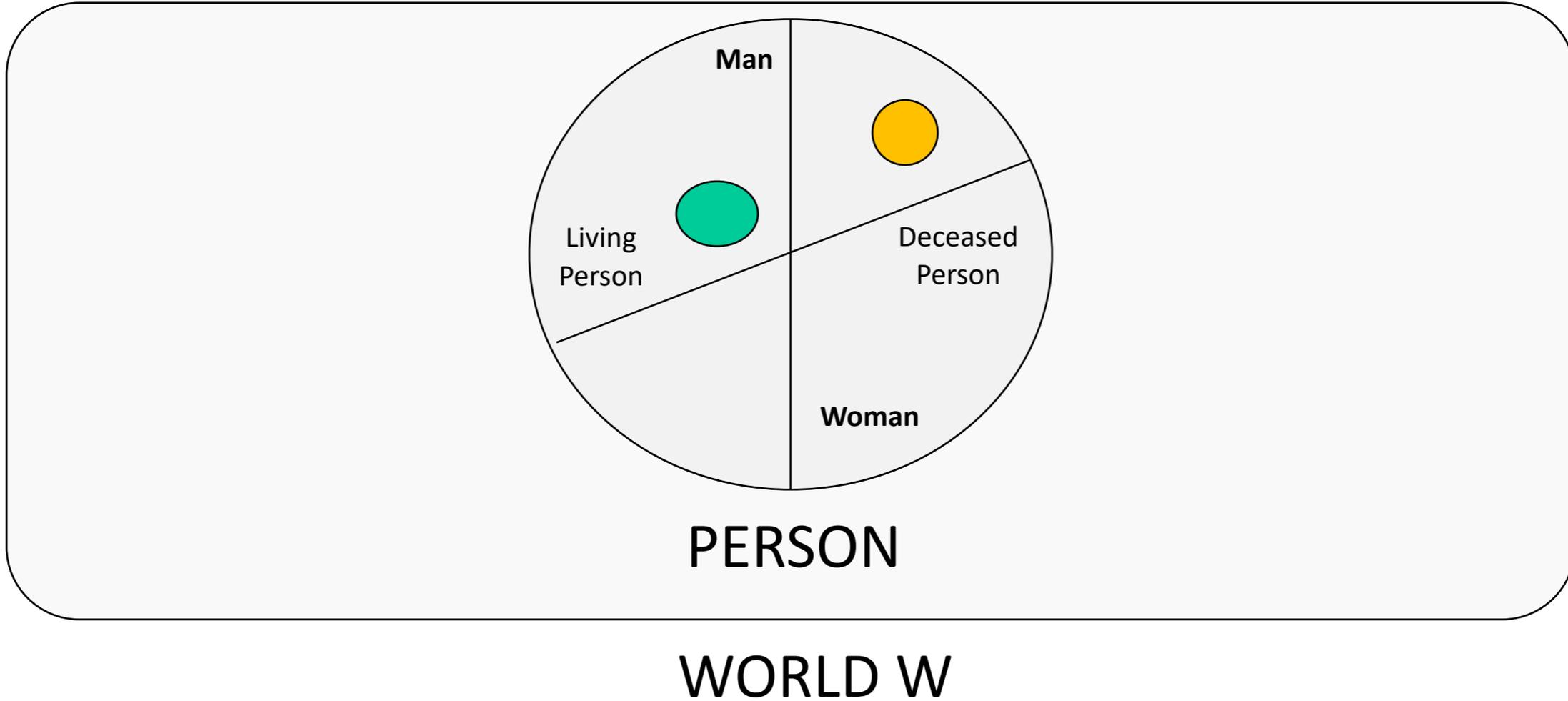
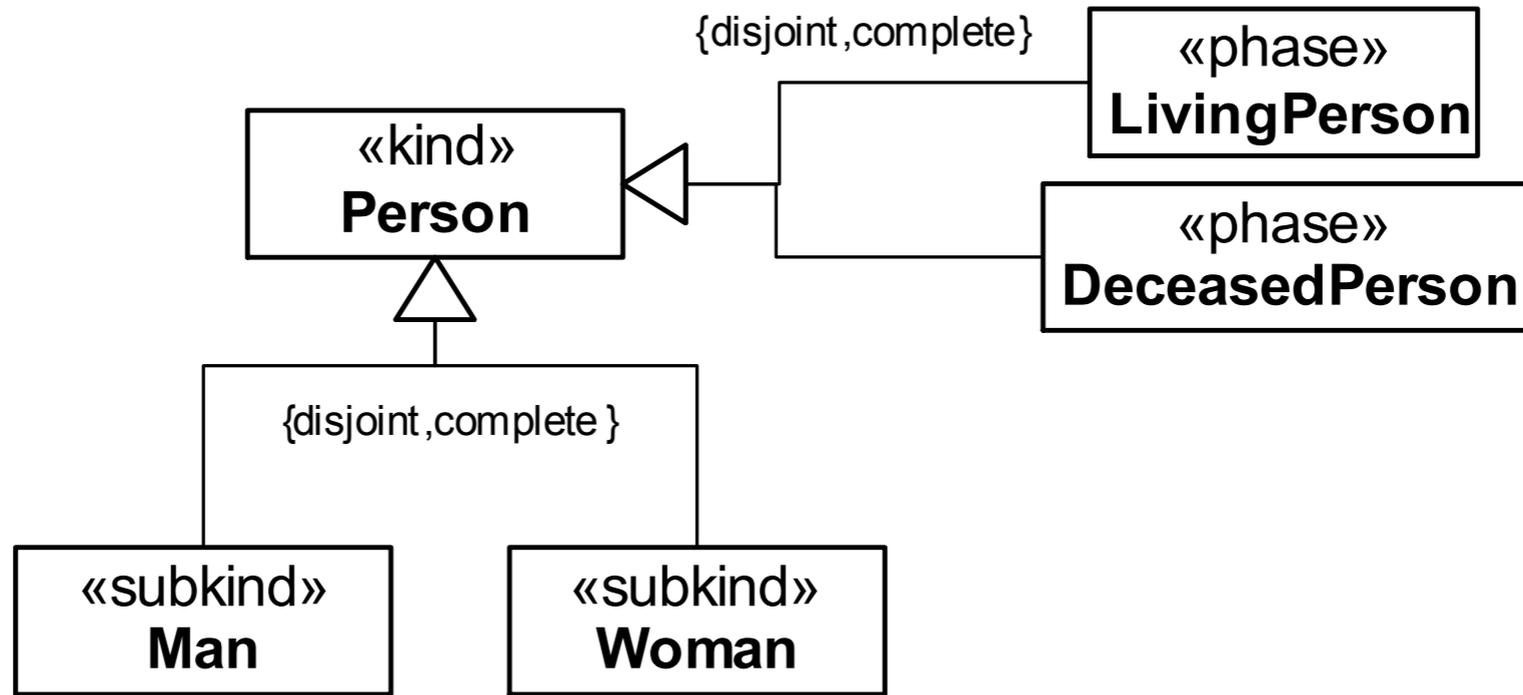


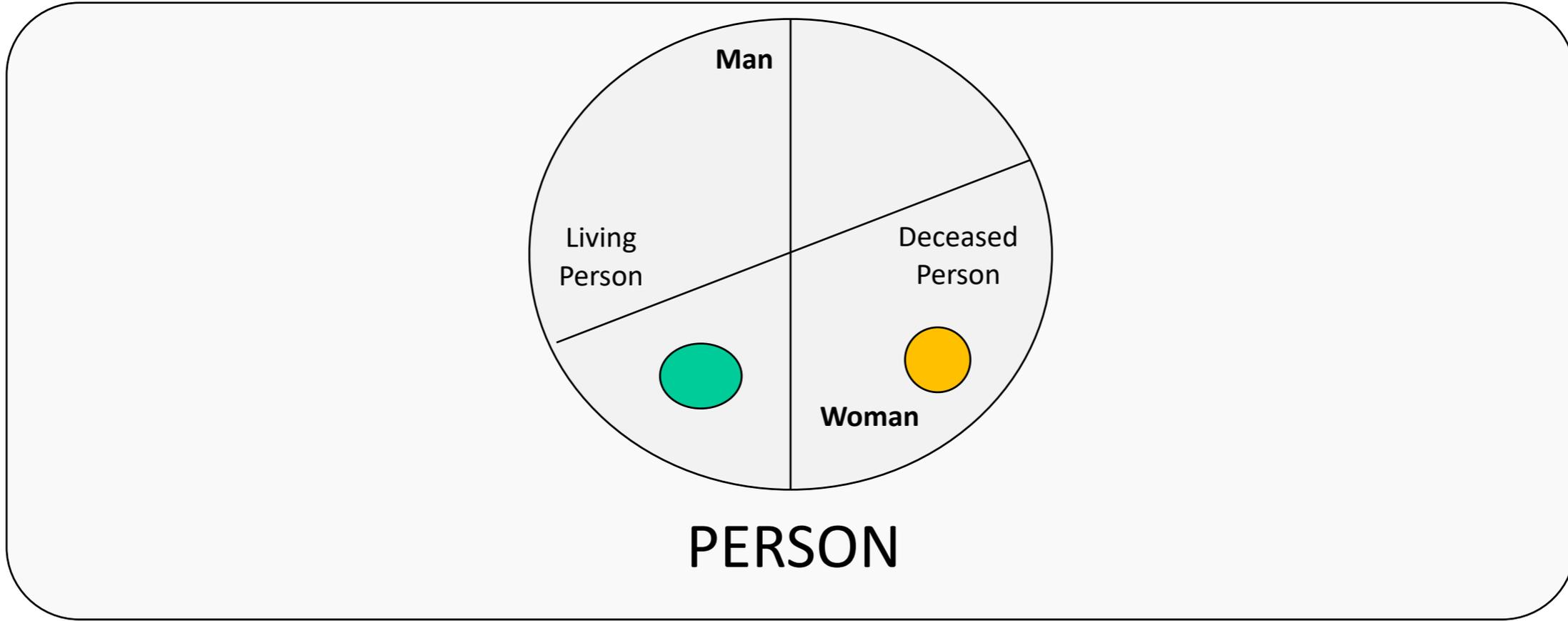
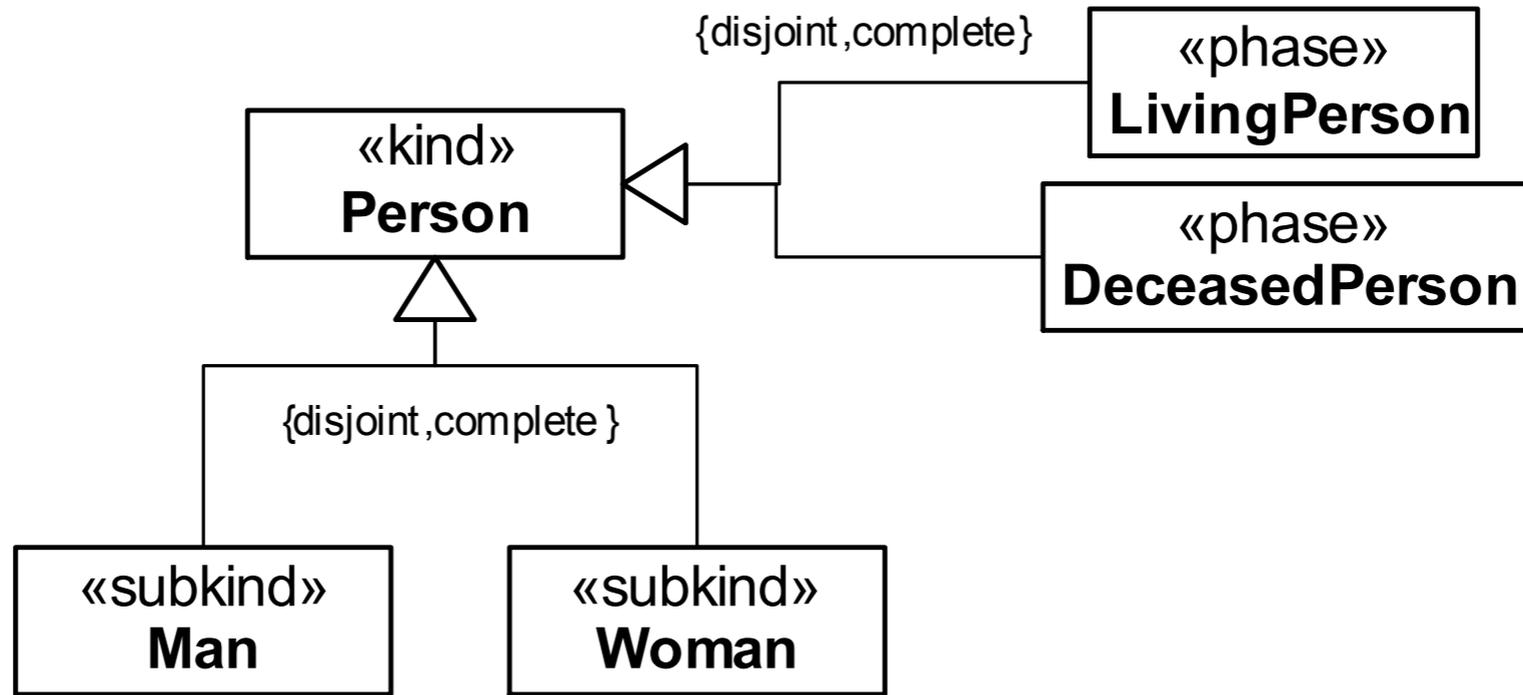
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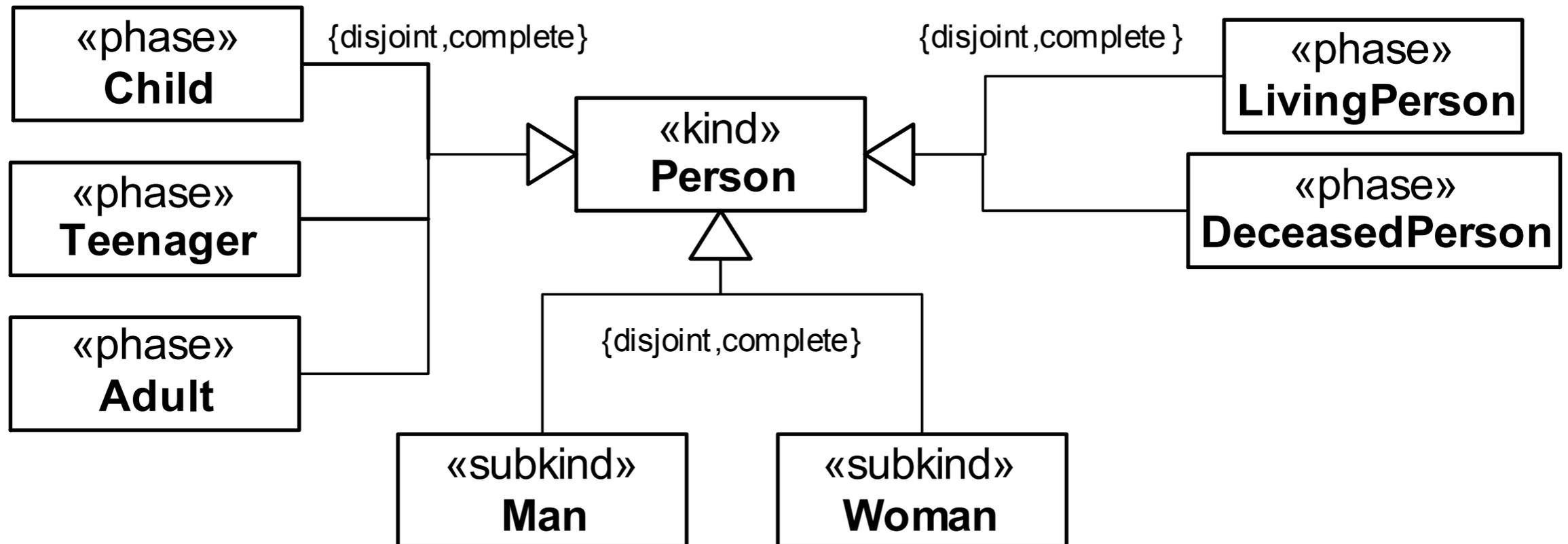


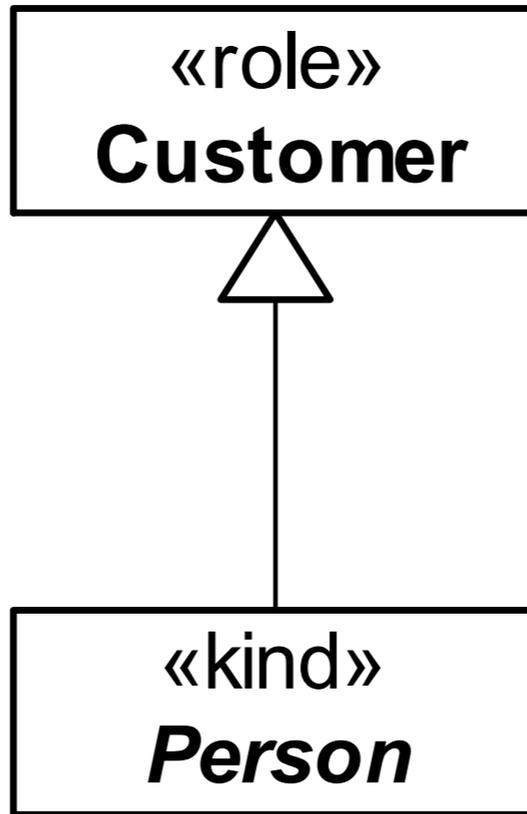


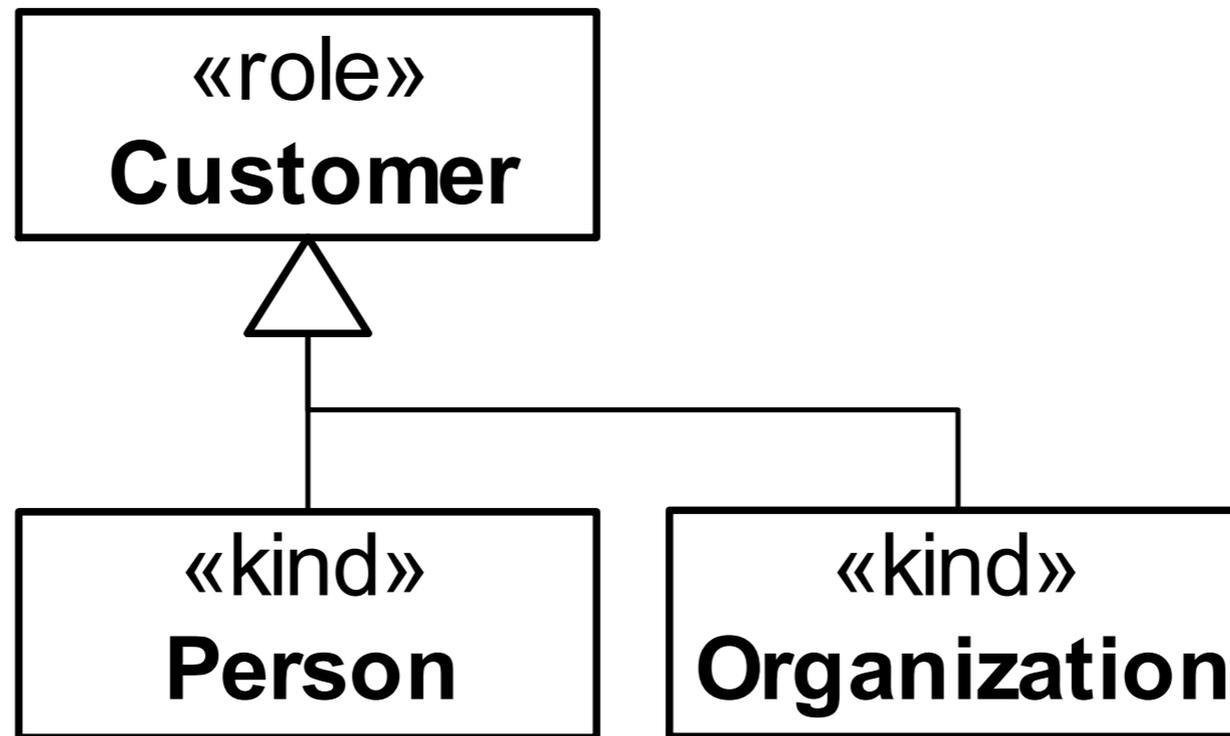


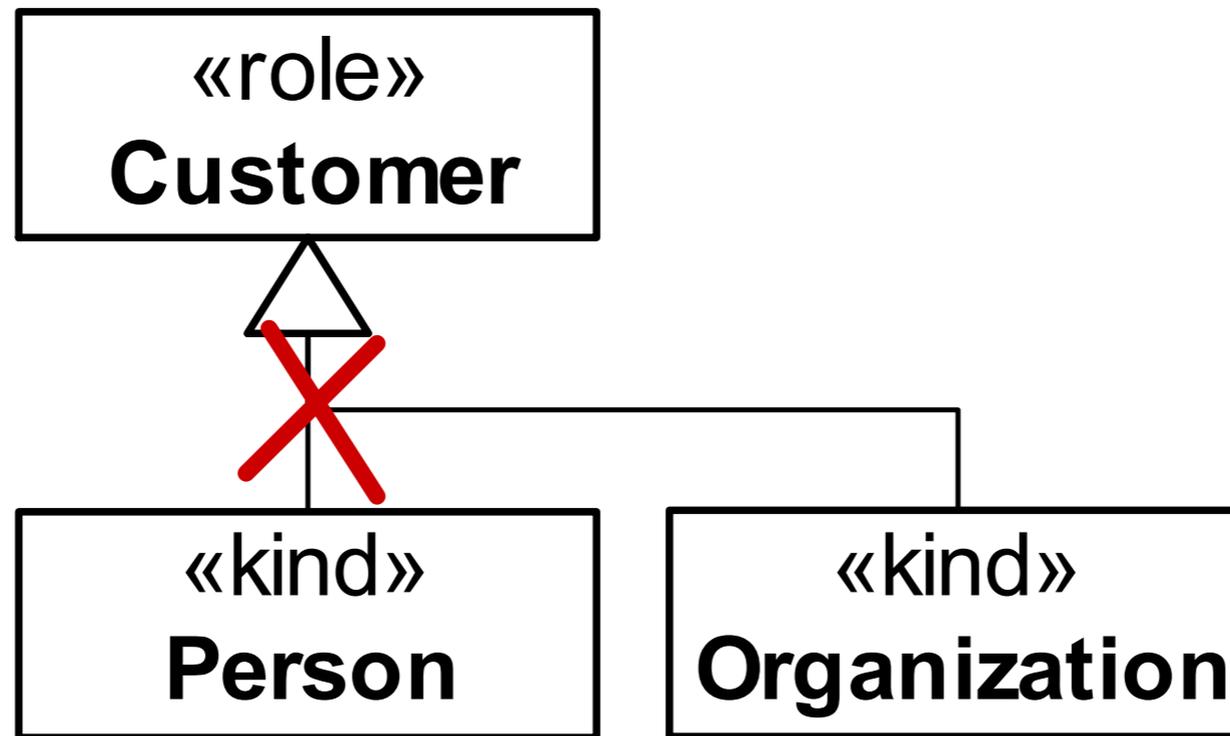


WORLD W'









An anti-rigid type cannot be a supertype of a Rigid Type

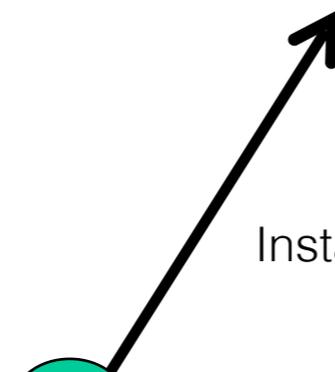
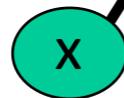
WORLD W

Customer

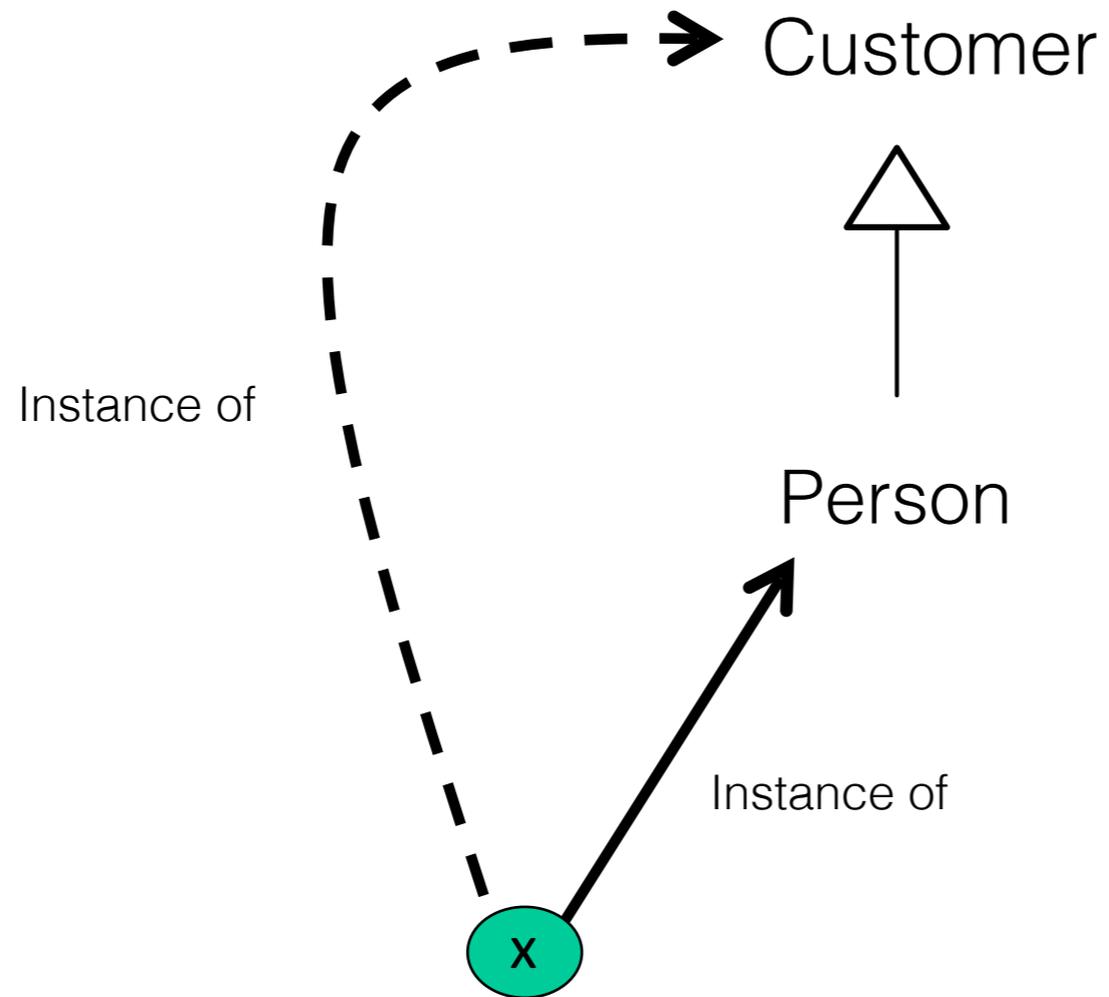


Person

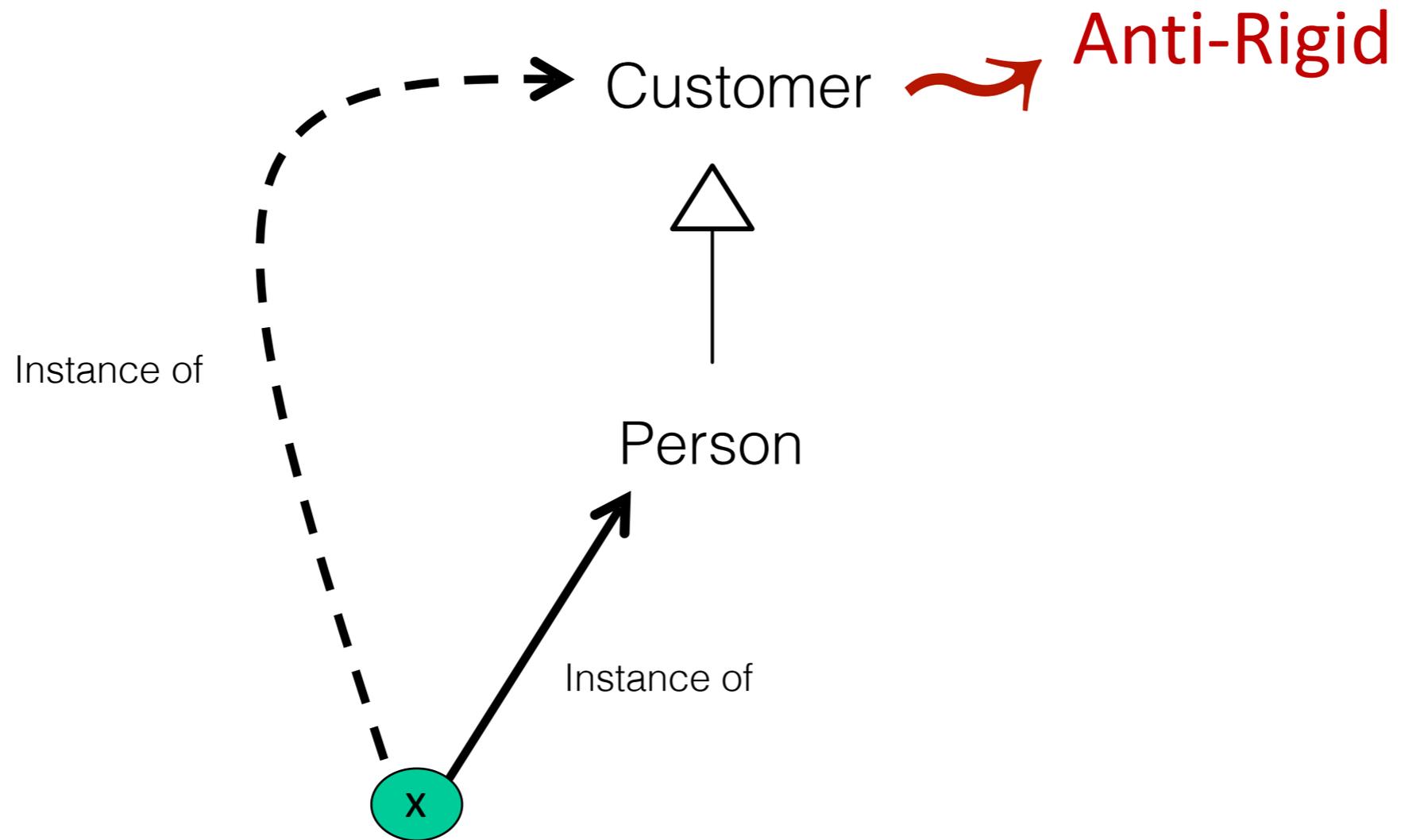
Instance of



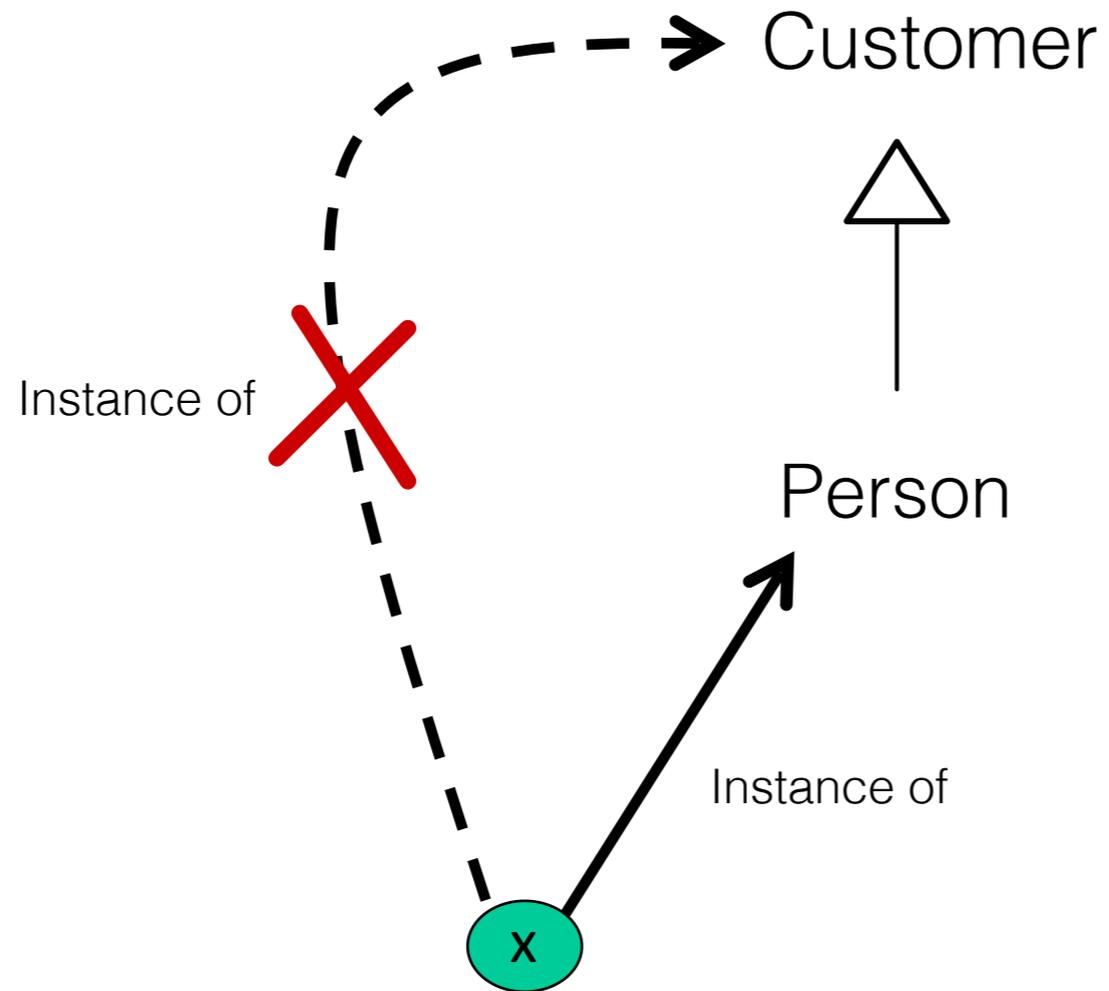
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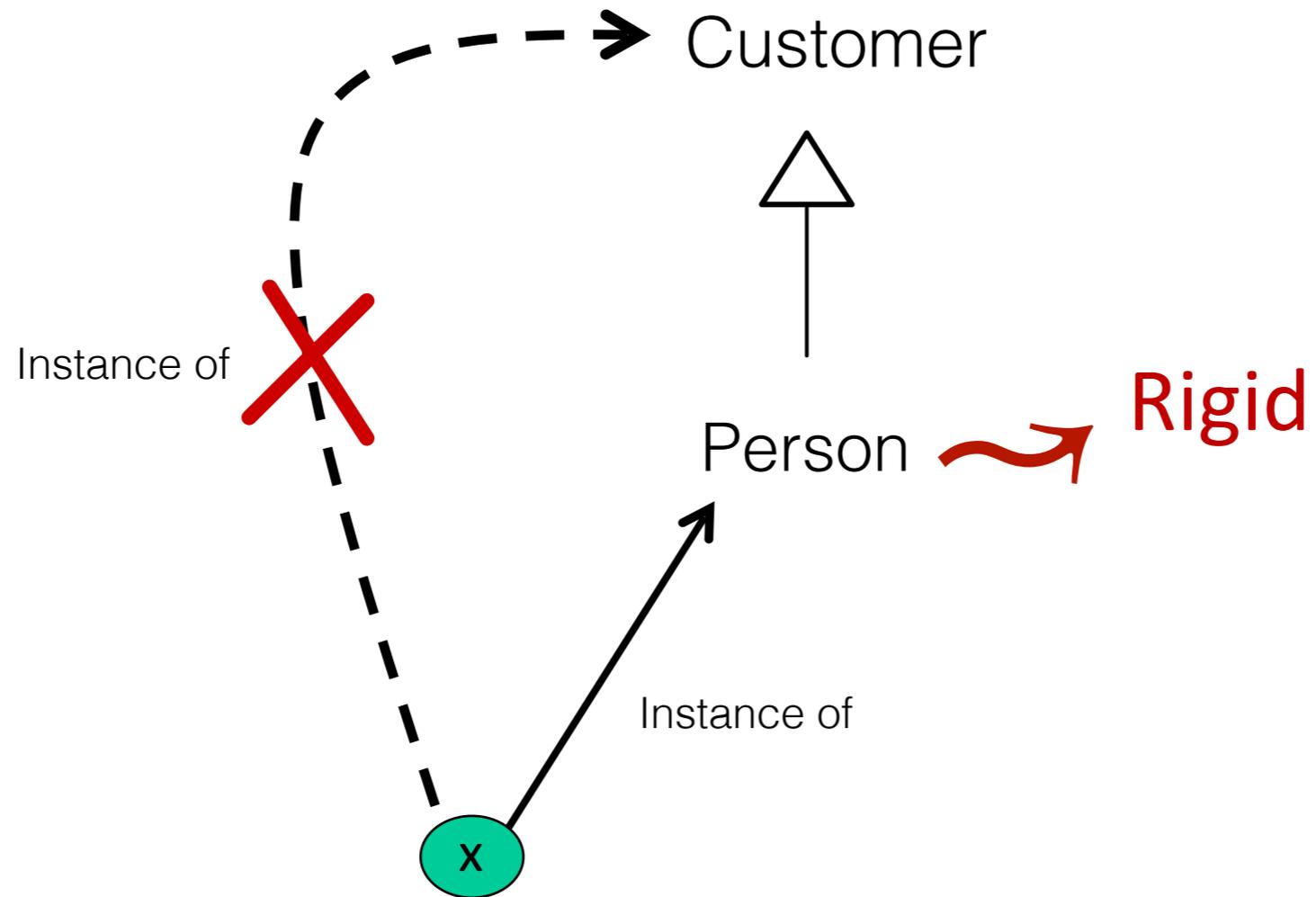
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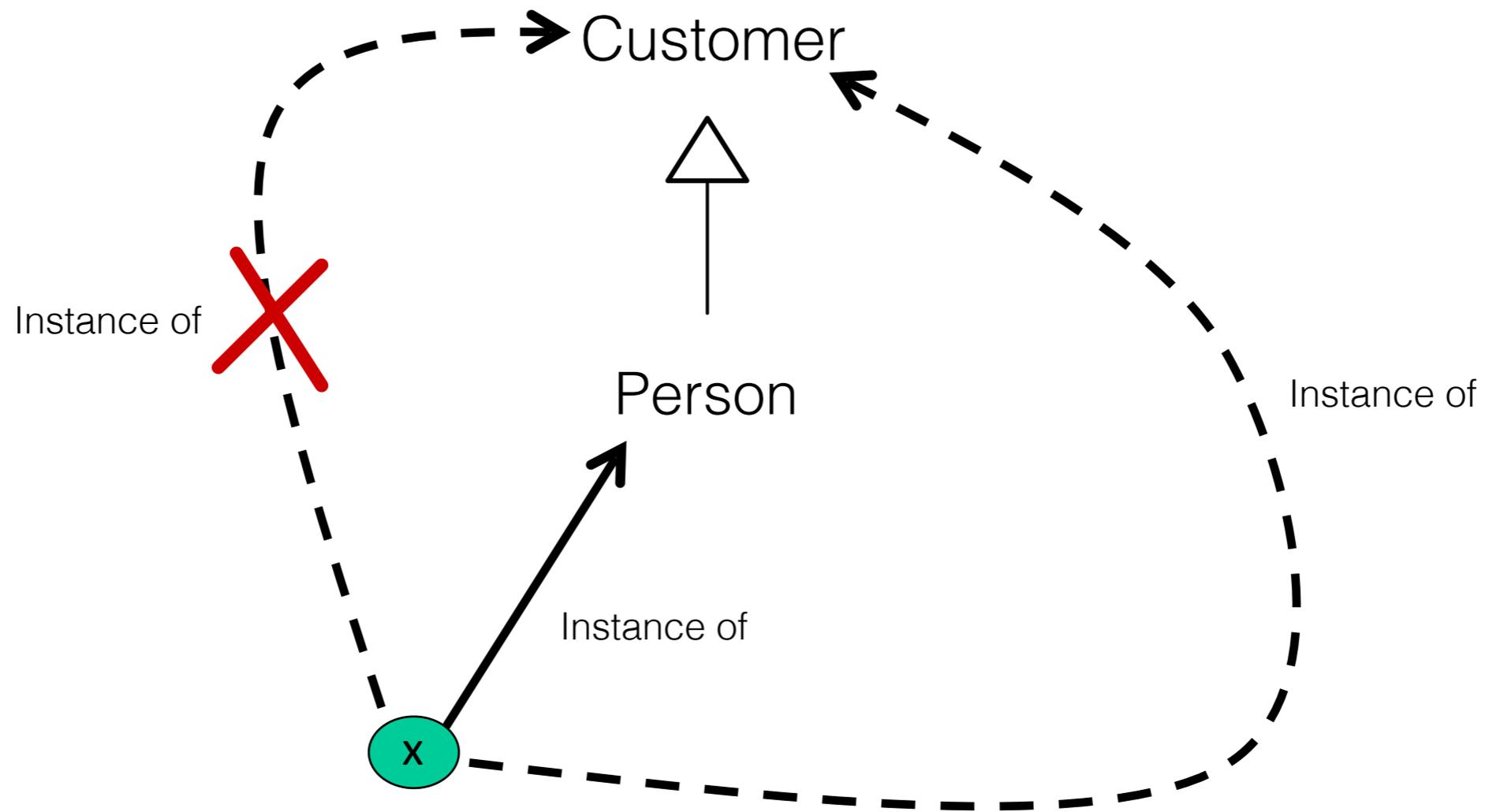
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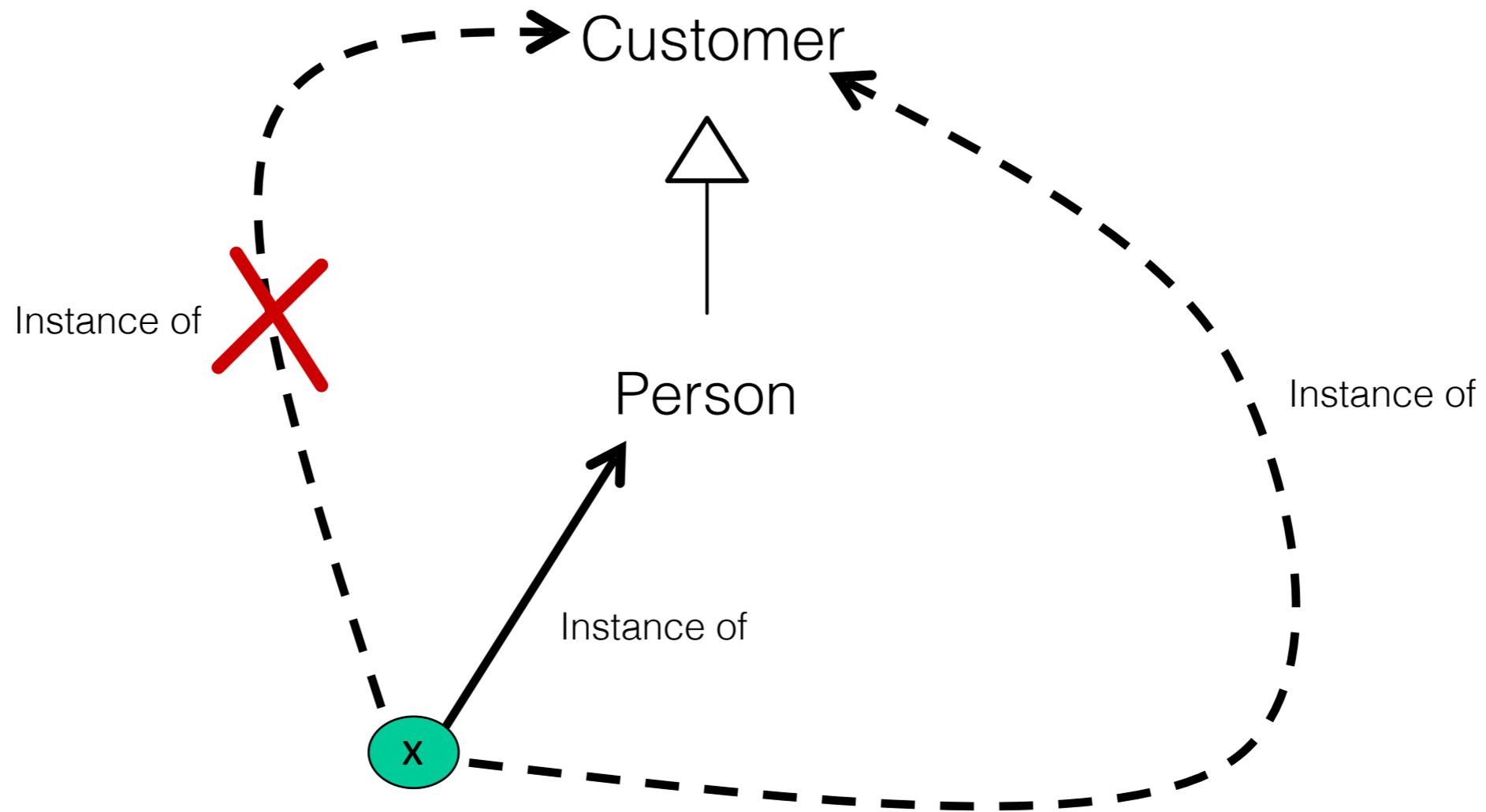
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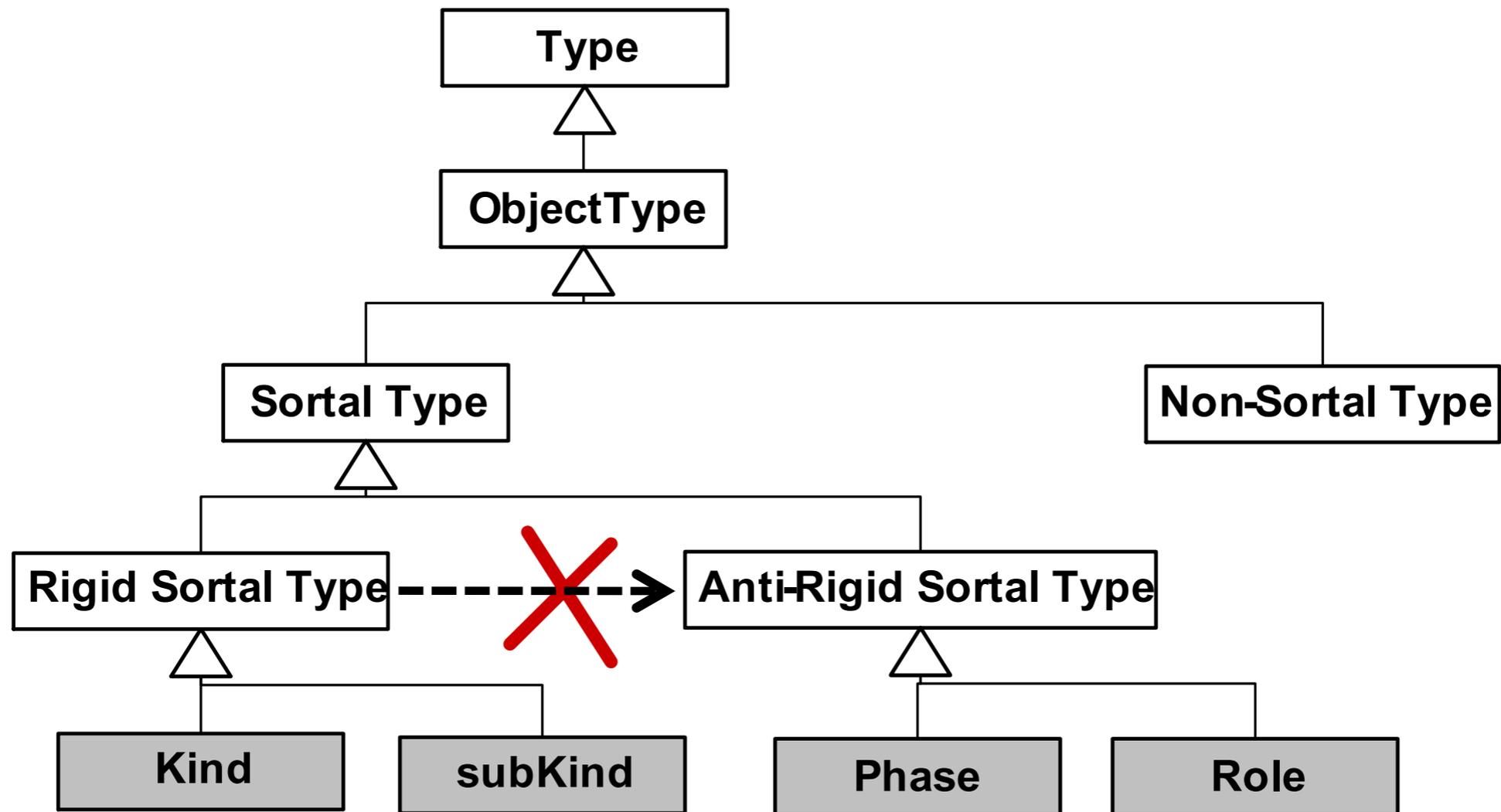
WORLD W'



WORLD W'

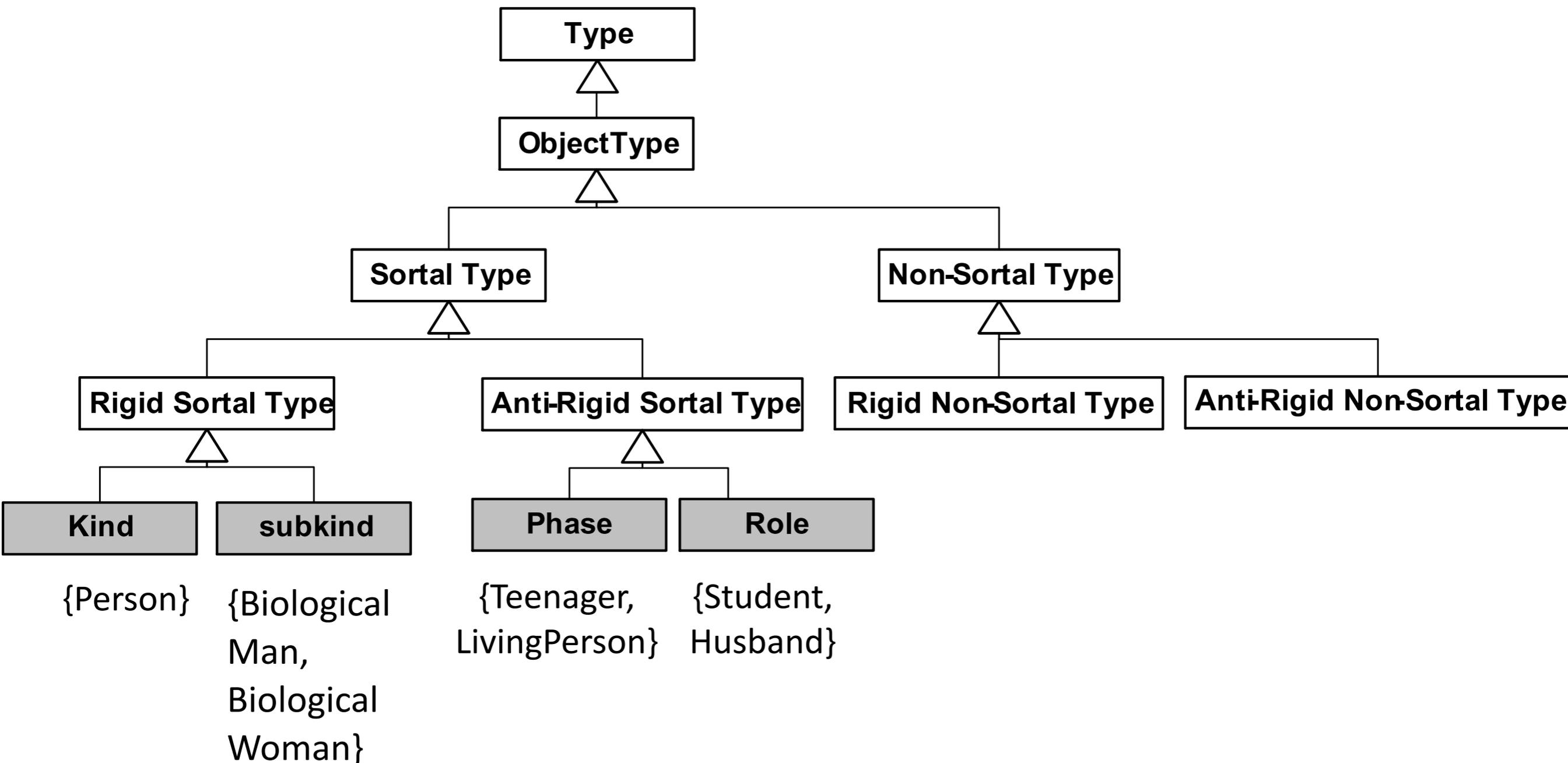


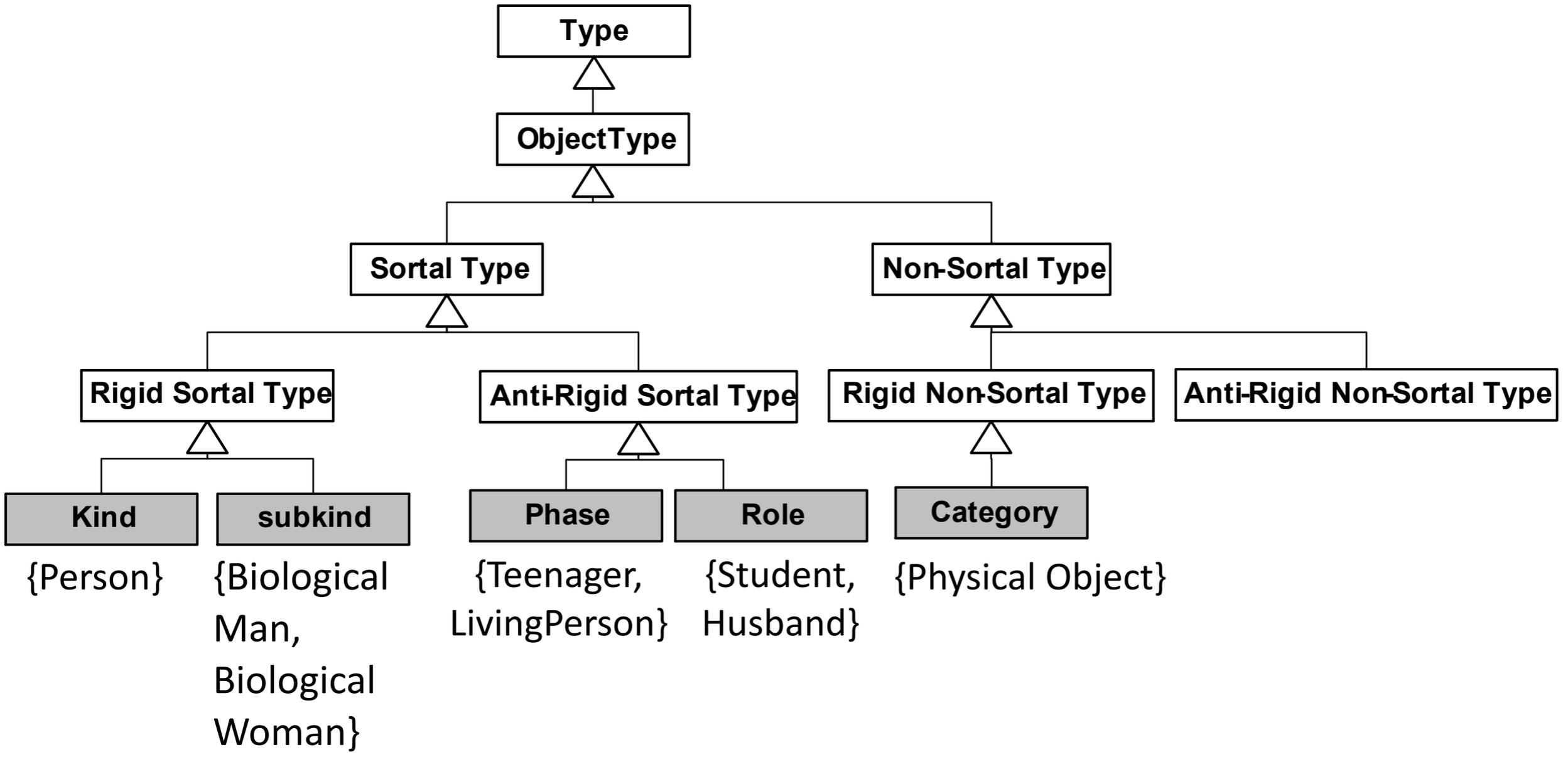
We run into a logical contradiction!



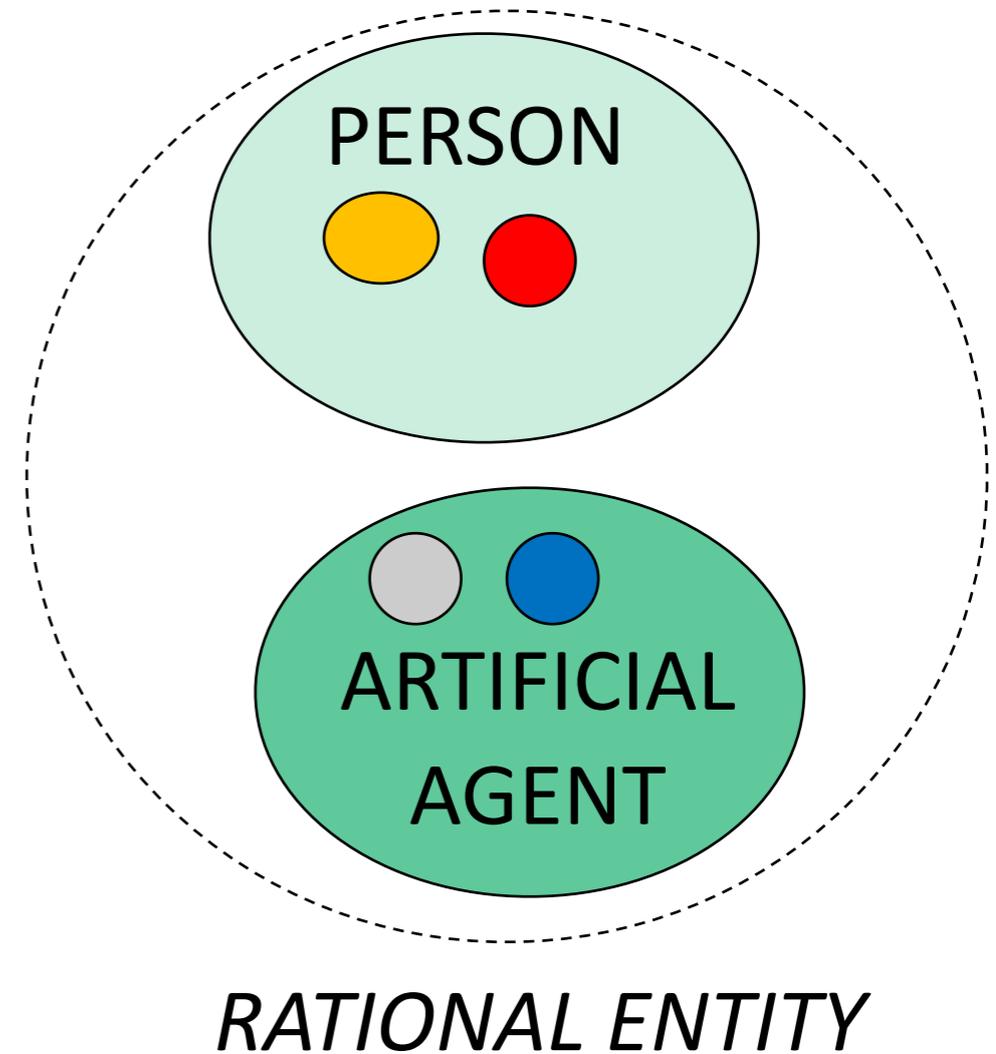
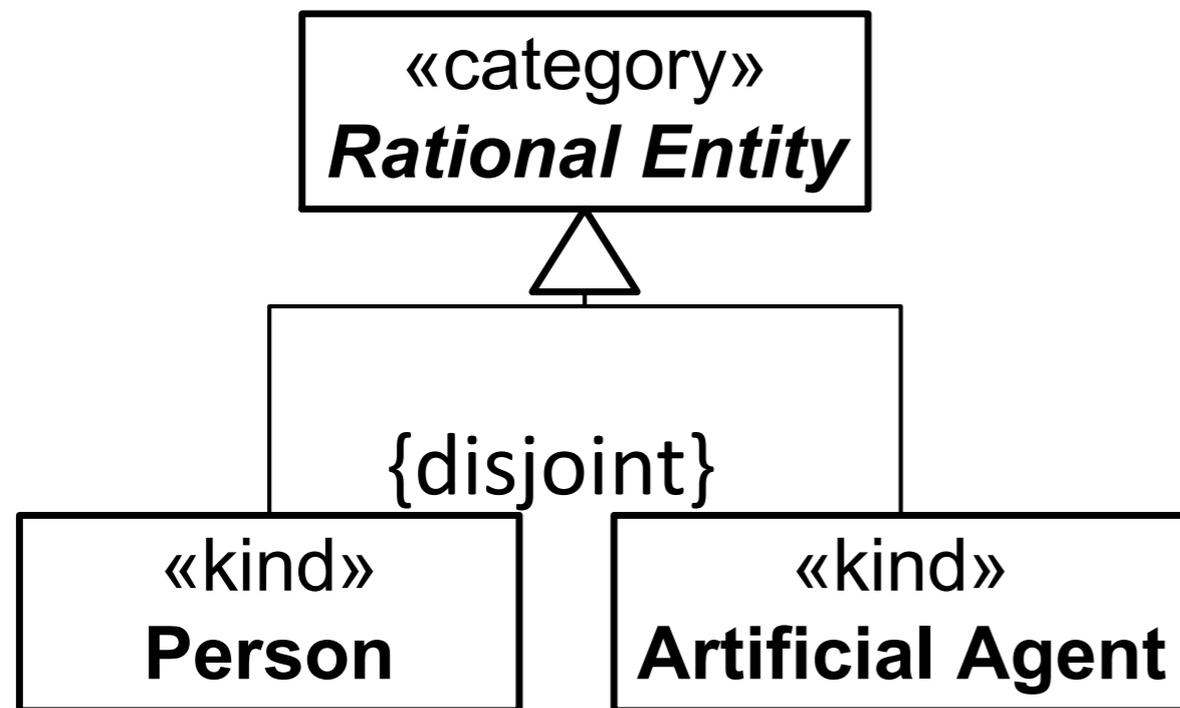
An anti-rigid type cannot be a supertype of a Rigid Type

Meta-types	Identity	Rigidity	Dependence
SORTAL			
kind		+	-
Subkind	+	+	-
Phase	+	-	-
Role	+	-	+
NON-SORTAL			

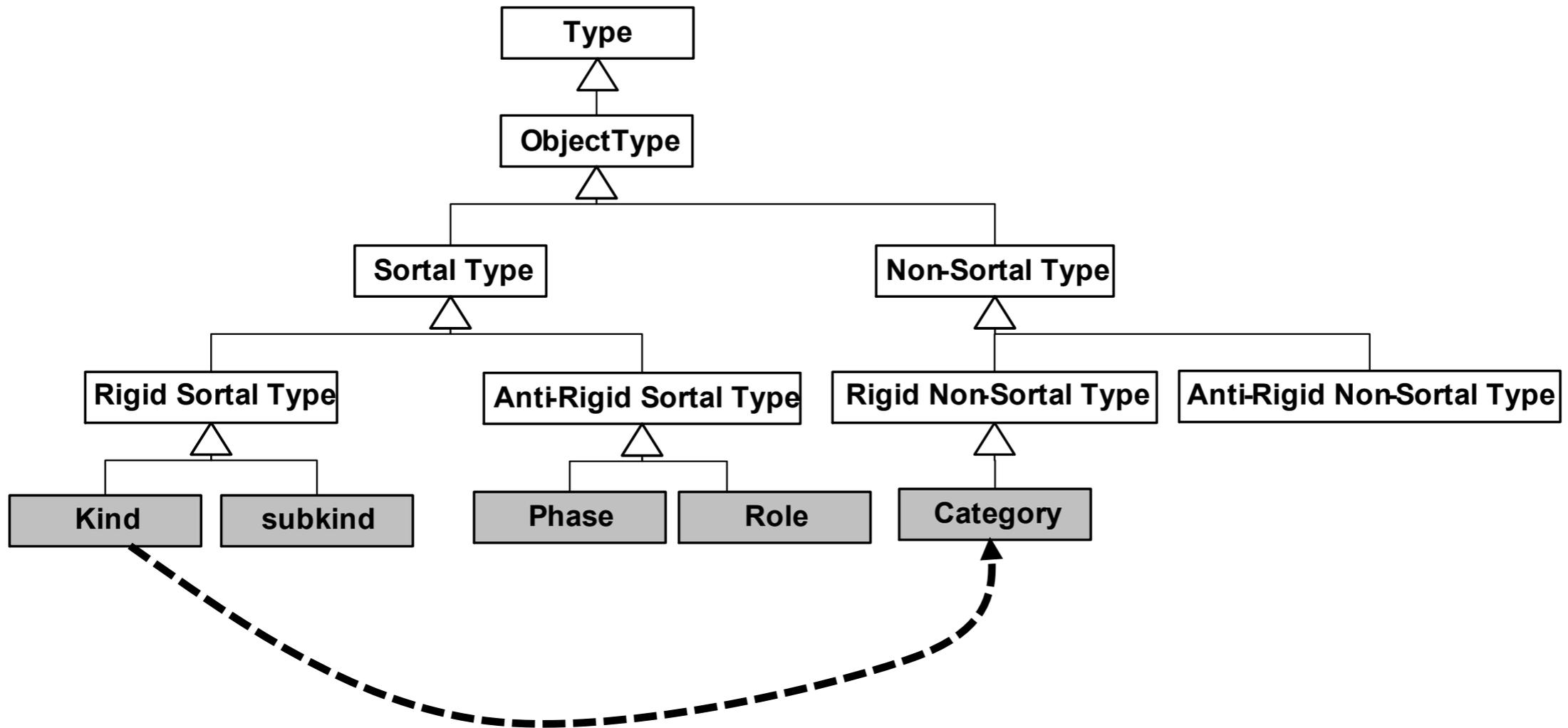




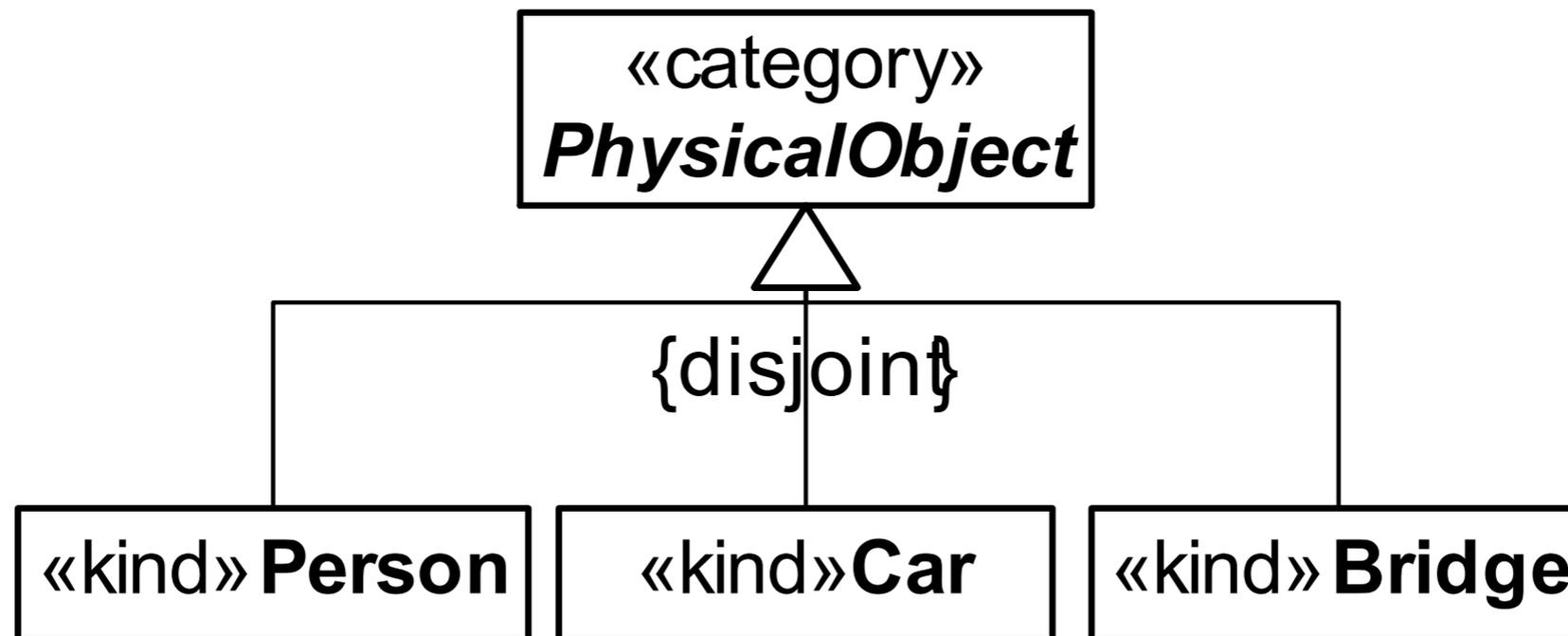
Categories

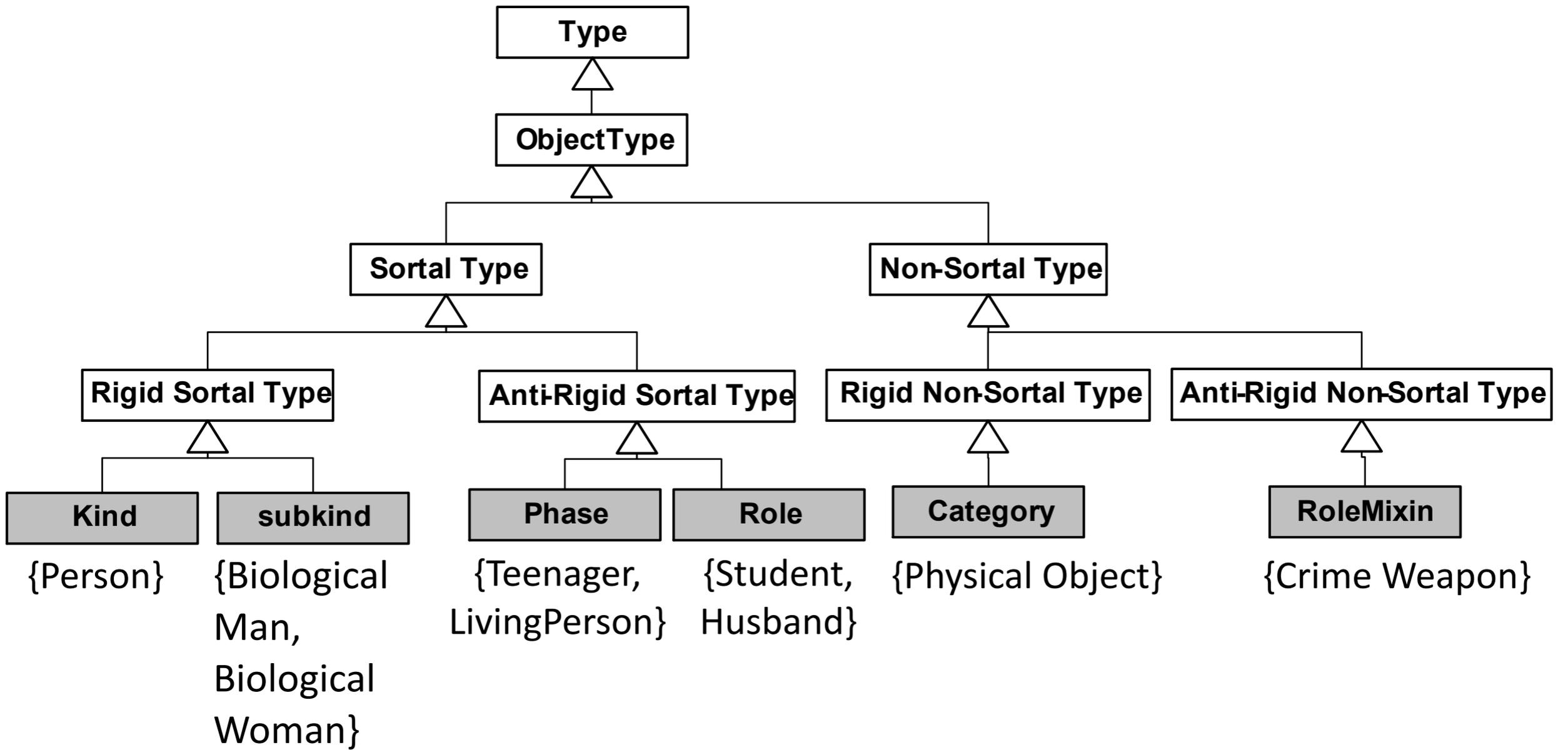


Categories



Categories

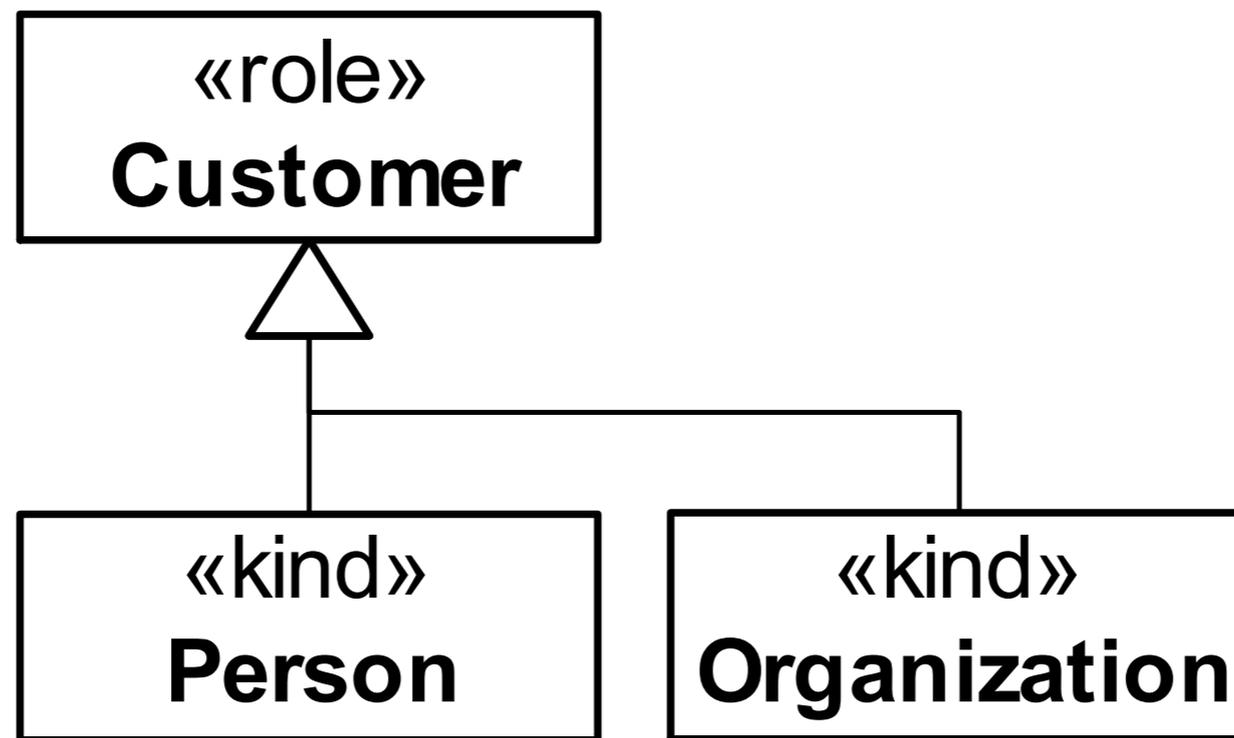


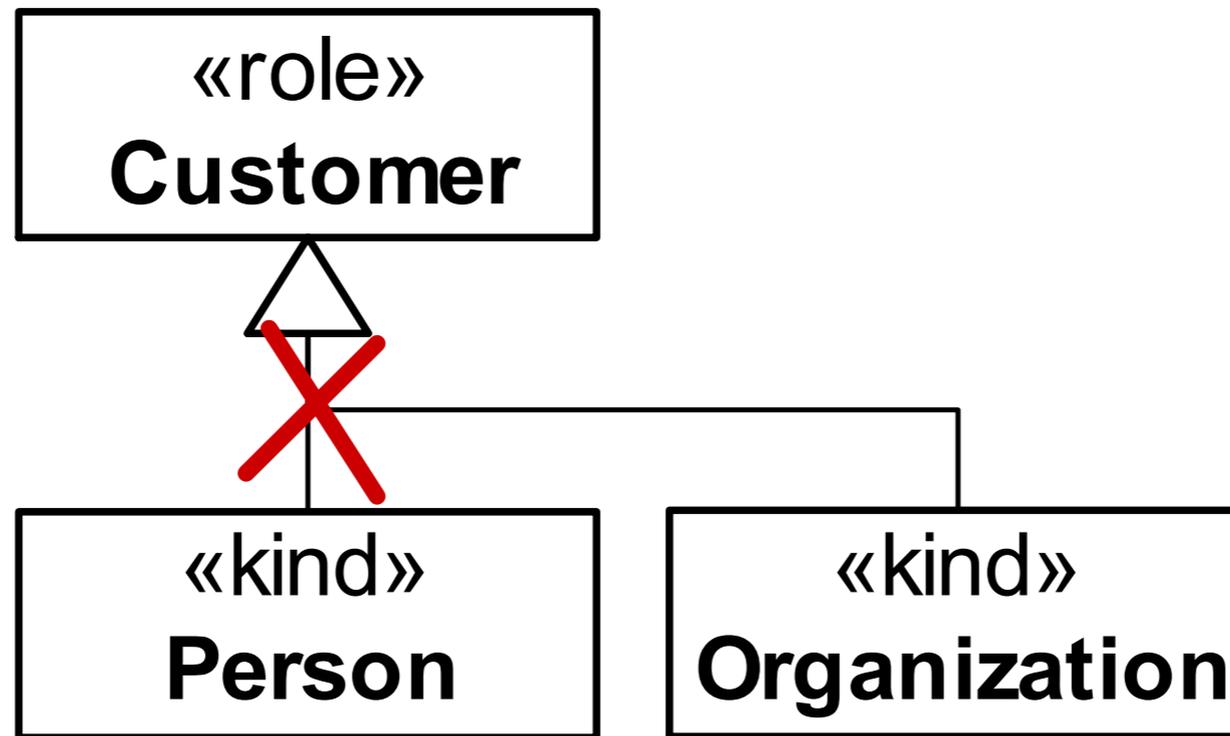


A Classic Problem

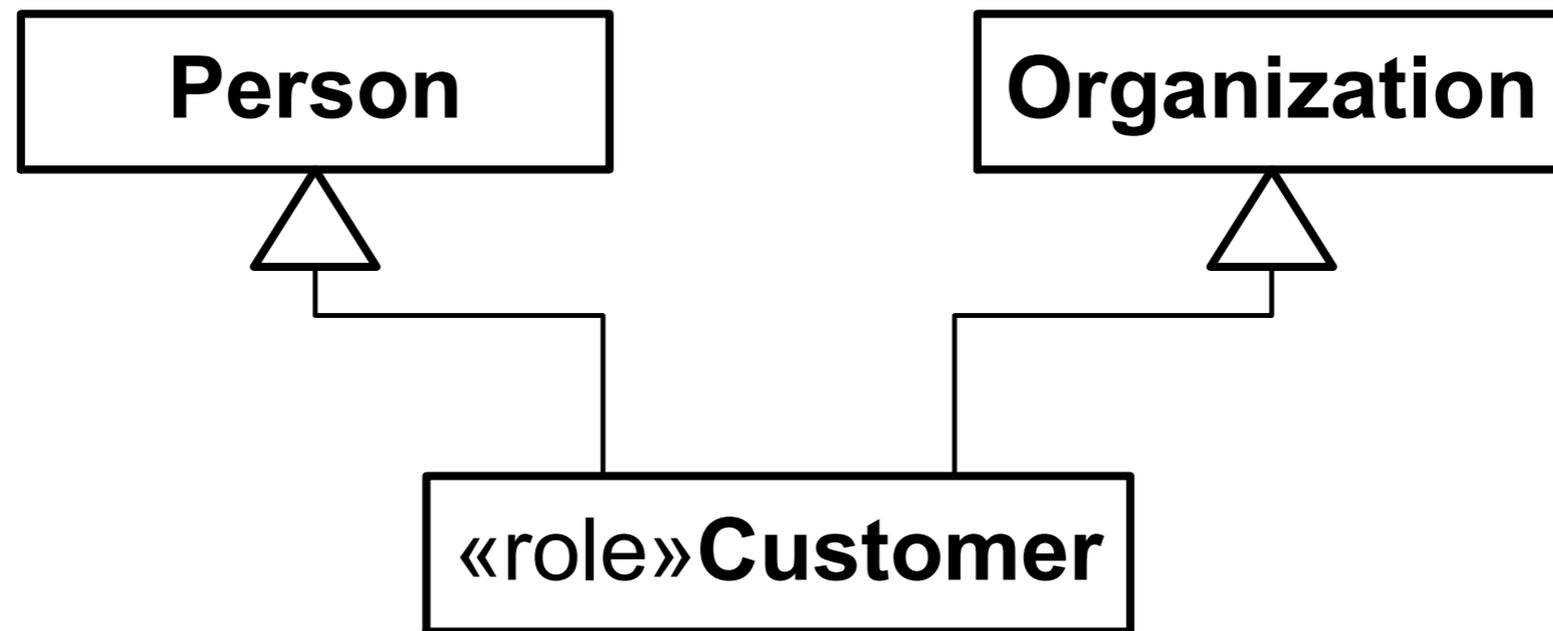
1. Suppose that I want to represent that the ROLE Customer can be played by entities of different KINDS, namely, People and Organizations. How to relate the ROLE and its *allowed types* using subtyping relations?

A Classic Problem

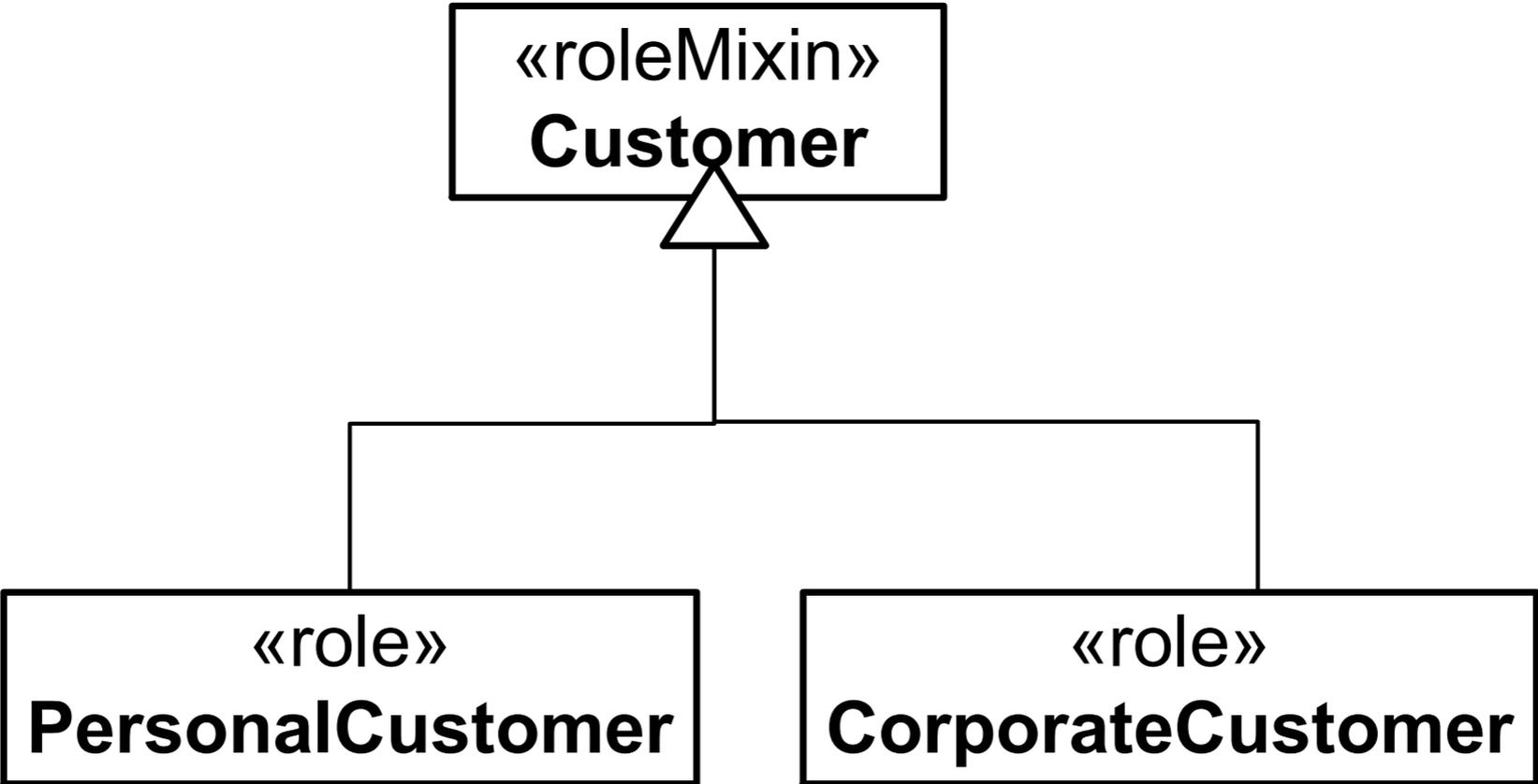


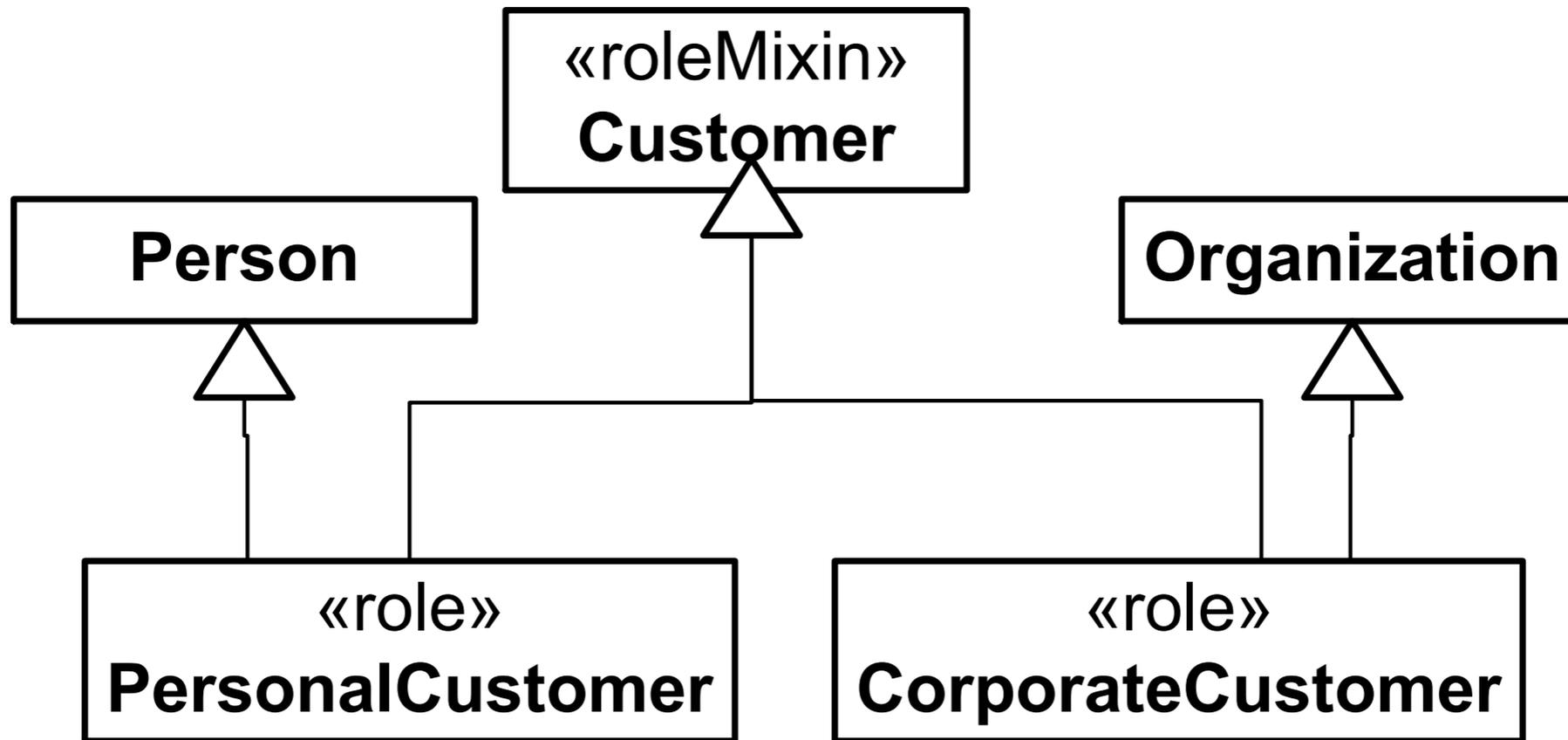


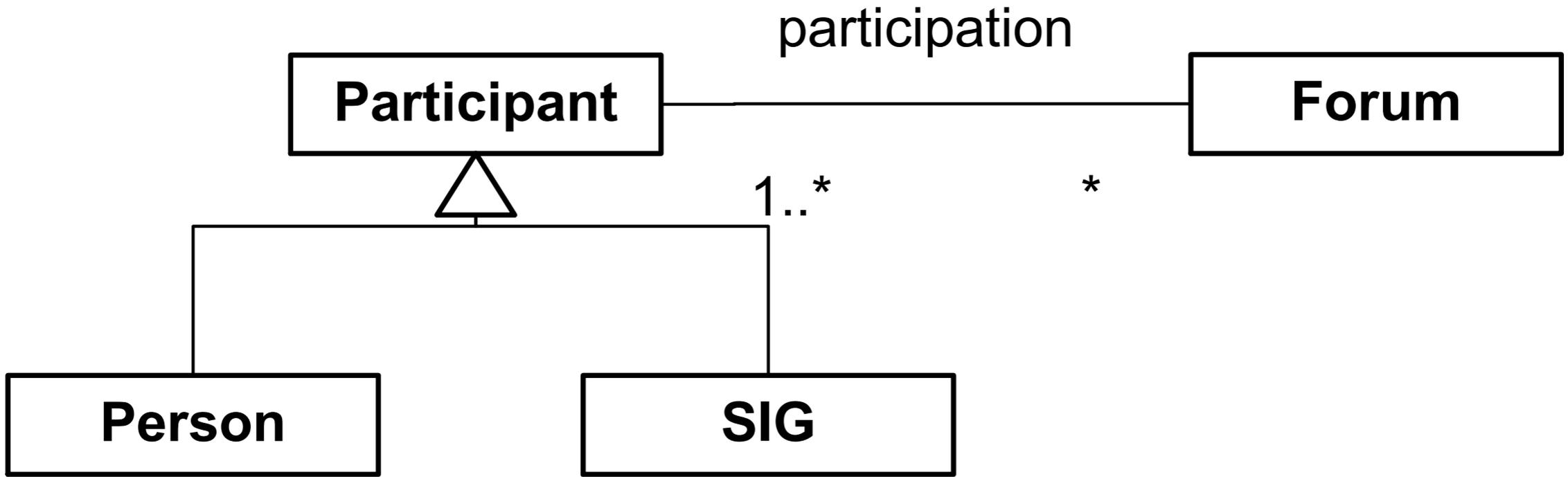
A Possible Alternative?

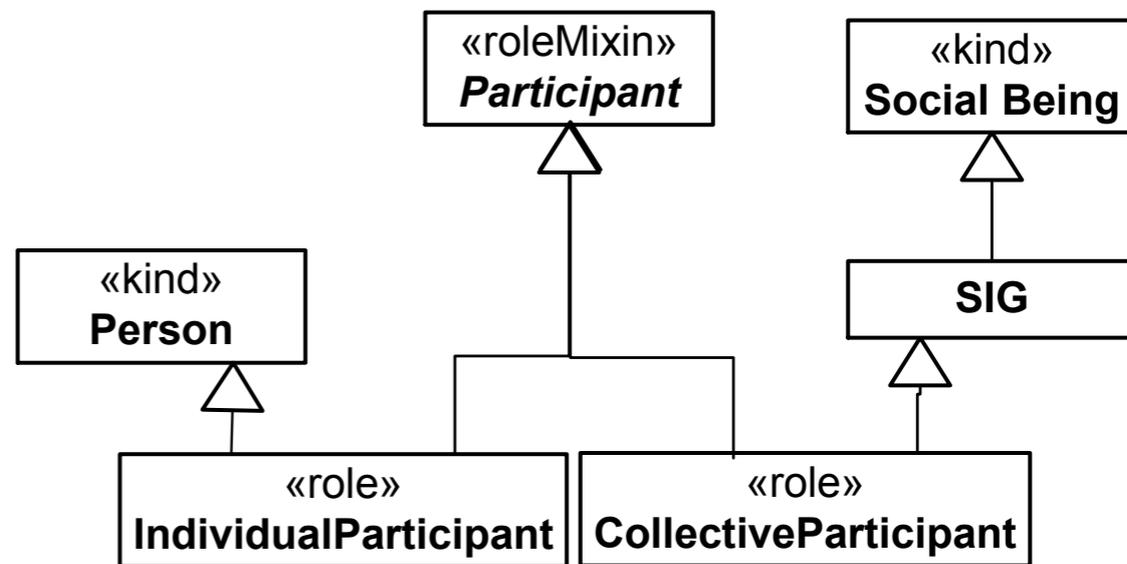
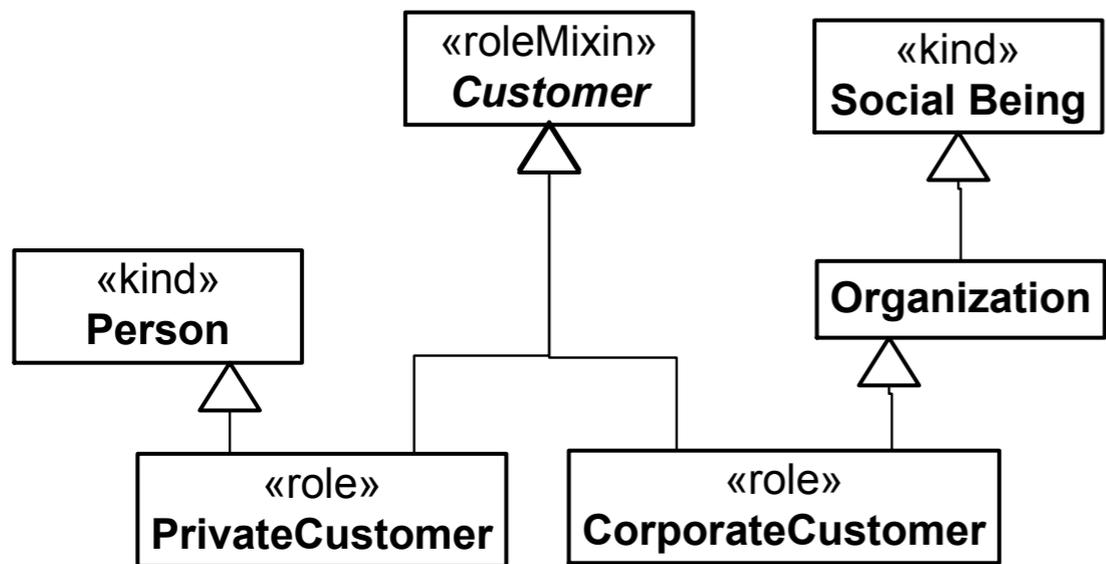


«roleMixin»
Customer

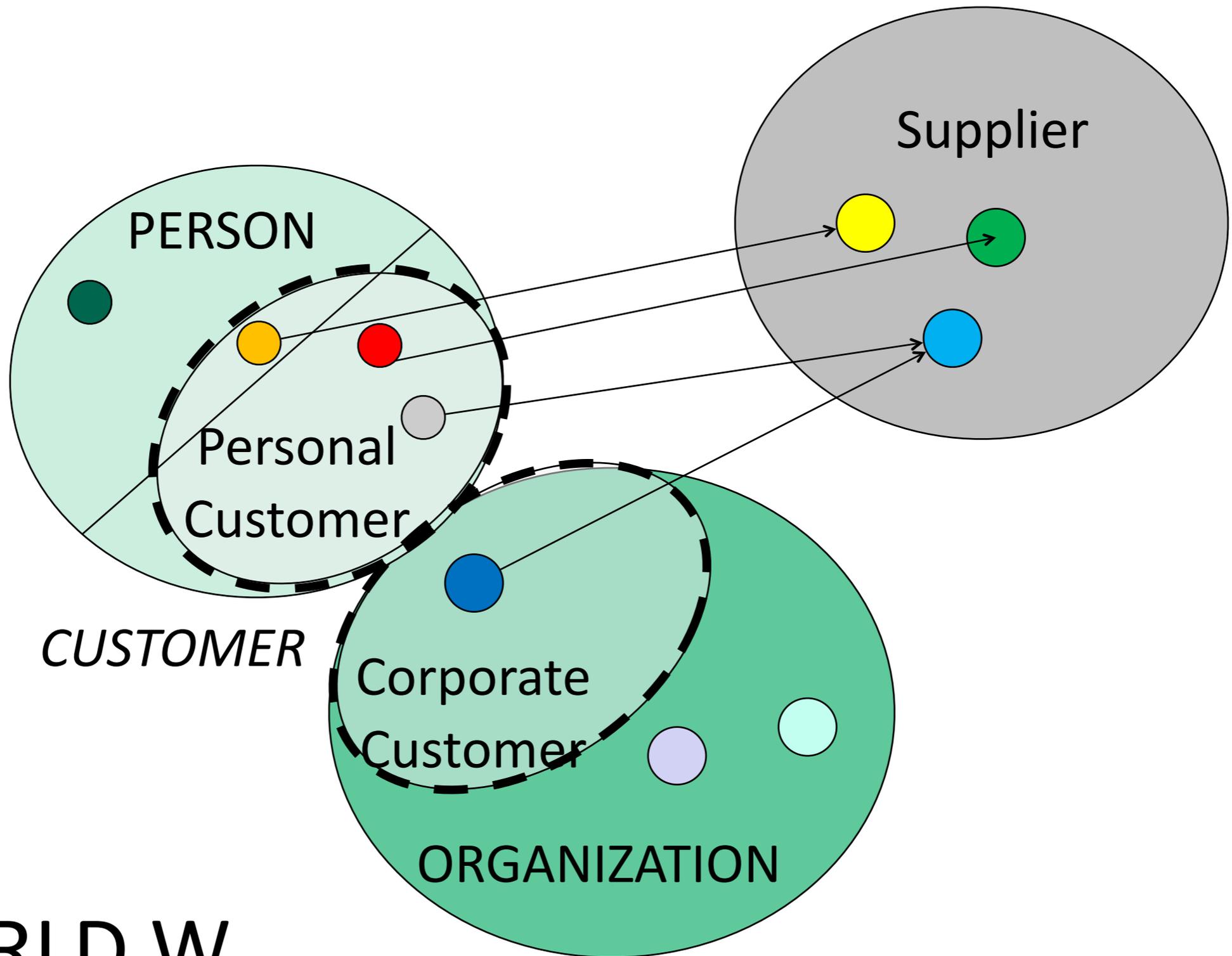




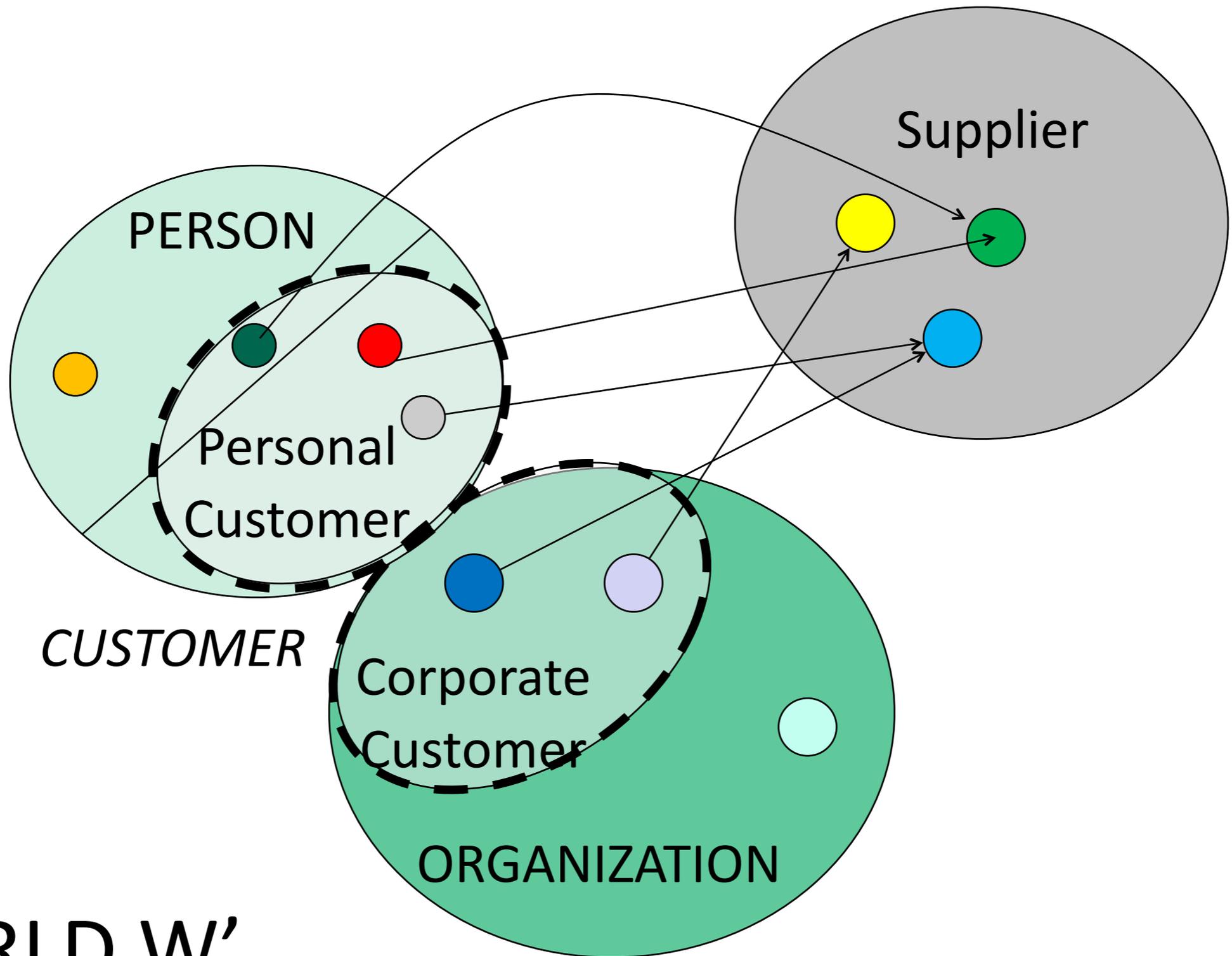




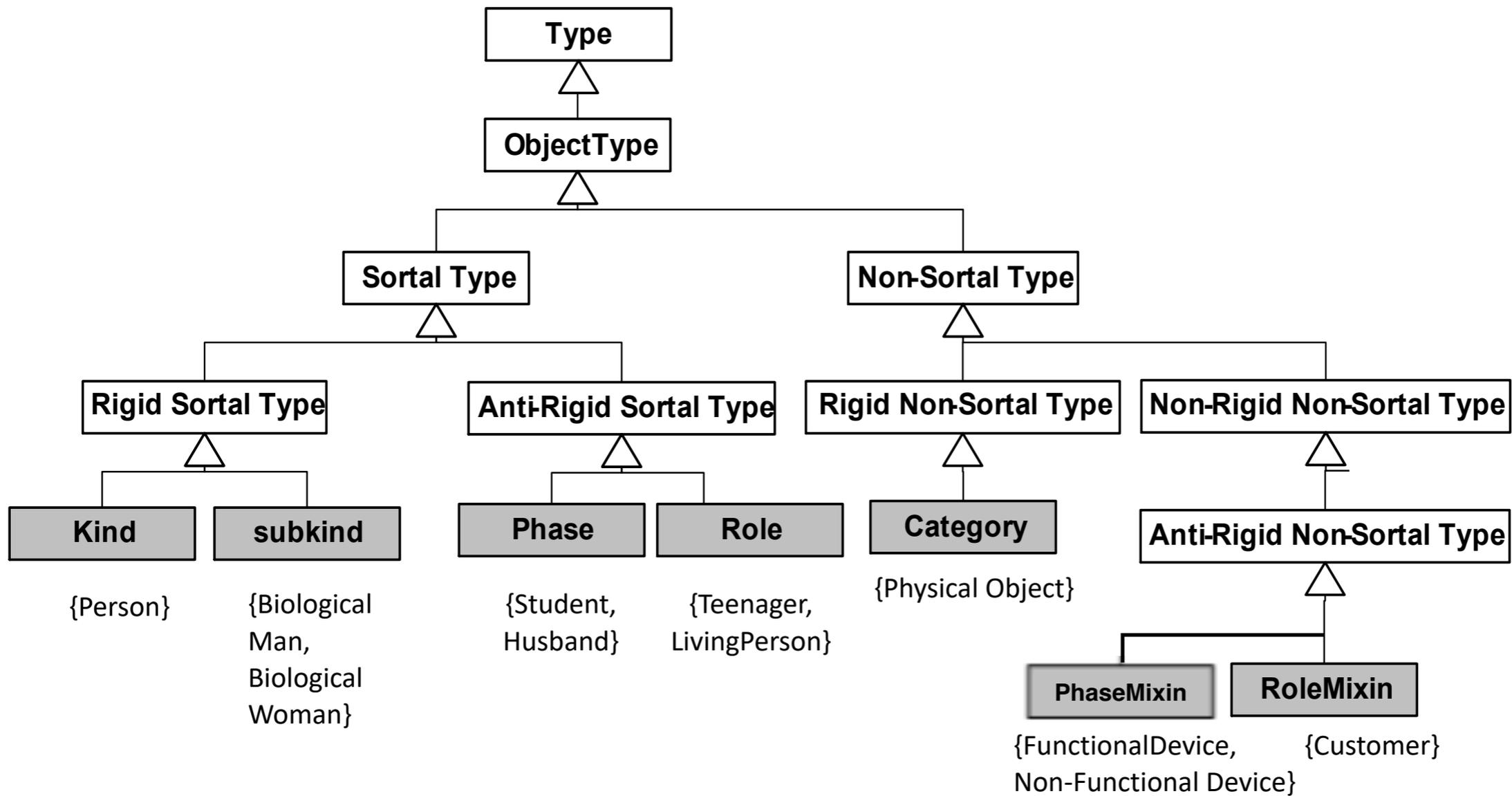
RoleMixin



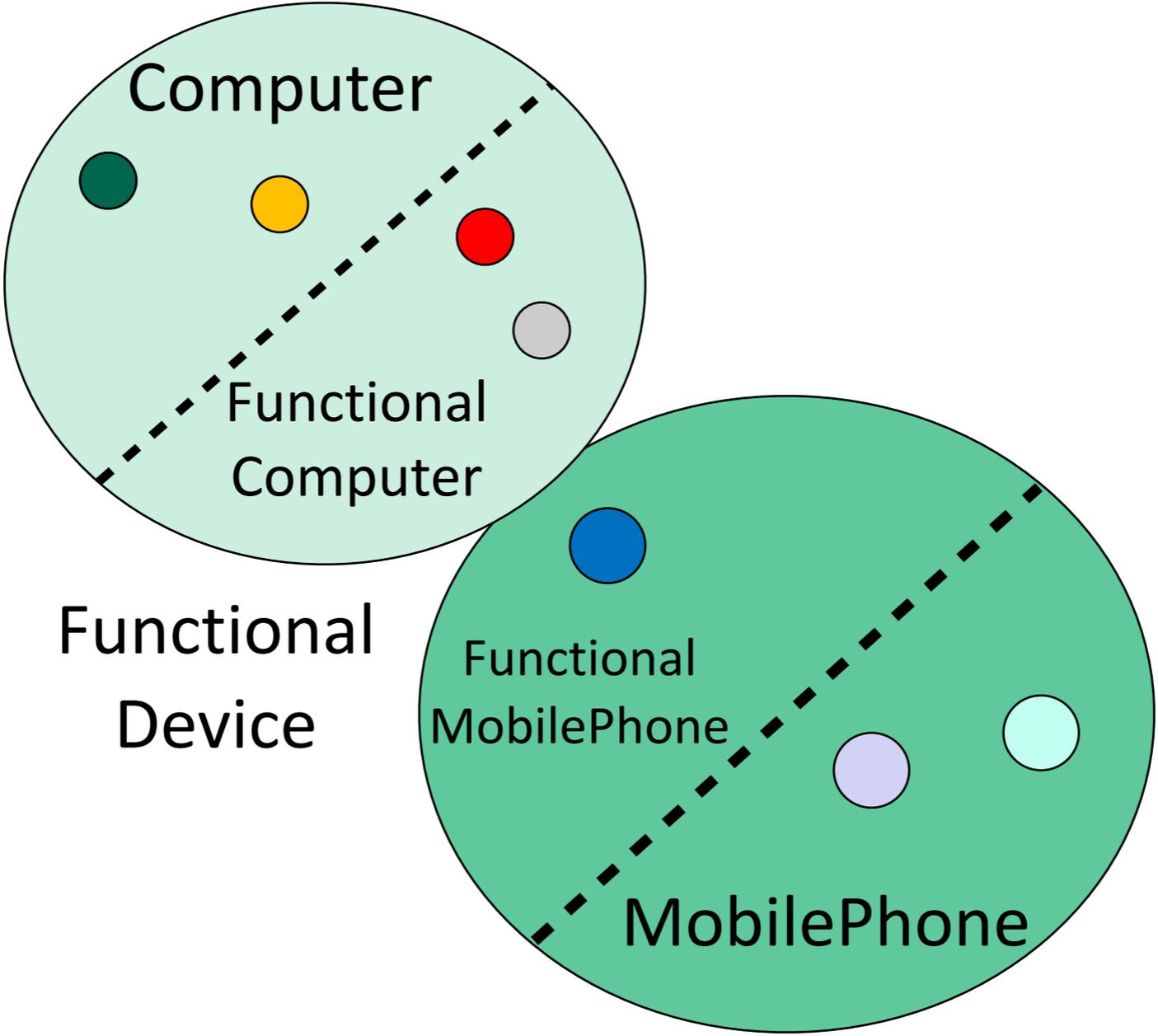
RoleMixin



WORLD W'

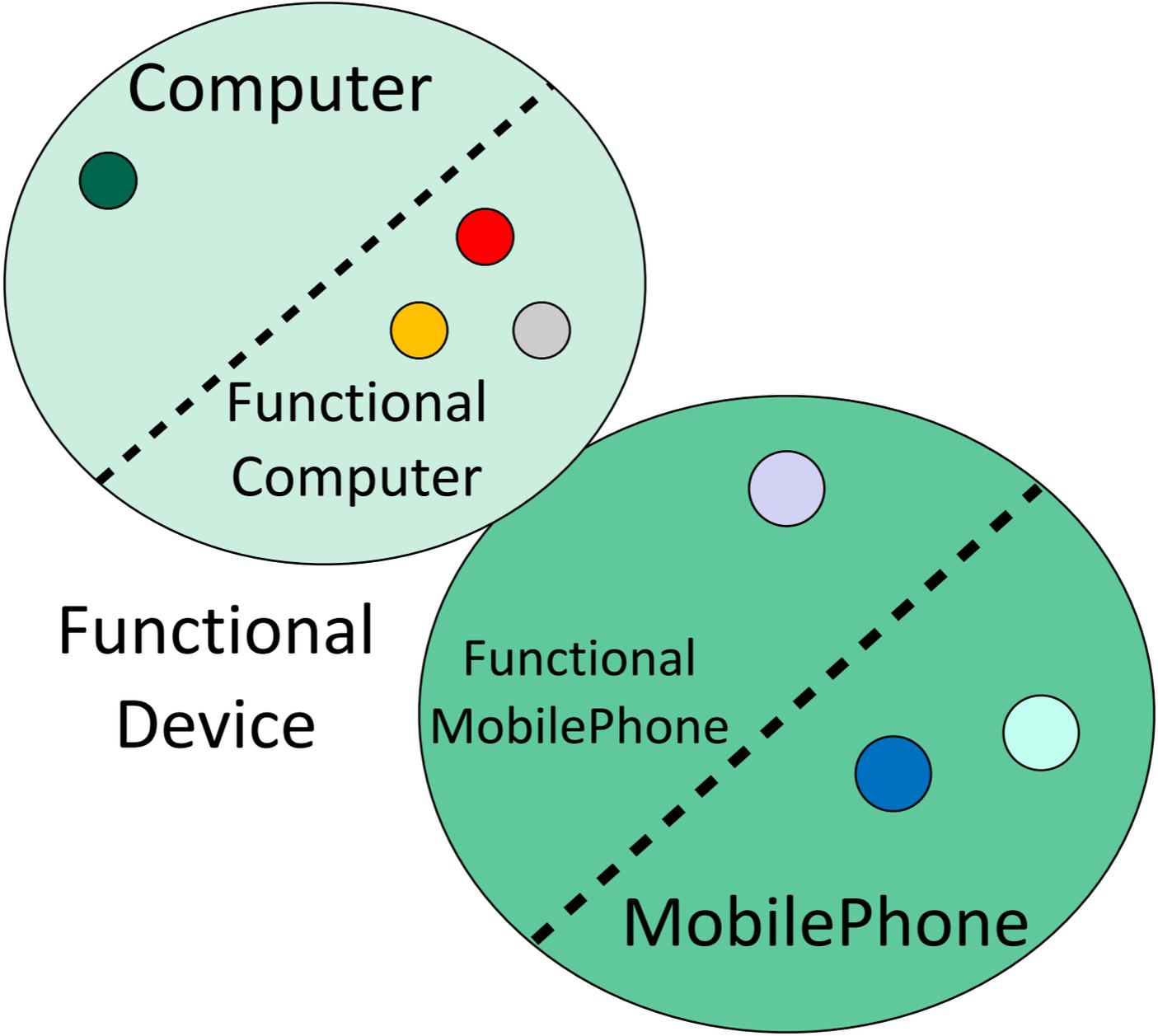


PhaseMixin



WORLD W

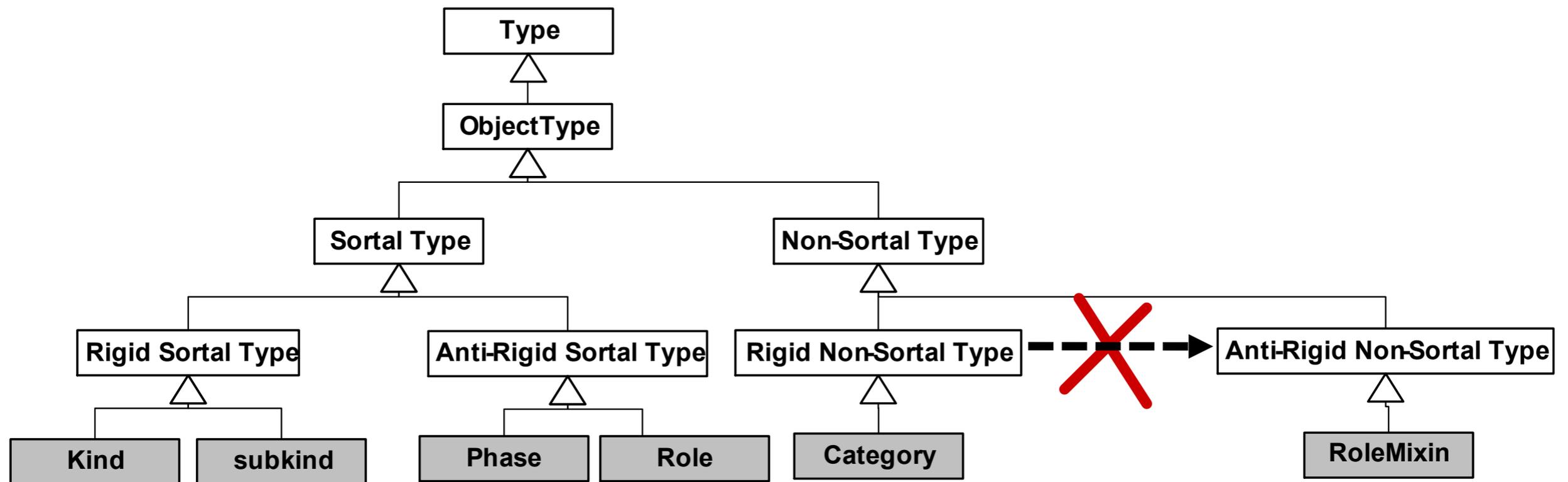
PhaseMixin

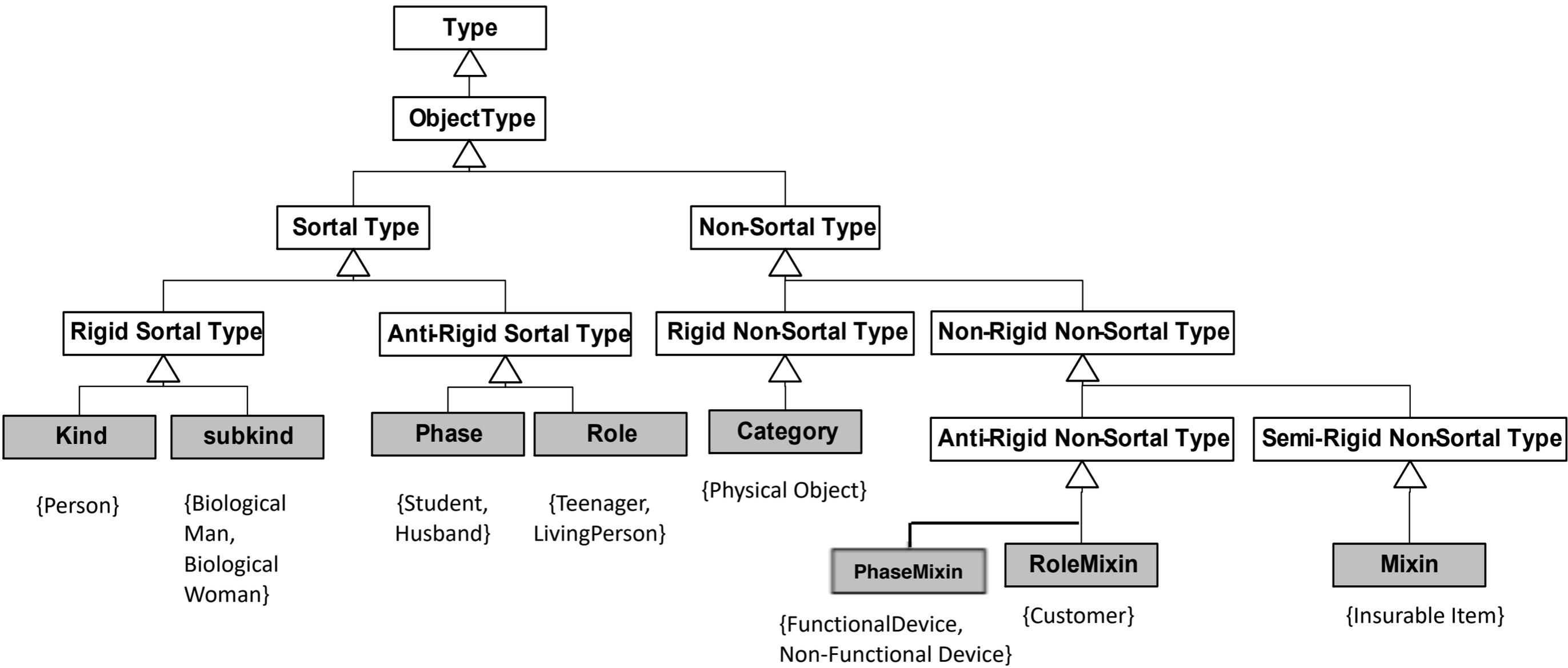


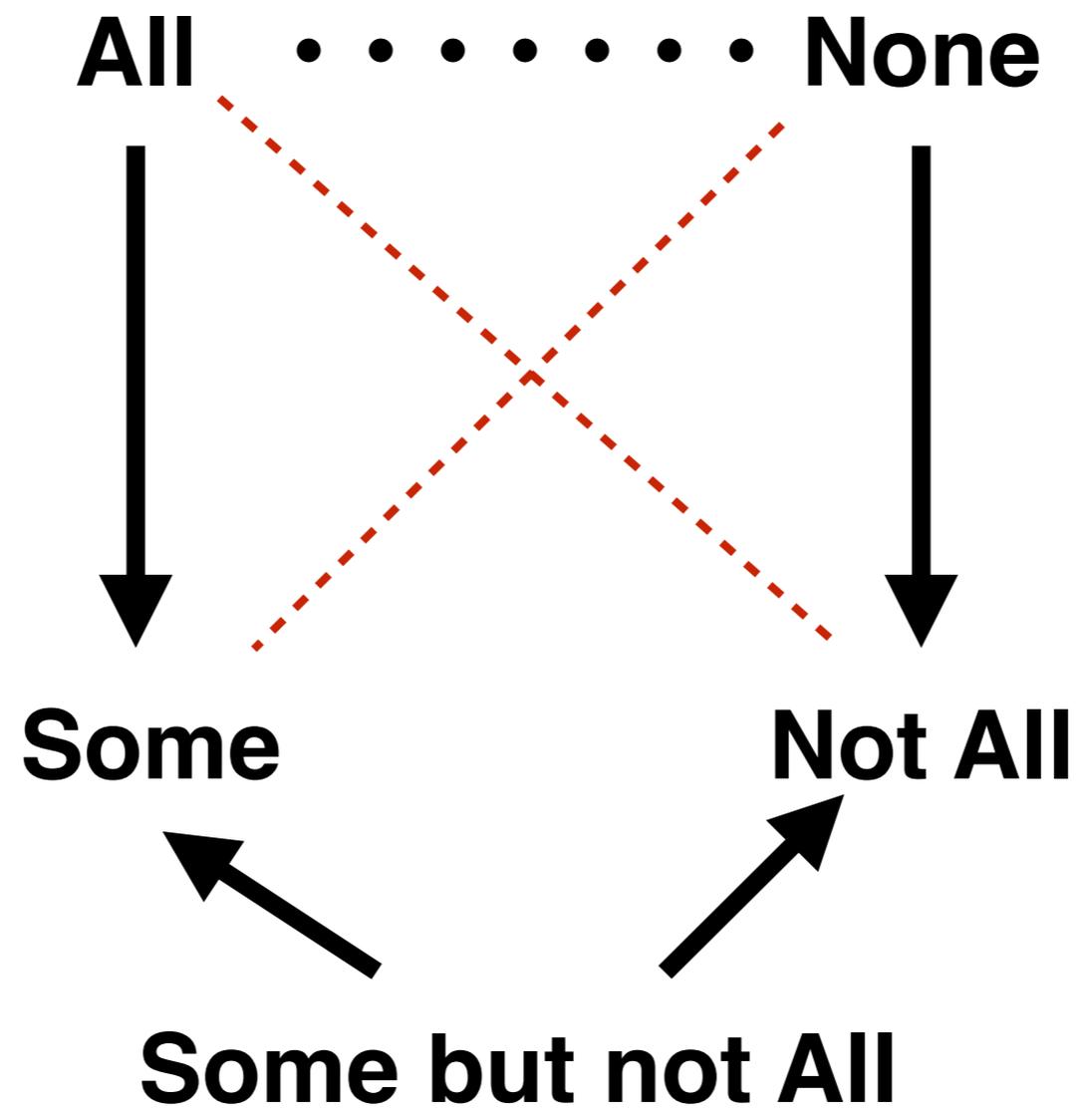
WORLD W

Anti-Rigid Non-Sortals

An Anti-Rigid Non-Sortal cannot be a super-type of a Rigid one







**All cats
are white**

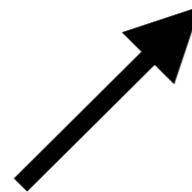
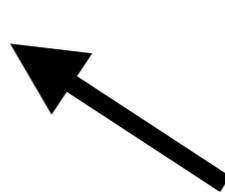
• • • • •

**No cat
is White**

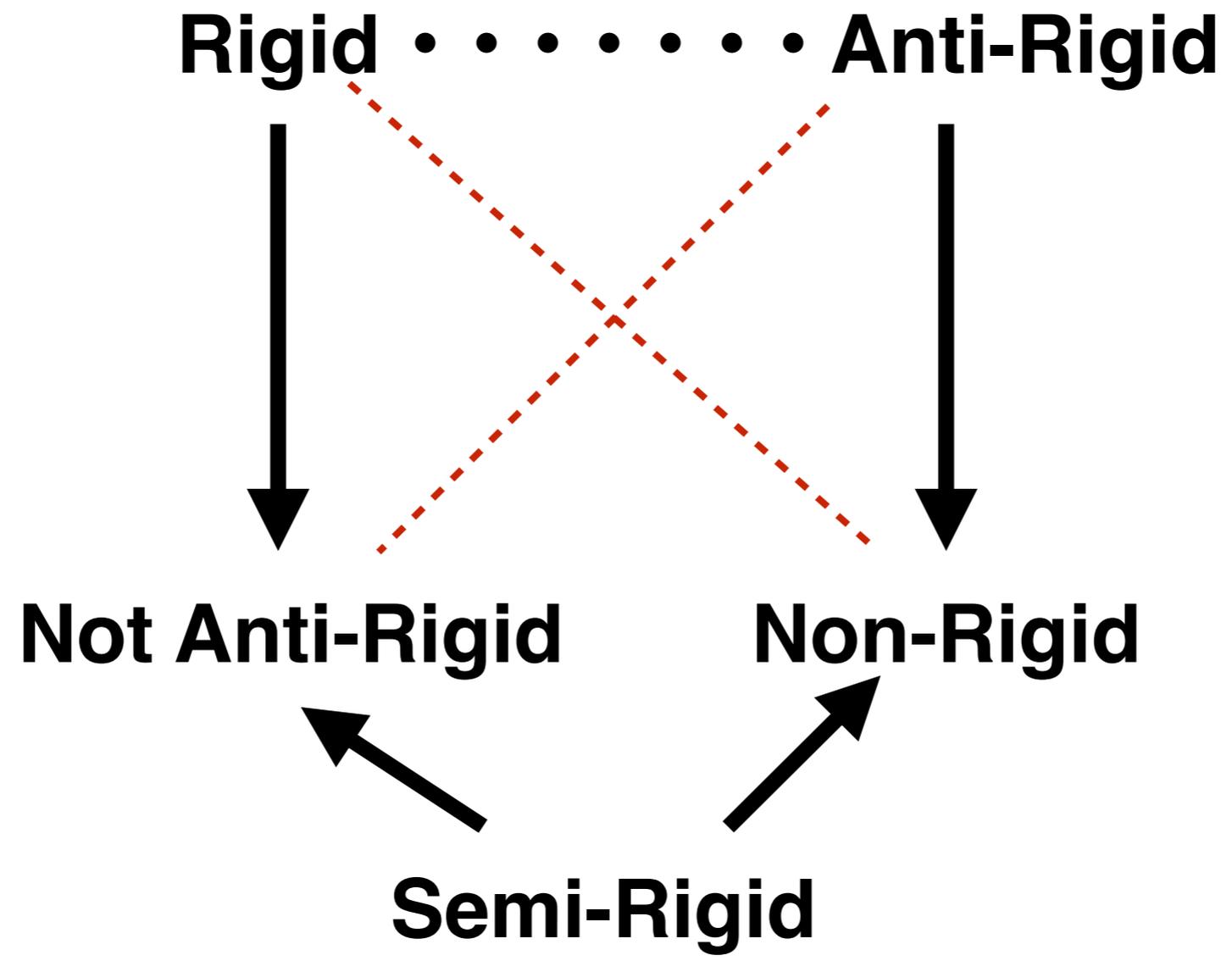


**Some cats
are White**

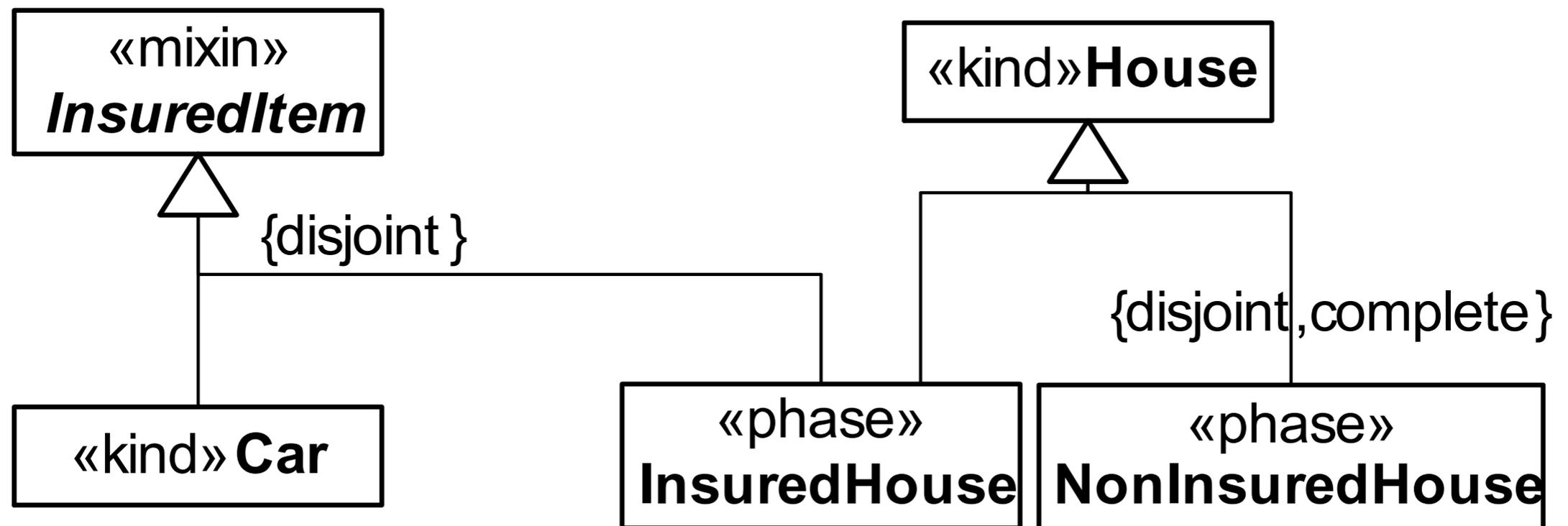
**Not all cats
are White**



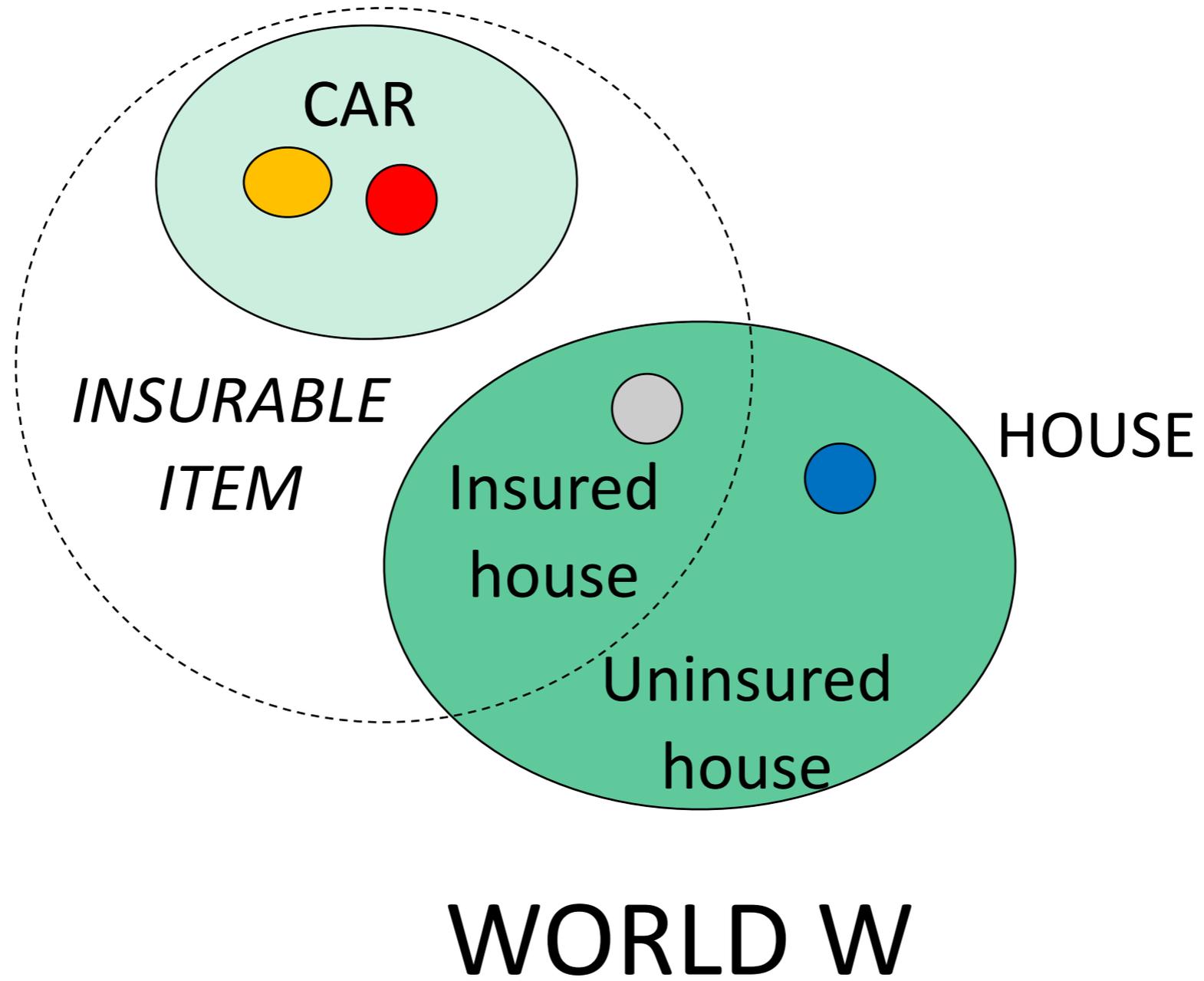
**Some cats are White but
not all Cats are White**



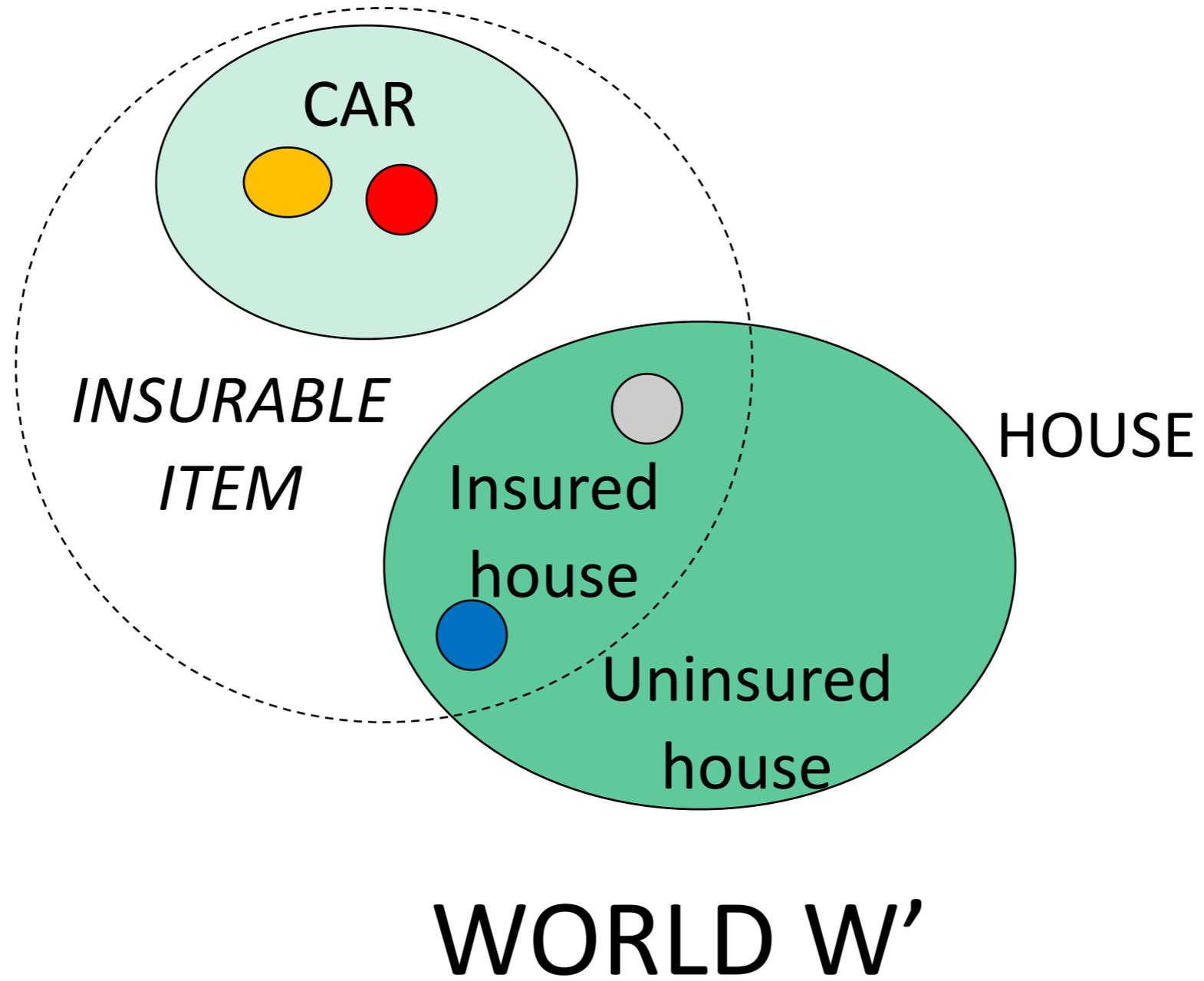
Mixin



Mixin



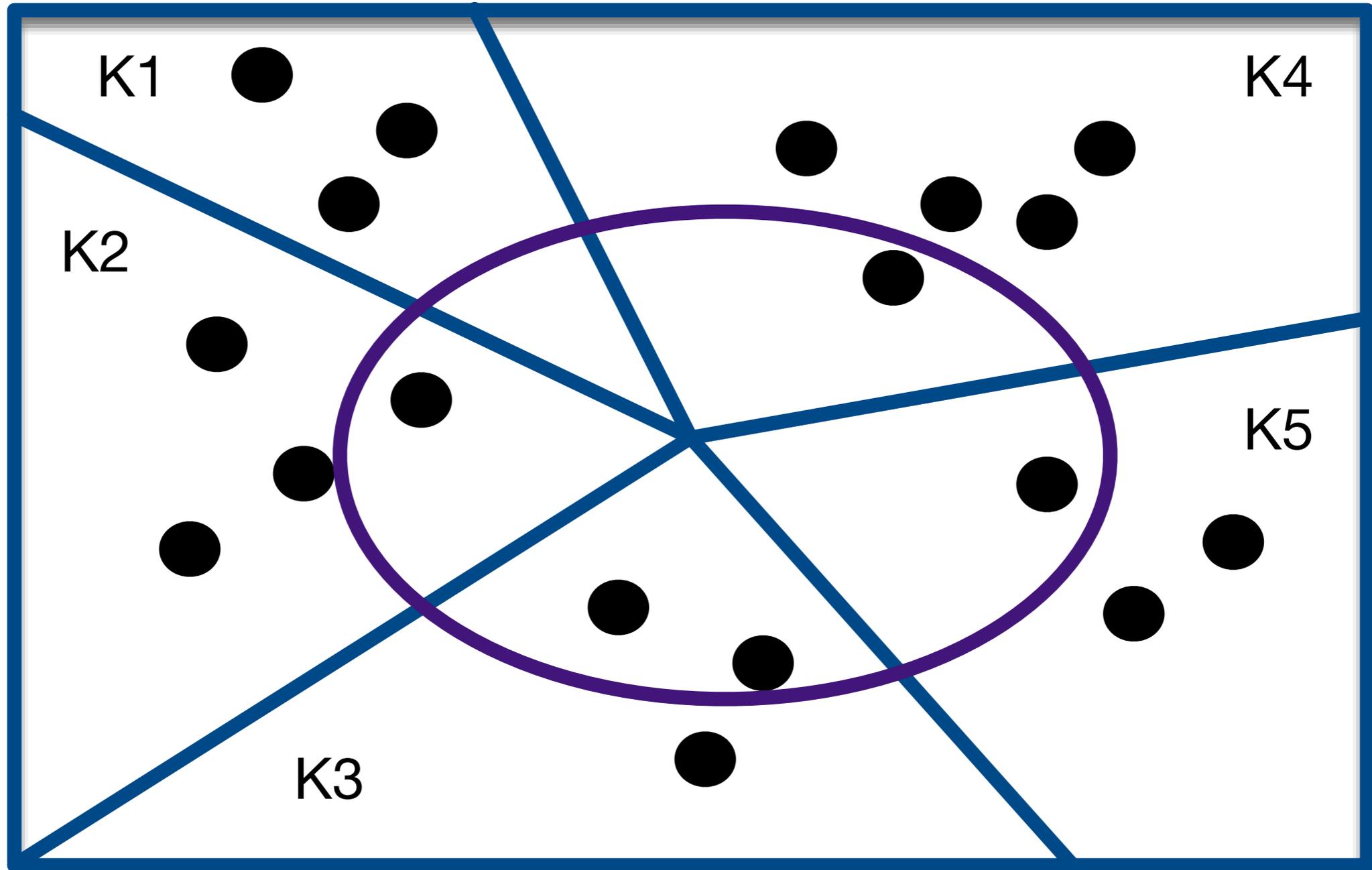
Mixin



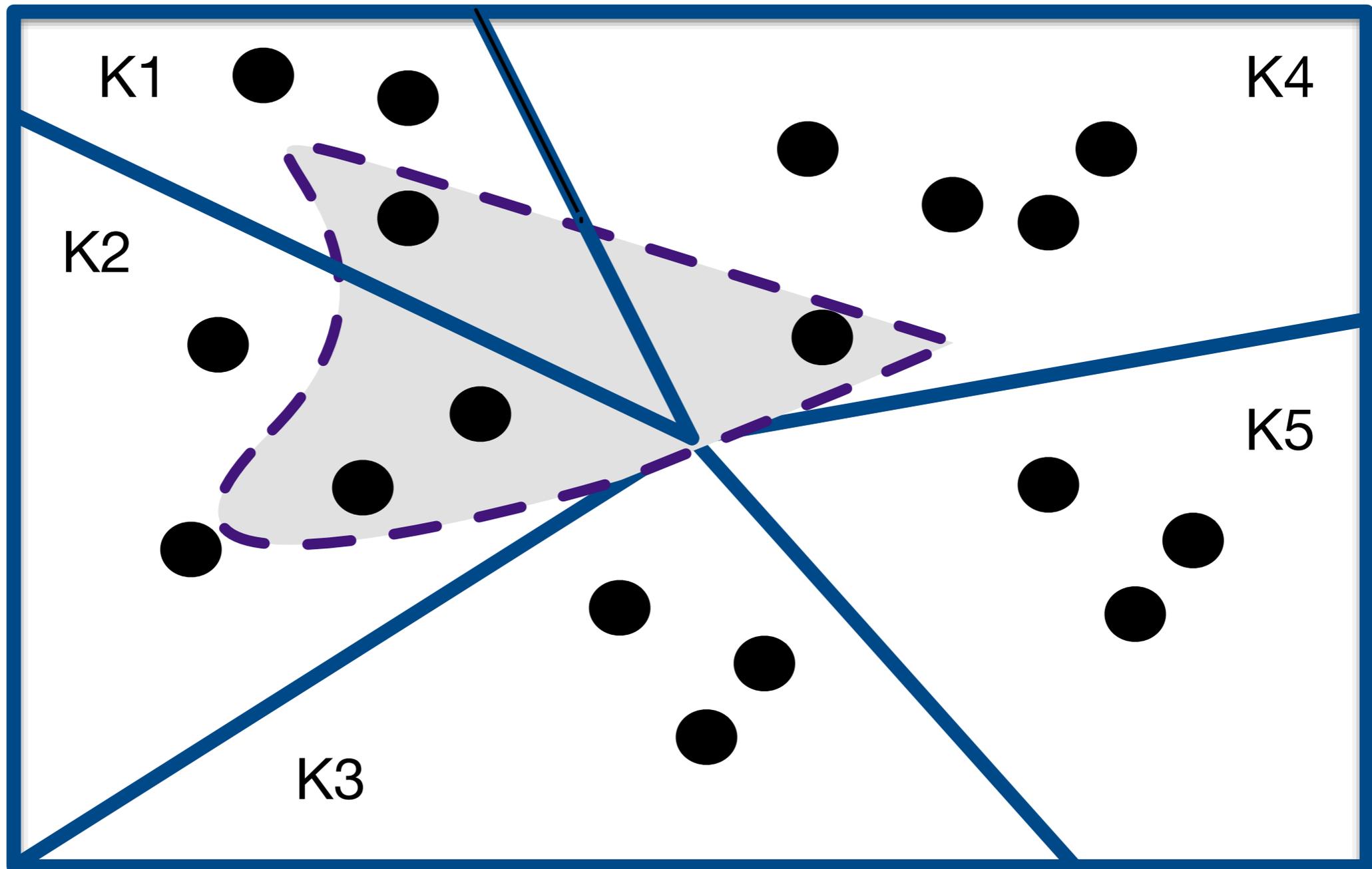
Meta-types	Identity	Rigidity	Dependence
SORTAL			
Kind		+	-
Subkind	+	+	-
Phase	+	-	-
Role	+	-	+
NON-SORTAL			
Category	-	+	-
PhaseMixin	-	-	-
RoleMixin	-	-	+
Mixin	-	+/-	-

****this typology is based on and evolves the theory of types behind OntoClean (Guarino and Welty)***

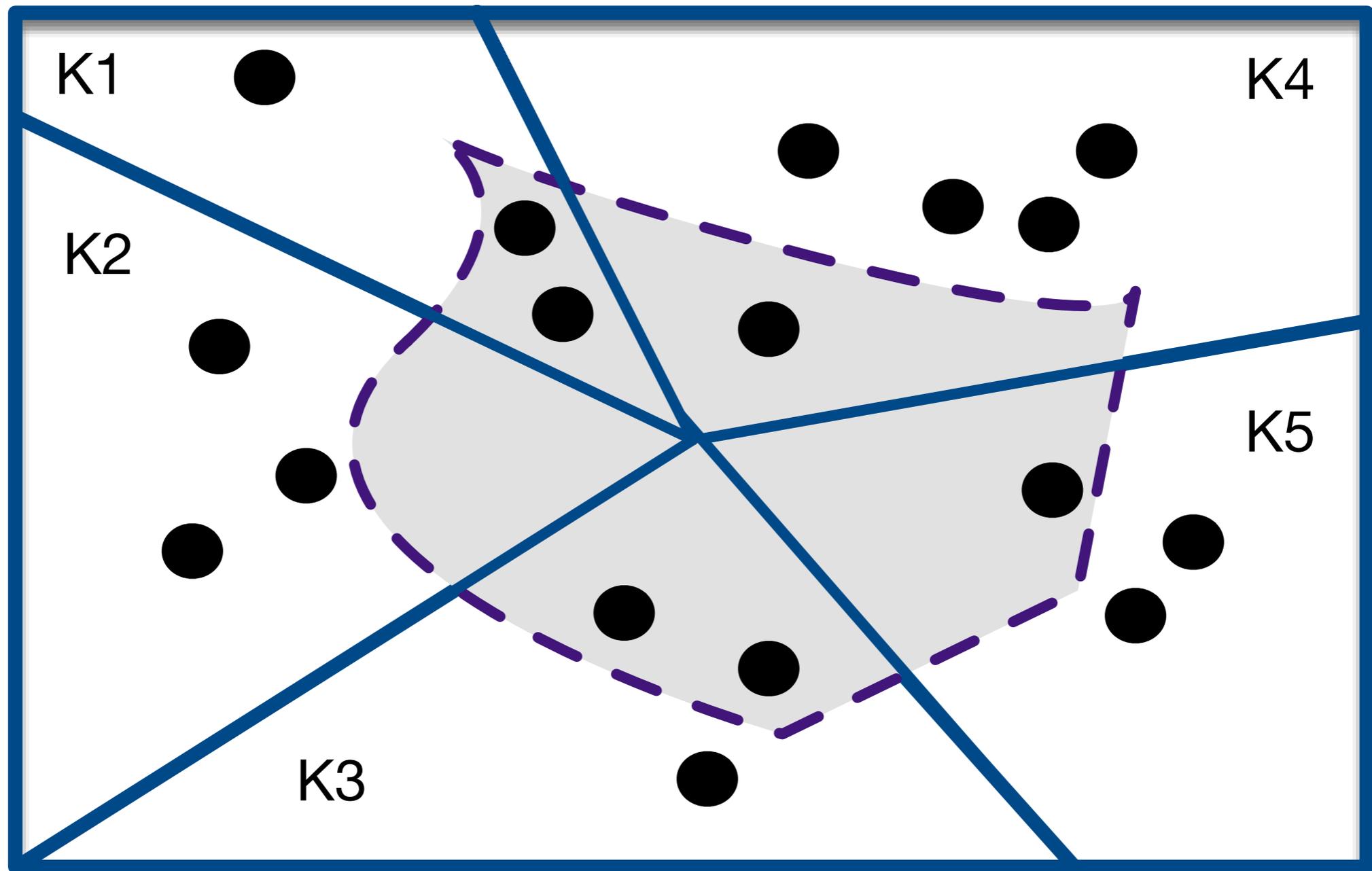
Rigid Non-Sortal



Anti-Rigid Non-Sortal



Anti-Rigid Non-Sortal



Meta-types	Identity	Rigidity	Dependence
SORTAL			
Kind		+	-
Subkind	+	+	-
Phase	+	-	-
Role	+	-	+
NON-SORTAL			
Category	-	+	-
PhaseMixin	-	-	-
RoleMixin	-	-	+
Mixin	-	+/-	-

Problem

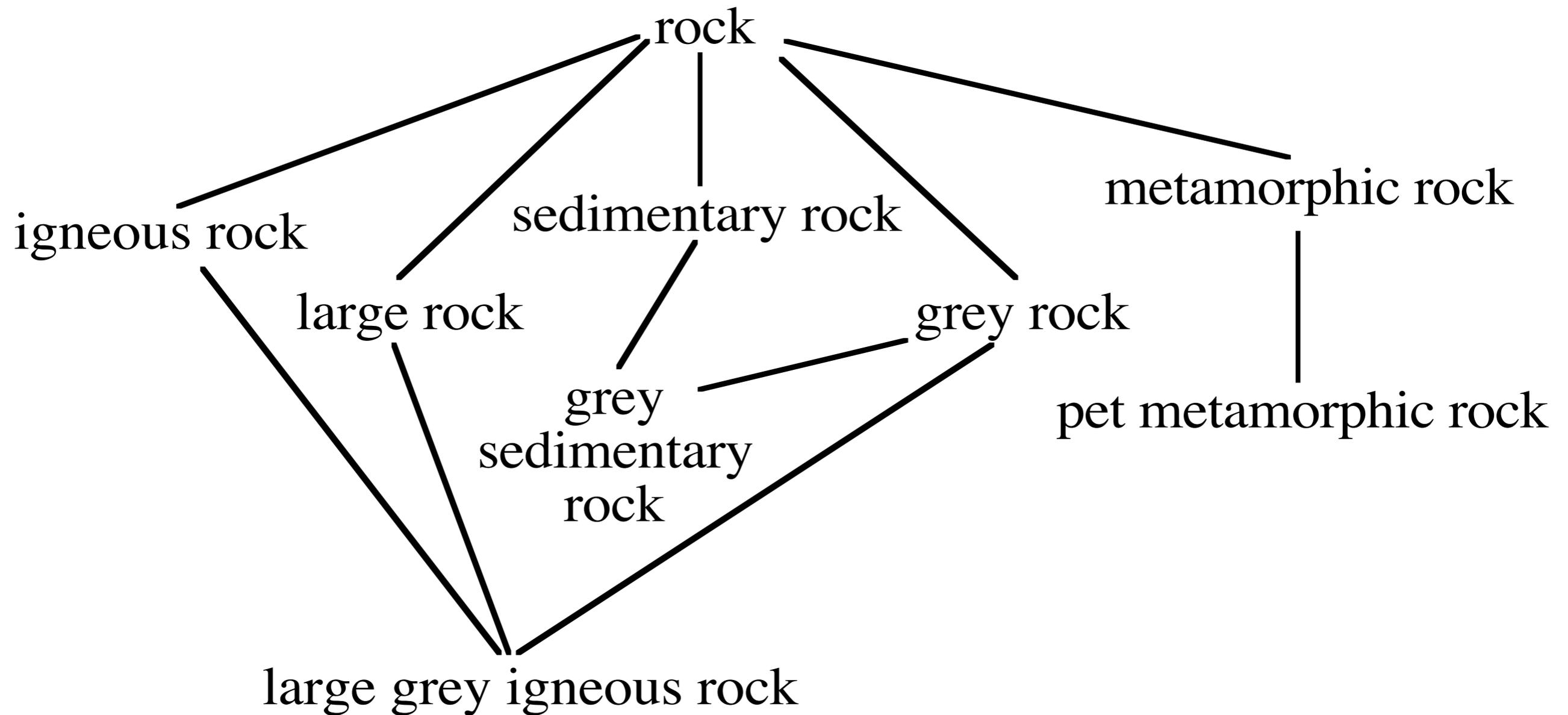
1. Characterize the difference between the following types:
 - Person, Apple, Car, Dog, Organization
 - Student, Singer, President, Employee
 - Adult, Puppy, Metropolis
 - Crime Weapon, Insurable Item, Sharp Object, Rational Agent, Cultural Heritage Item

Solution

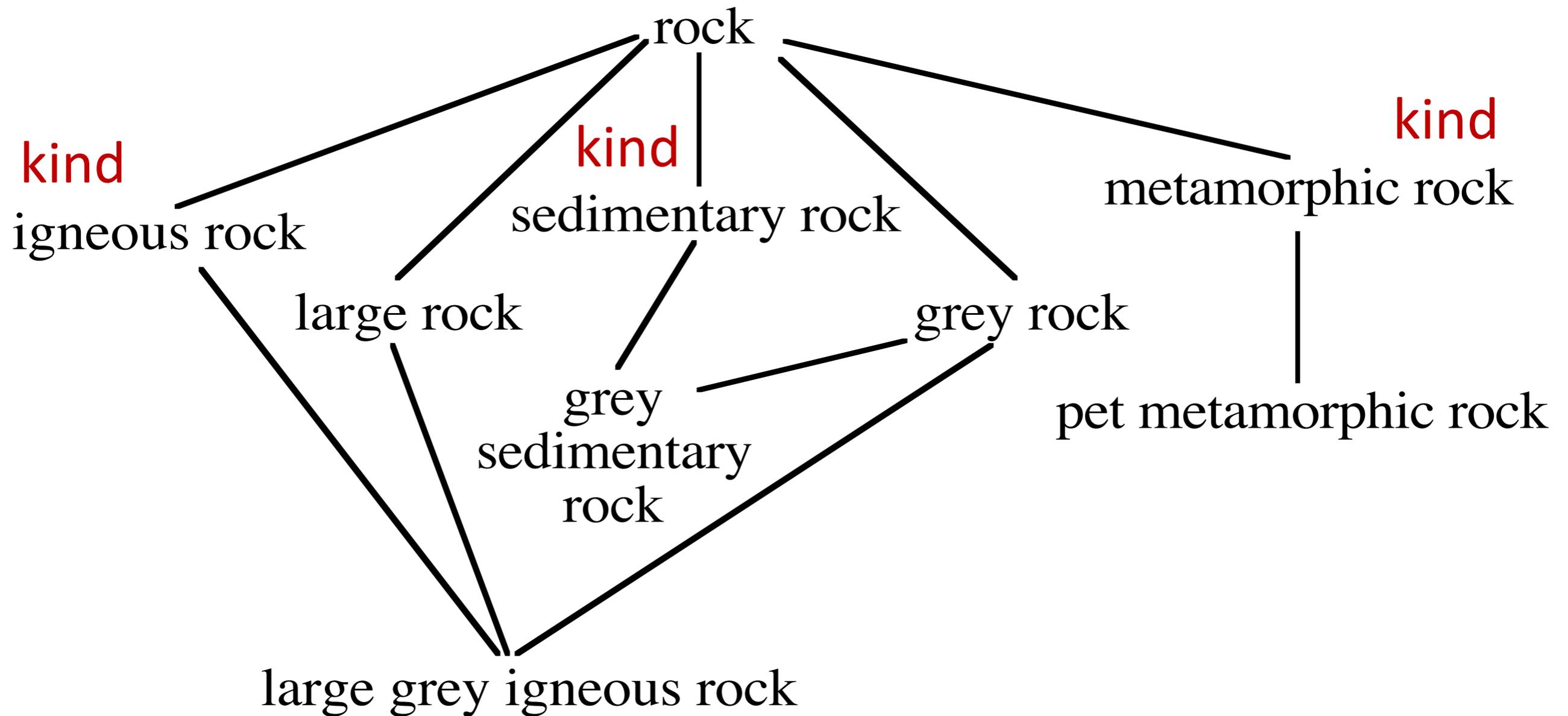
1. Characterizing the difference between:

- NATURAL TYPE/KIND (e.g., **PERSON**) = **RIGID SORTAL**
- ROLE (e.g., **SINGER, ECONOMIST, BRITISH CITIZEN, KNIGHT OF THE BRITISH EMPIRE**) = **ANTI-RIGID + RELATIONALLY DEPENDENT SORTAL**
- PHASE (e.g., **LIVING PERSON, ADULT MAN**) = **ANTI-RIGID + RELATIONALLY INDEPENDENT SORTAL**
- *NON-SORTAL* (e.g., **CULTURAL HERITAGE ENTITY, PHYSICAL ENTITY, INSURABLE ITEM**)? = **CLASSIFYING THINGS OF MULTIPLES KINDS**

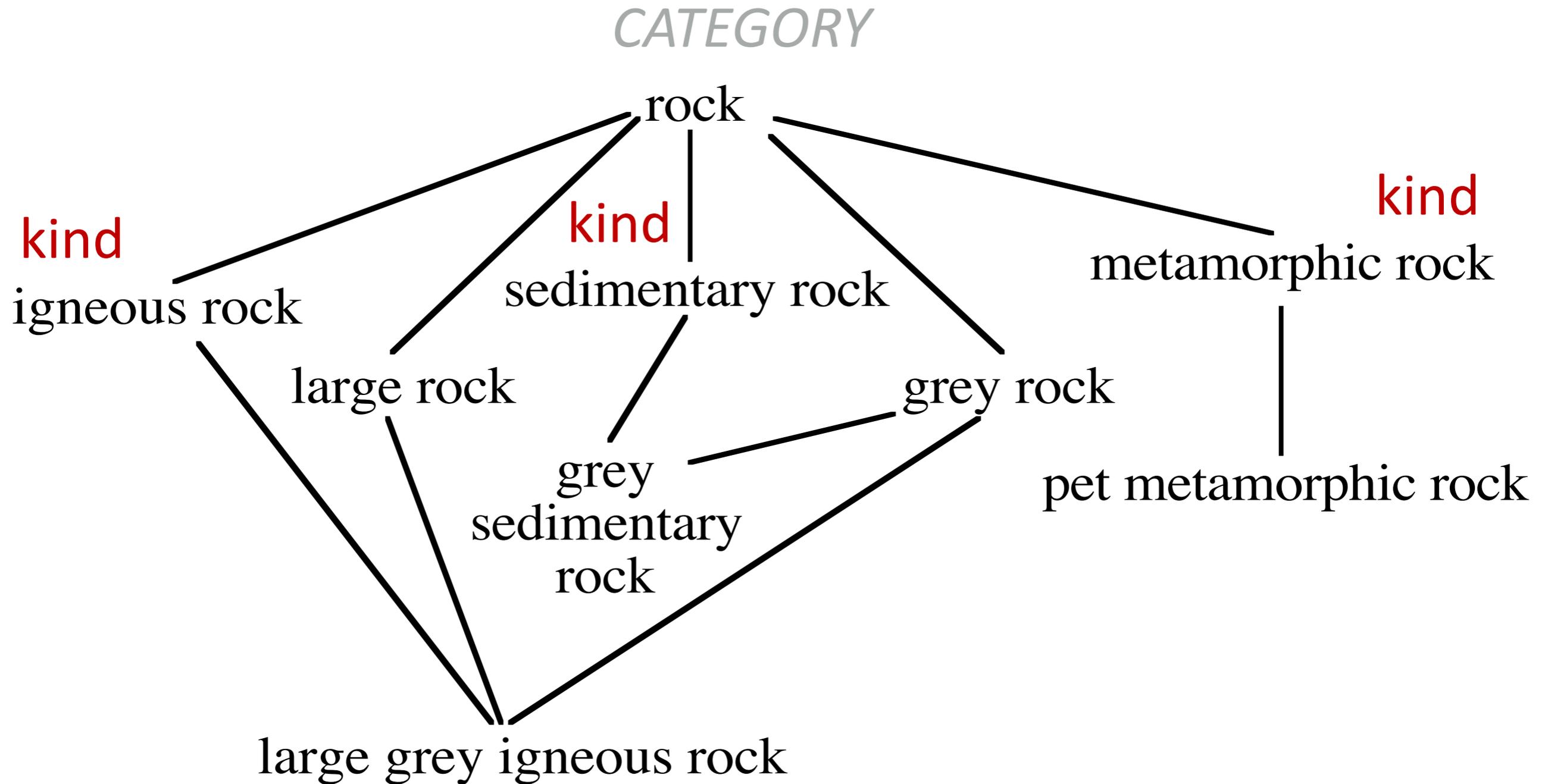
How many kinds of rock?



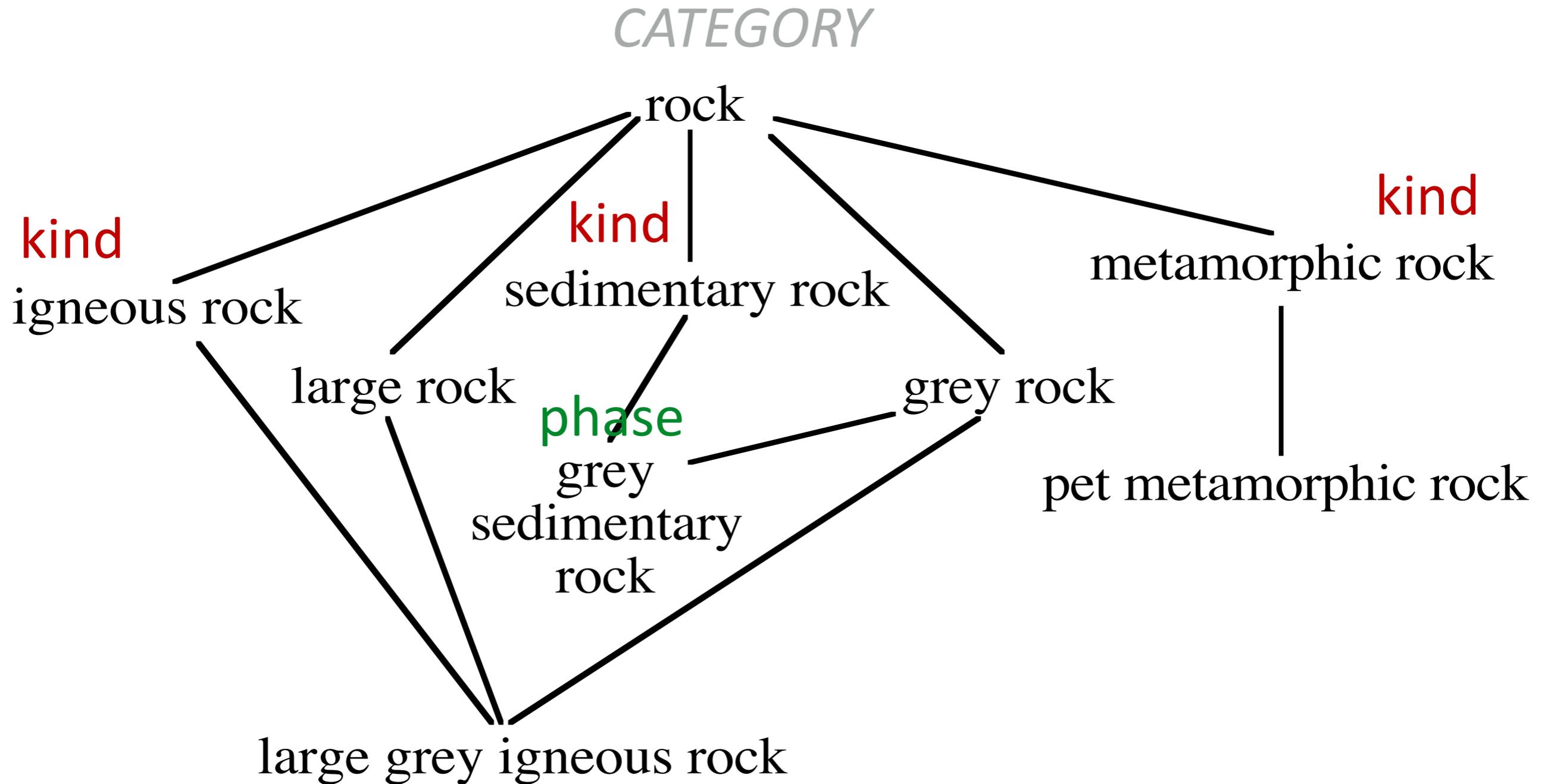
How many kinds of rock?



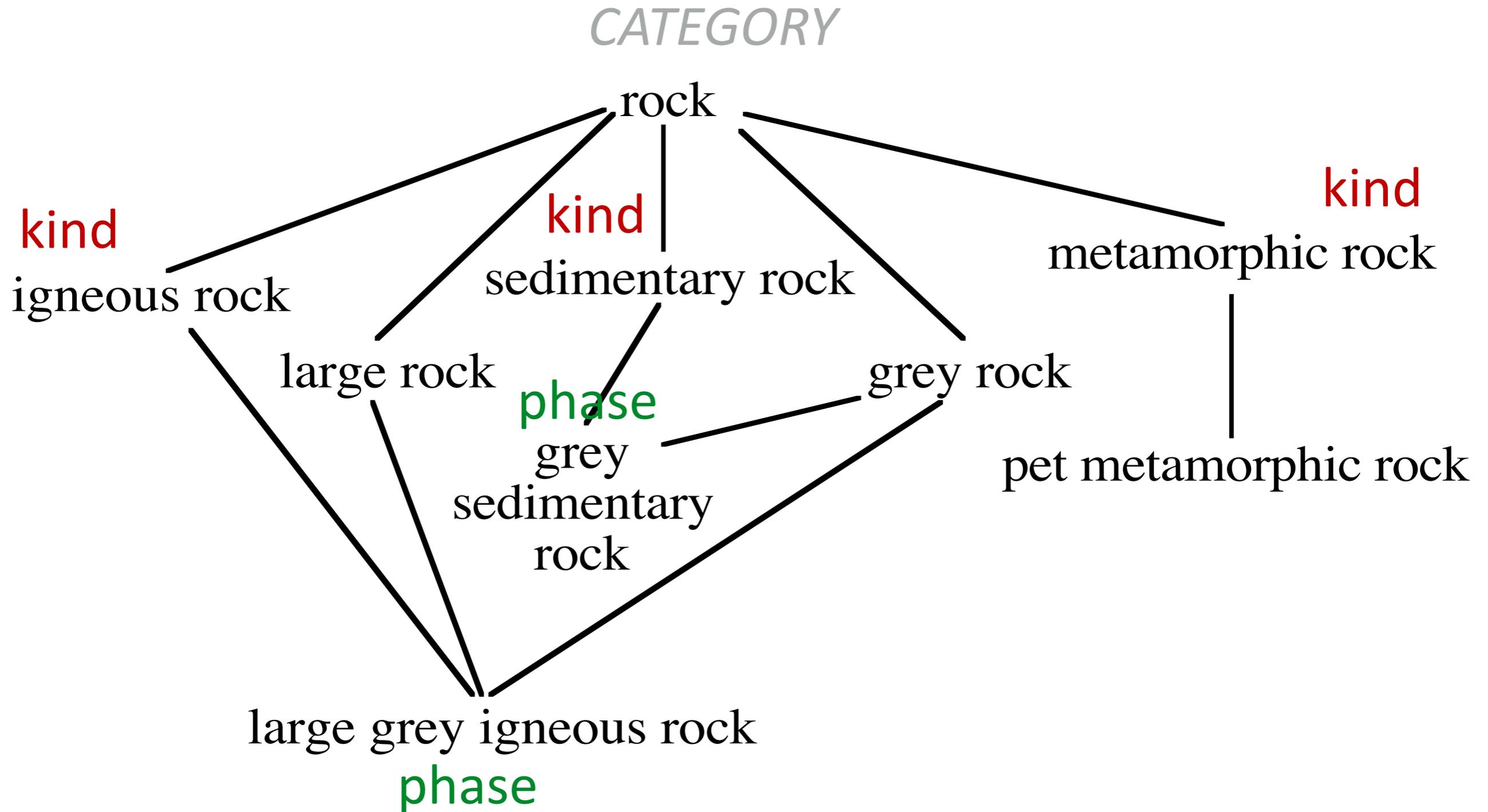
How many kinds of rock?



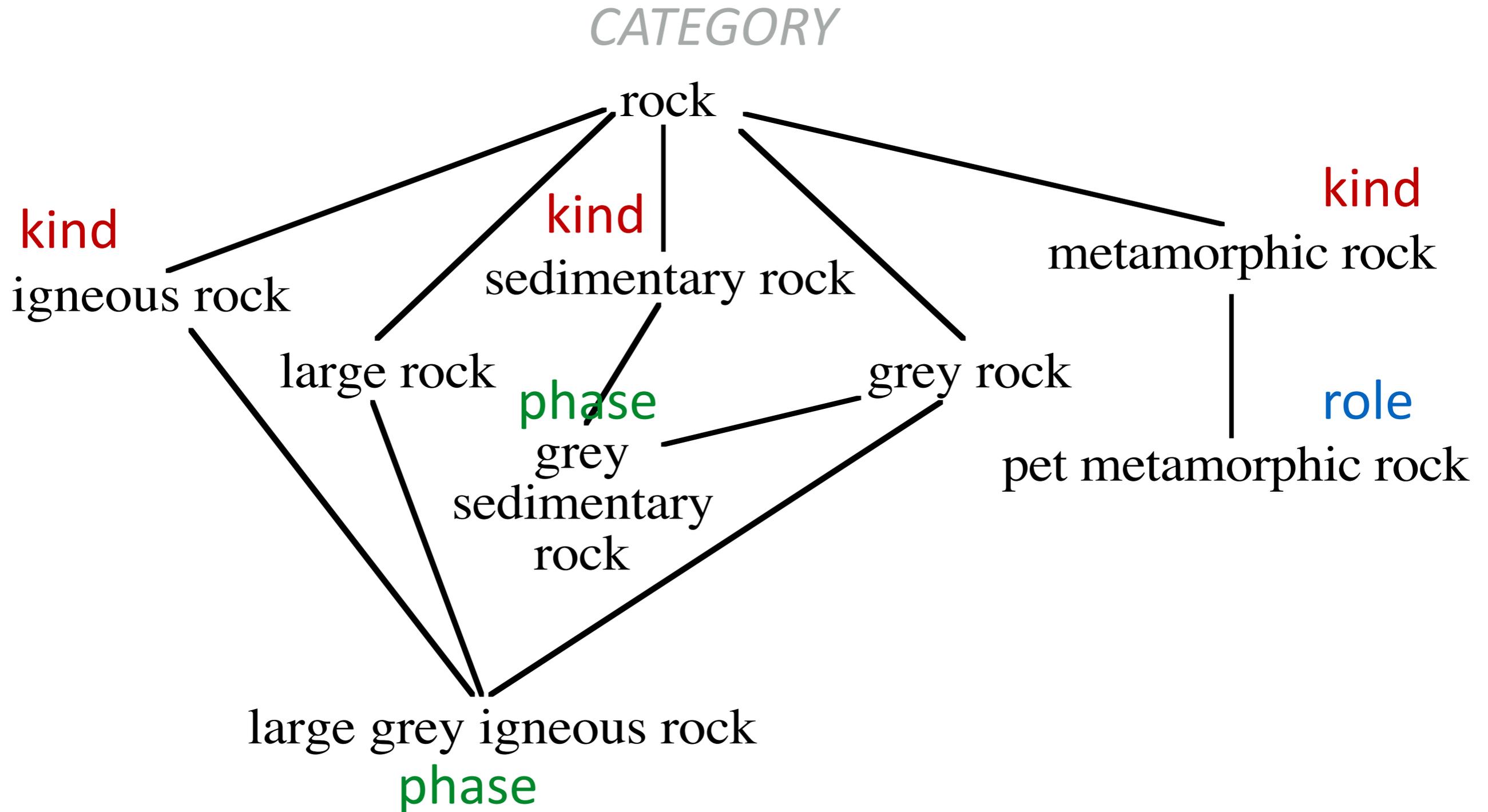
How many kinds of rock?



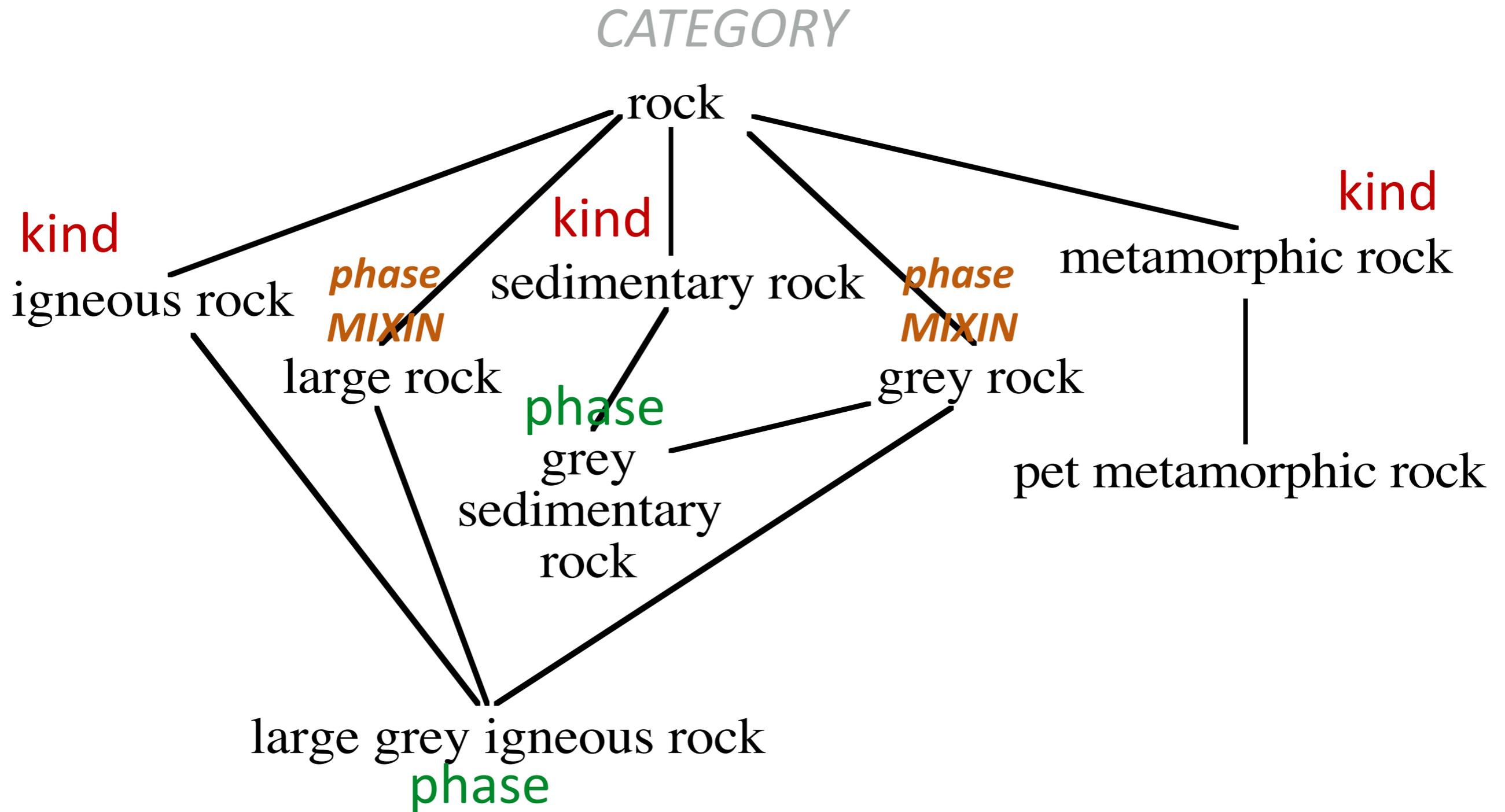
How many kinds of rock?



How many kinds of rock?

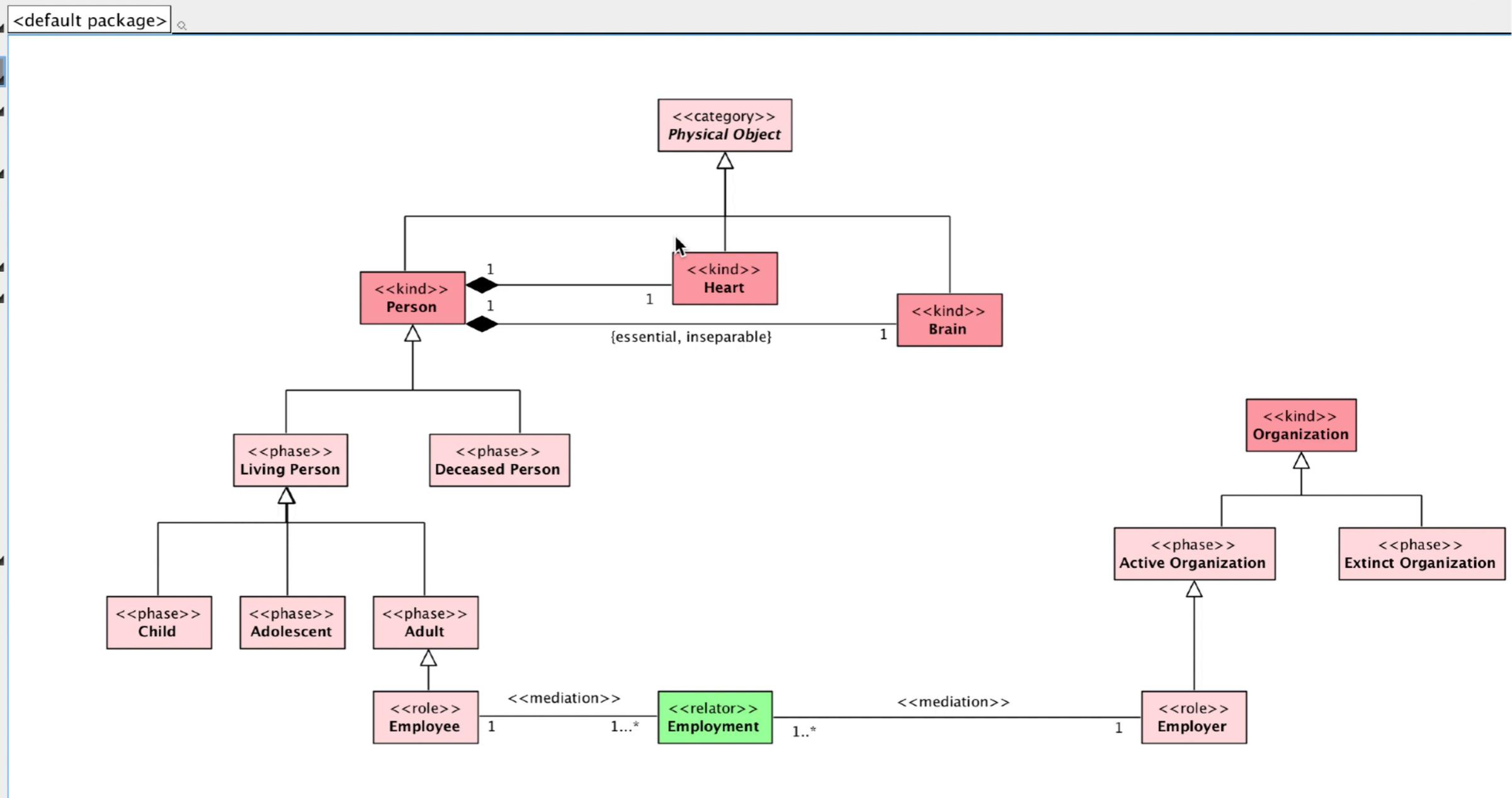


How many kinds of rock?



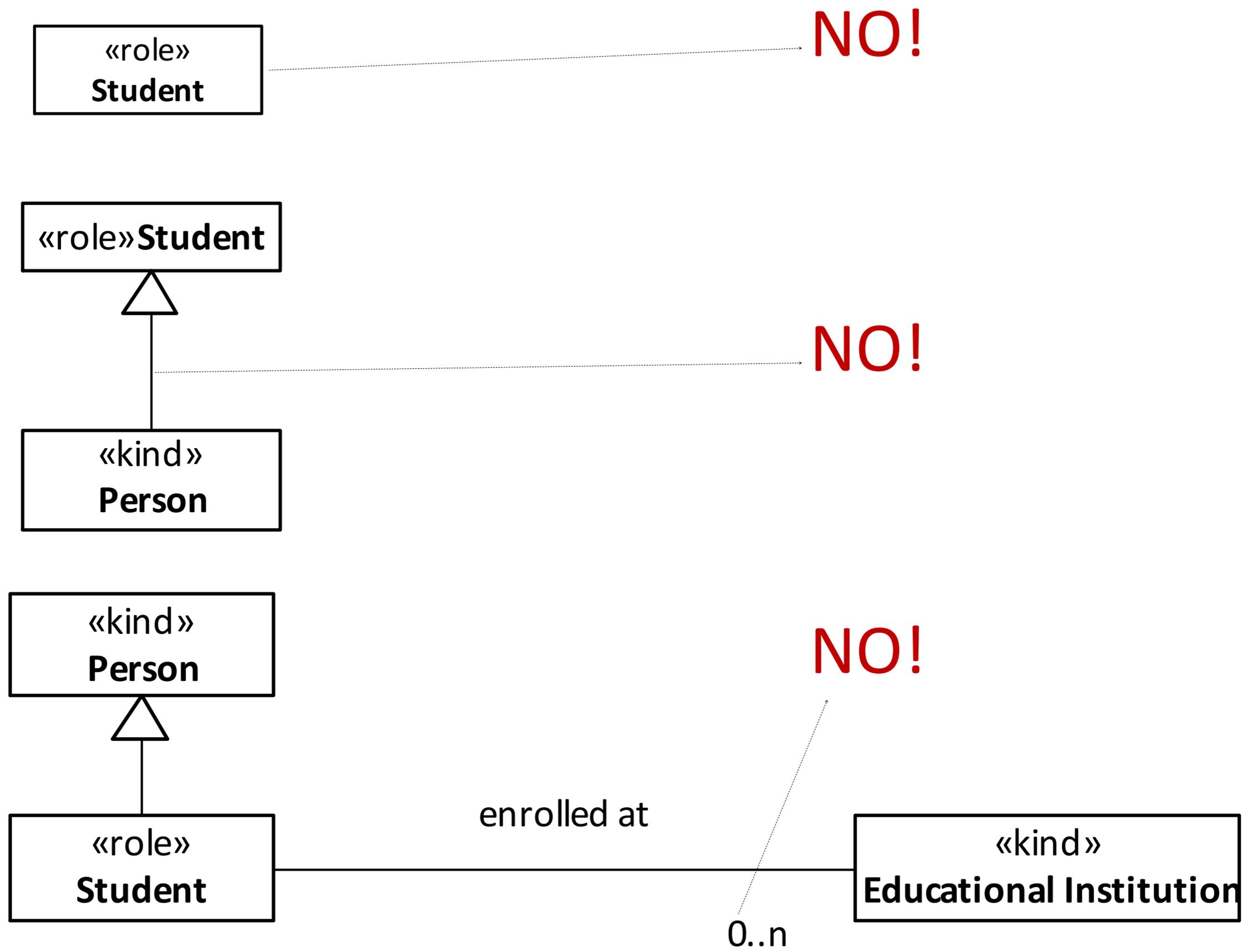
Check Model Check Diagram Export to JSON Settings Export to gUFO Report Error Update Plugin

- Cursor
- Class
- Generalization
- Usage
- Association
- N-ary Association
- Association Class
- Dependency
- Abstraction
- Collaboration
- Model
- REST Service
- Note
- Anchor
- Constraint
- Containment
- Package
- Diagram Overview
- Generic Connector
- User Story
- Image
- Screen Capture
- Callout
- Rectangle



Role

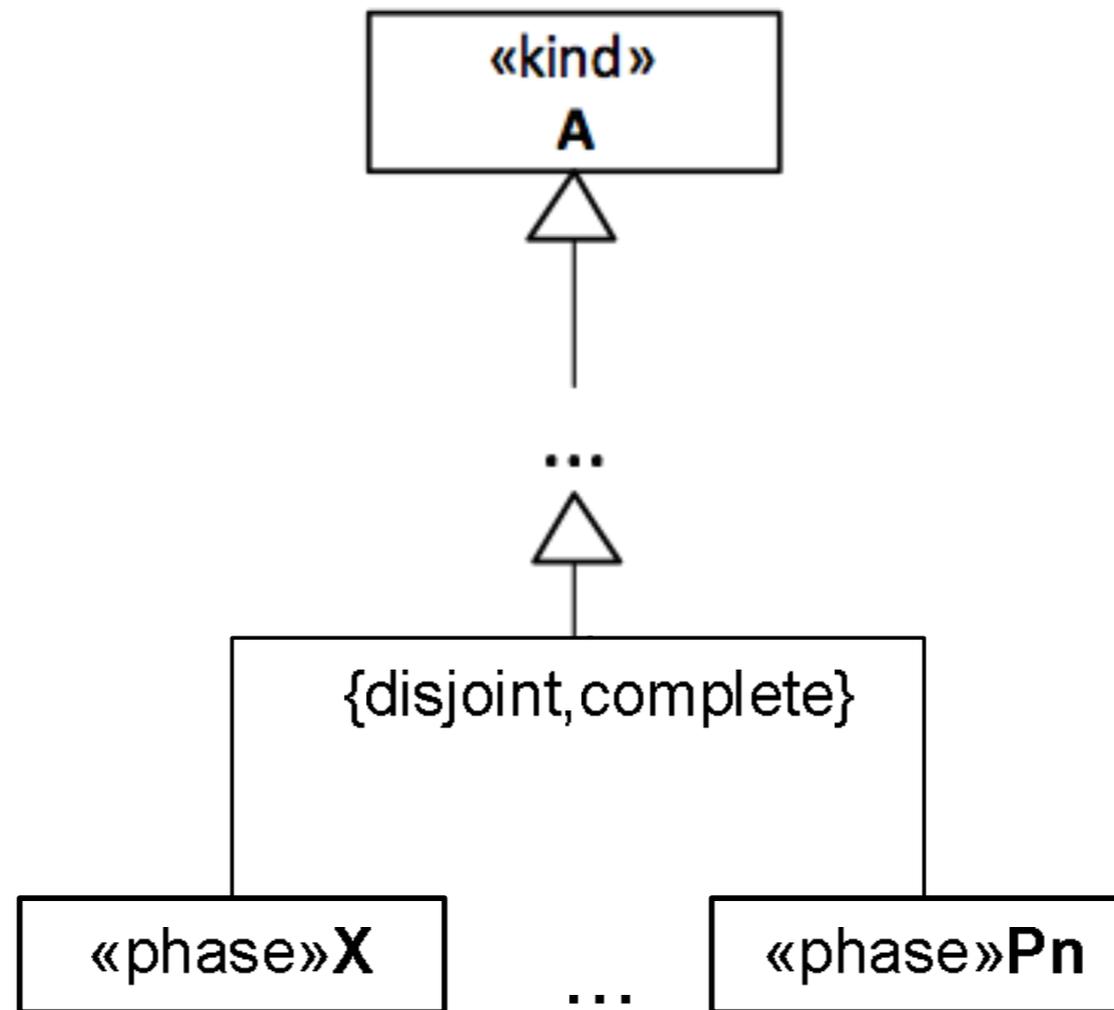
- All instances of a given ROLE are of the same KIND (e.g., all Students are Person)
- All instances of a ROLE instantiate that type only contingently (e.g., no Student is necessarily a Student)
- Instances of a KIND instantiate that ROLE when participating in a certain RELATIONAL CONTEXT (e.g., instances of Person instantiate the Role Student when enrolled in an Educational Institution)
- **A ROLE cannot be a supertype of a Rigid Type**



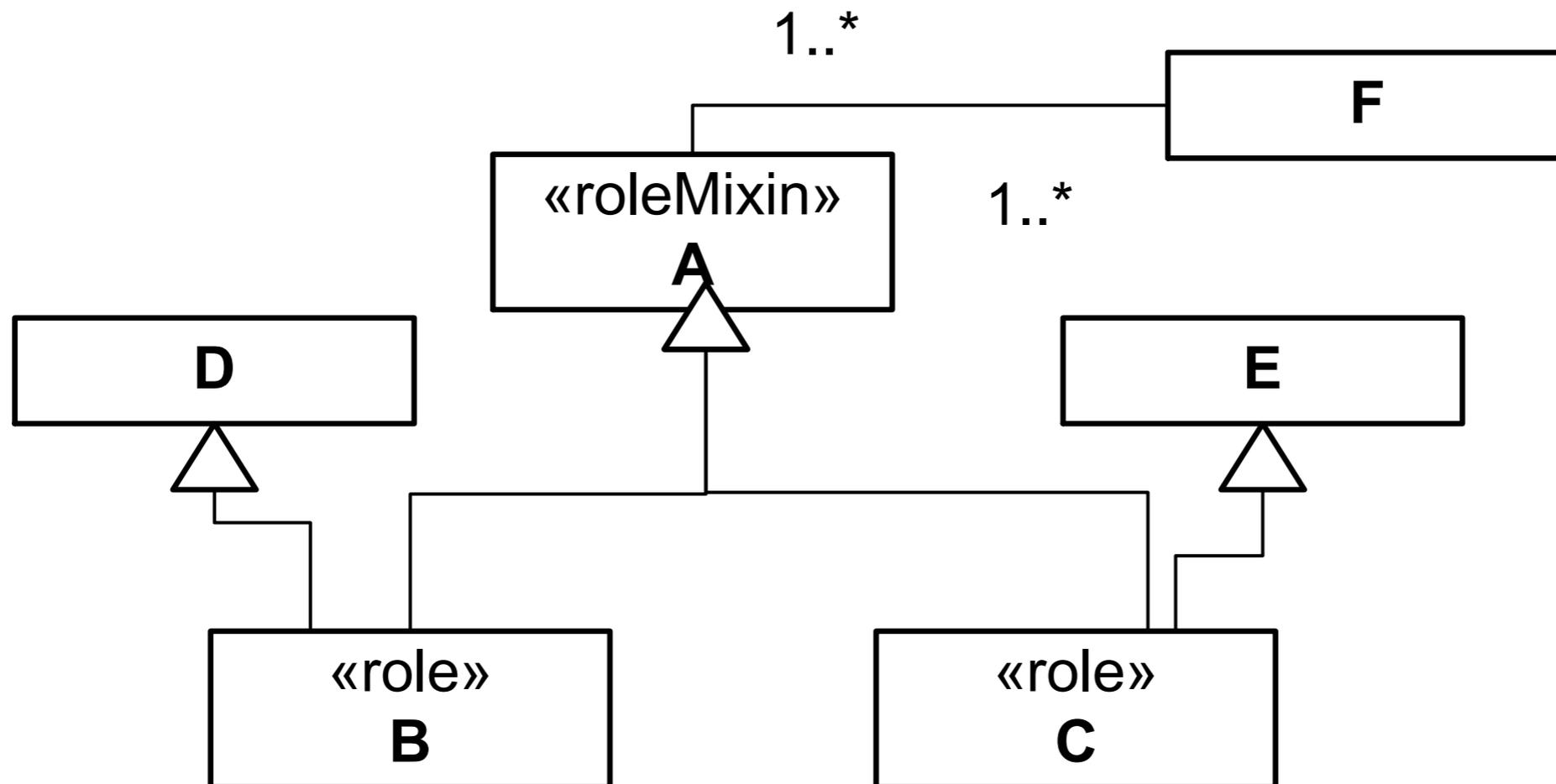
The Emerging **Role** Pattern

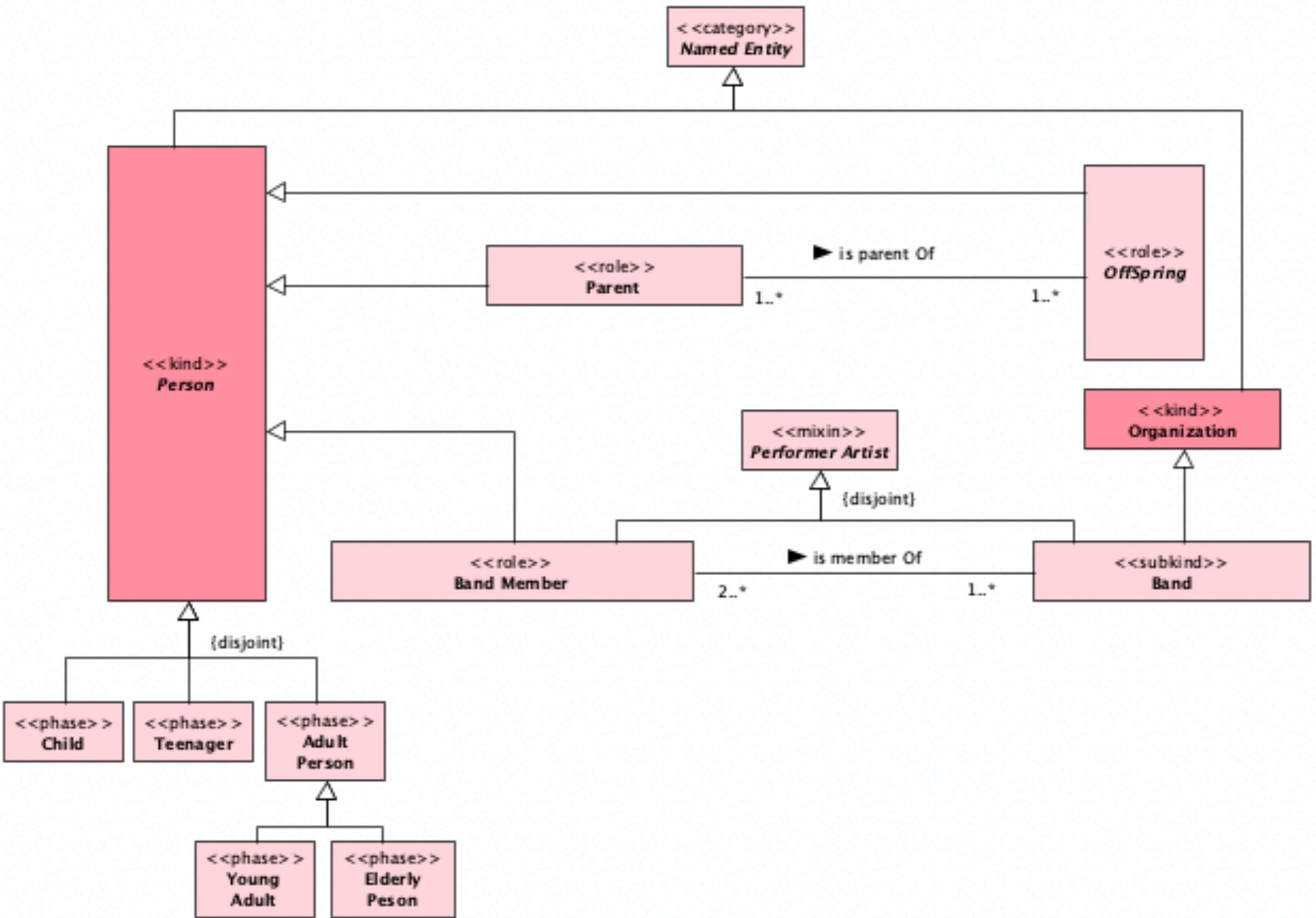


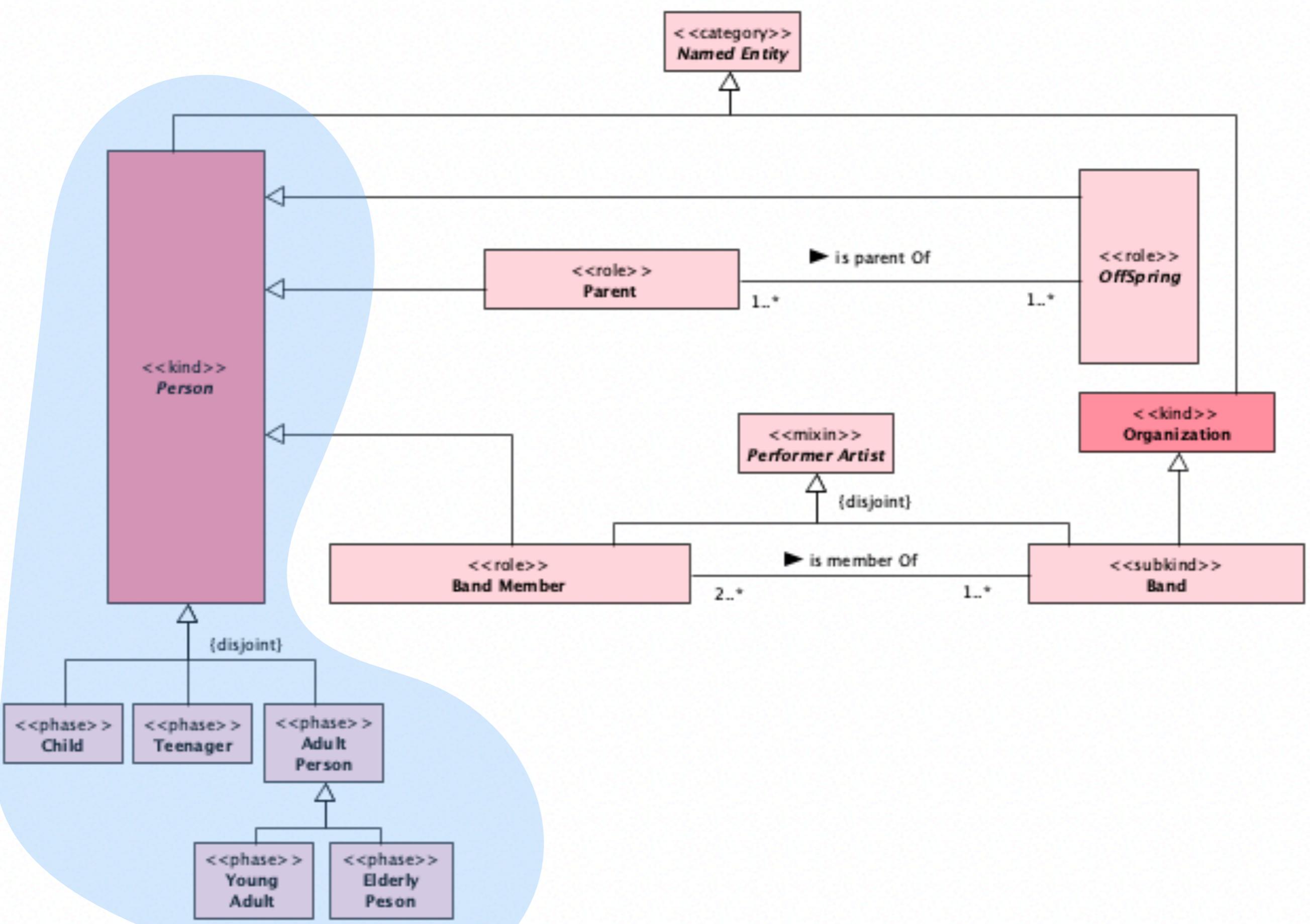
The Emerging **Phase** Pattern

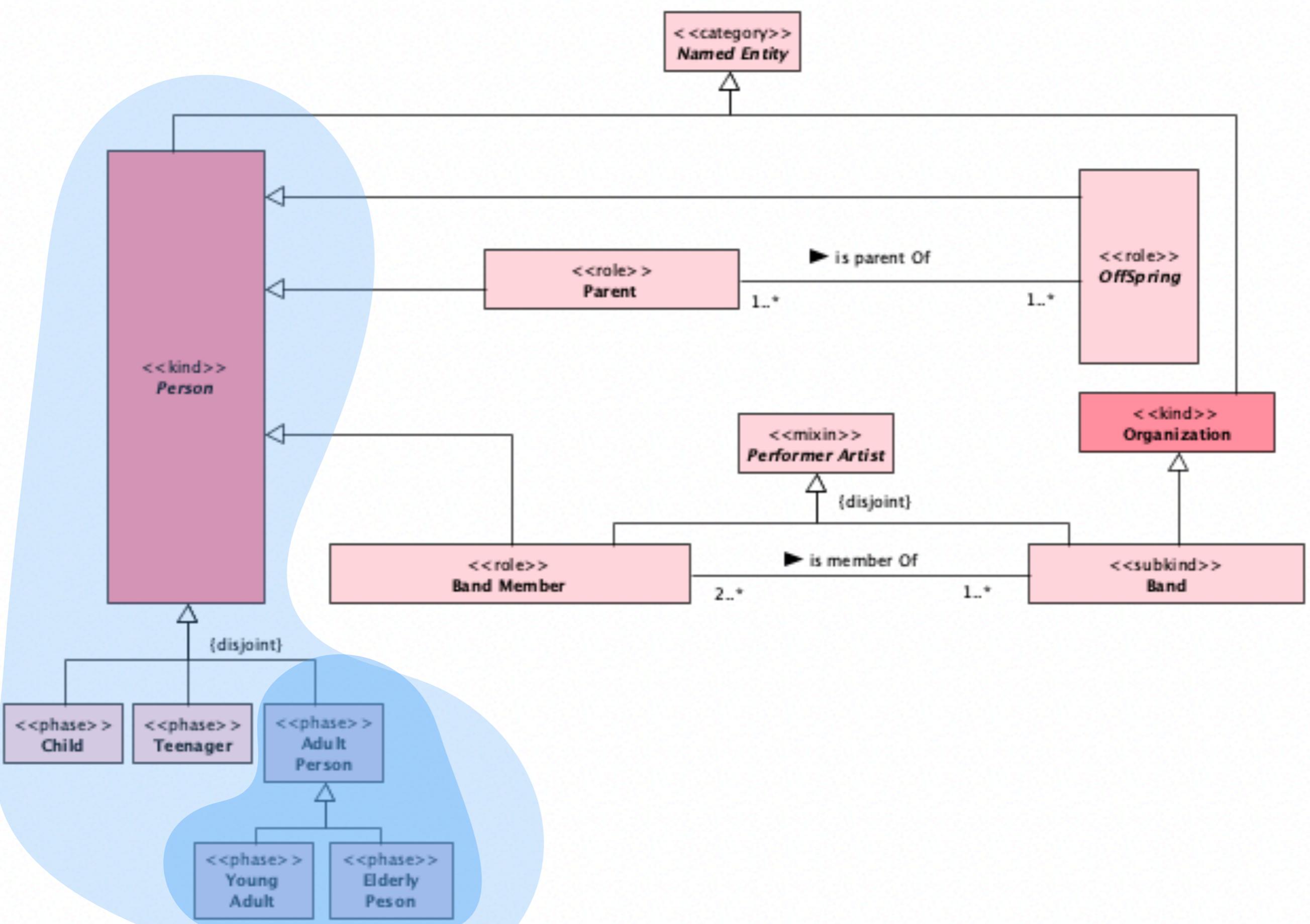


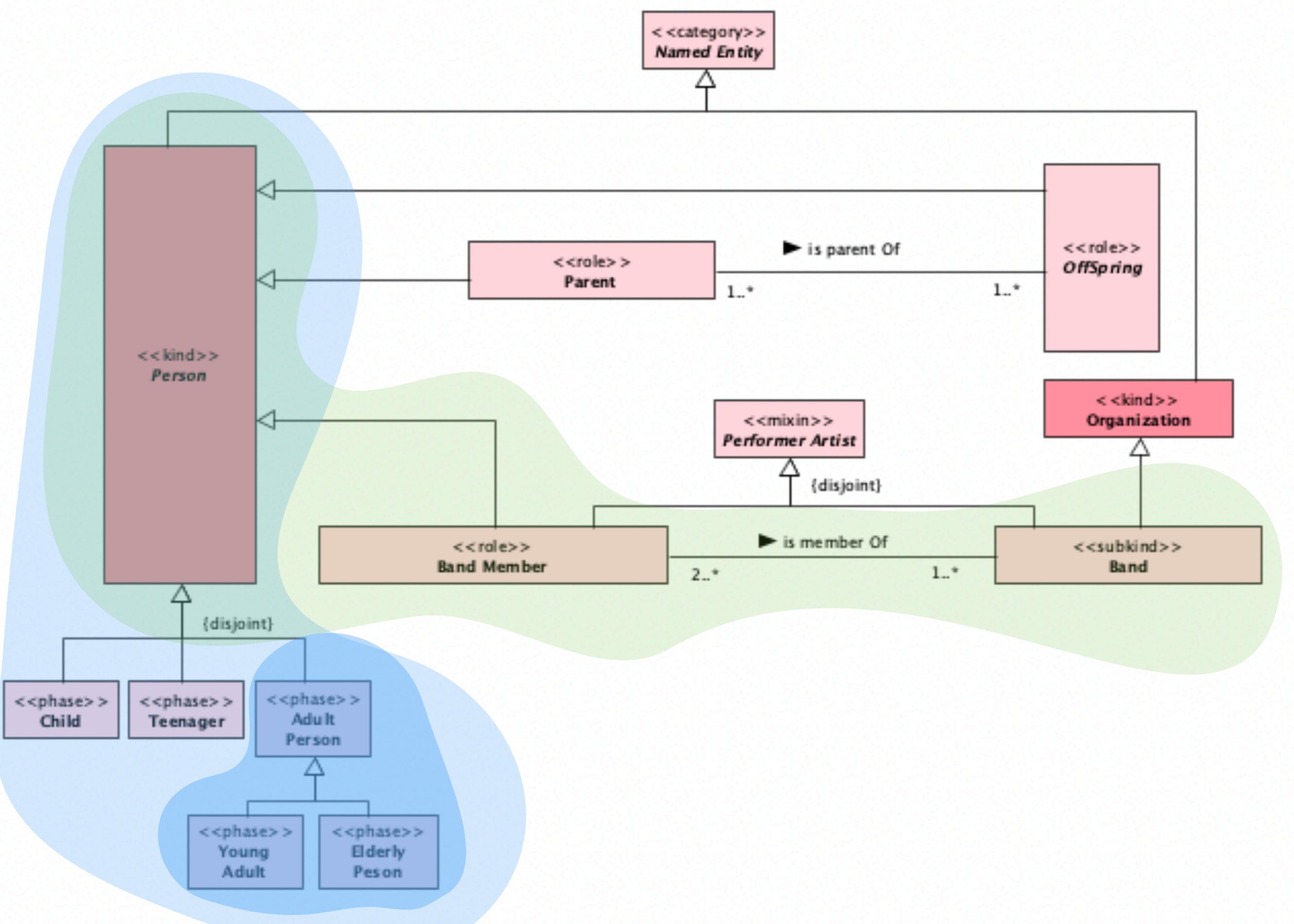
The emerging **RoleMixin** Pattern

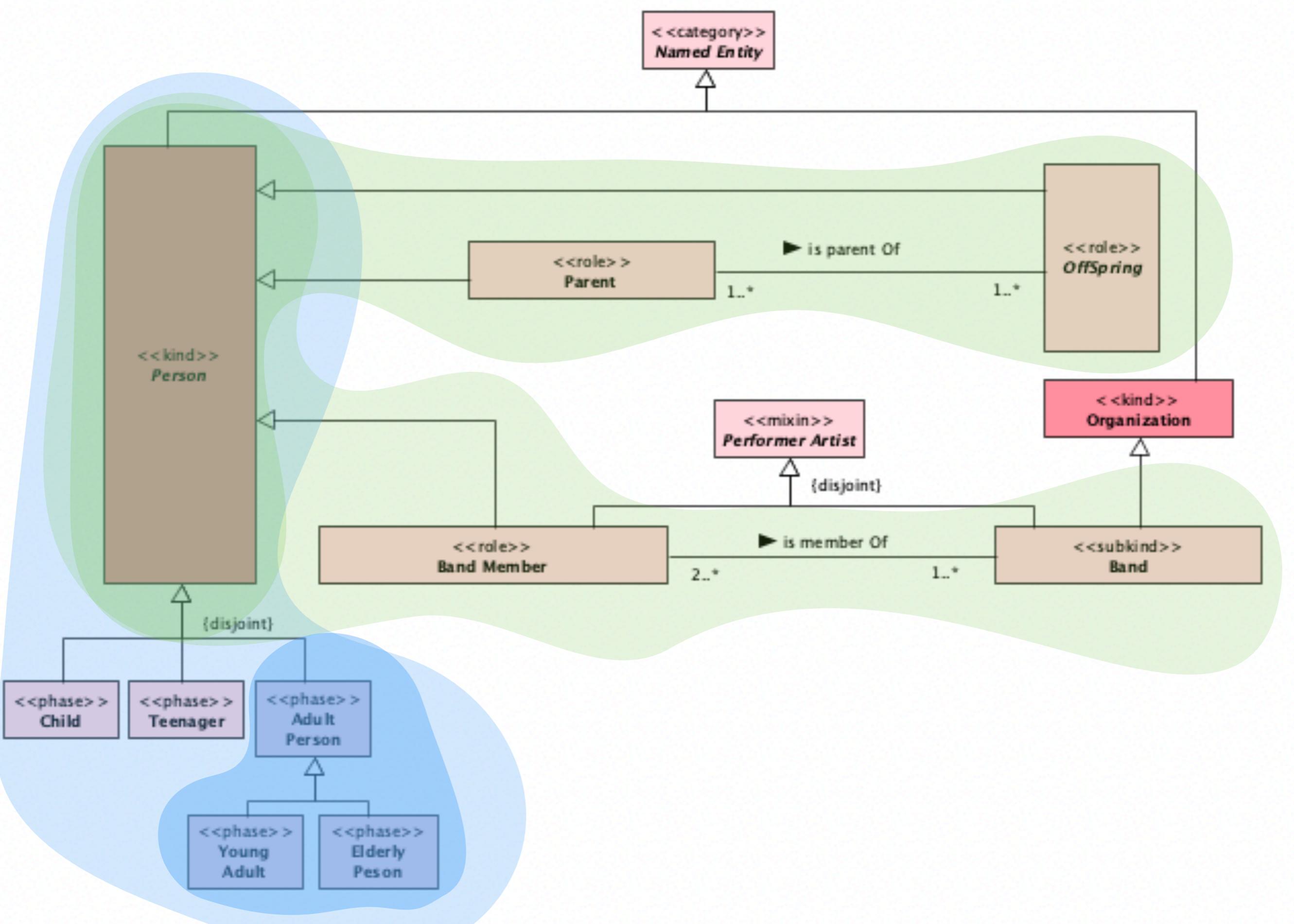


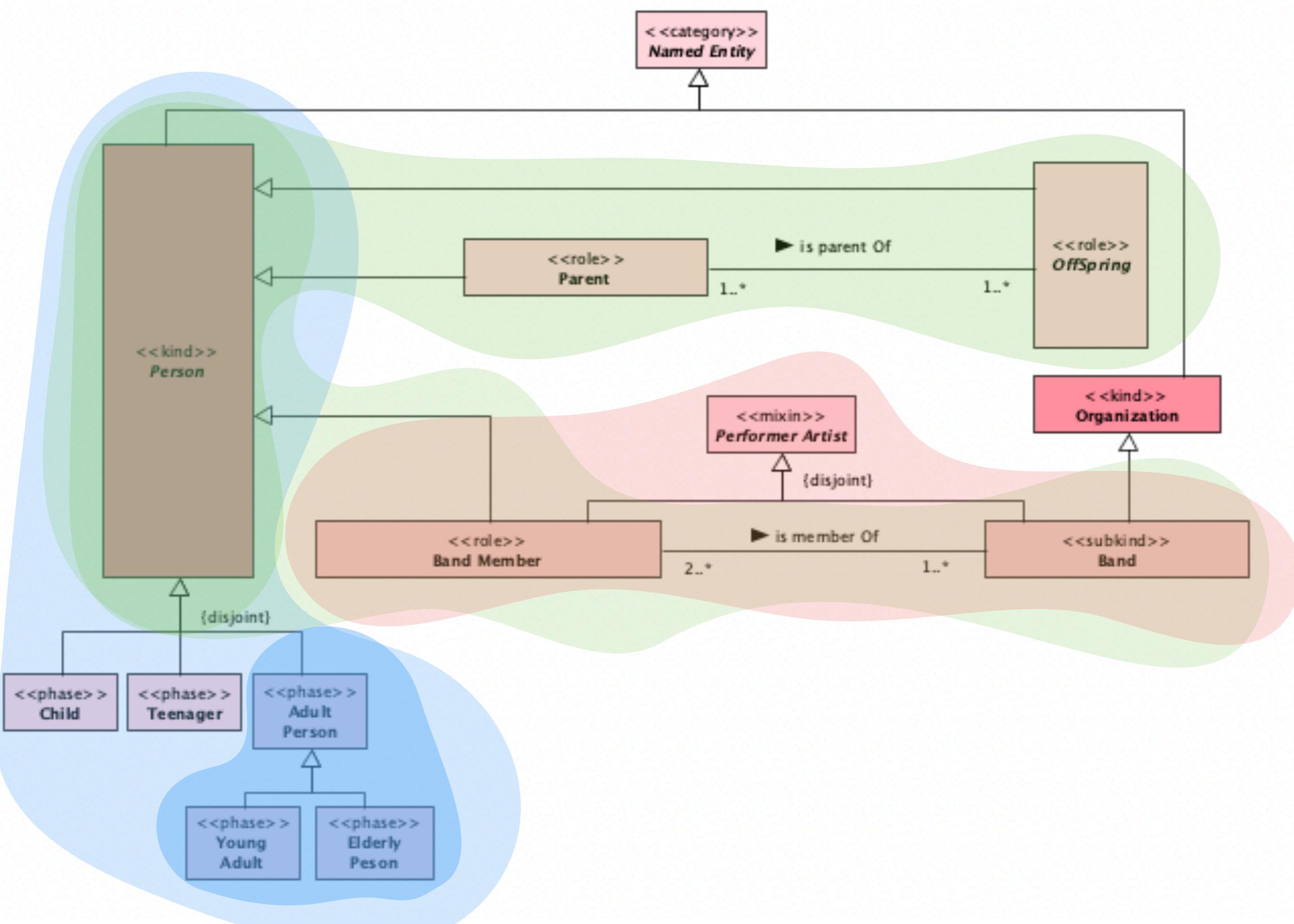


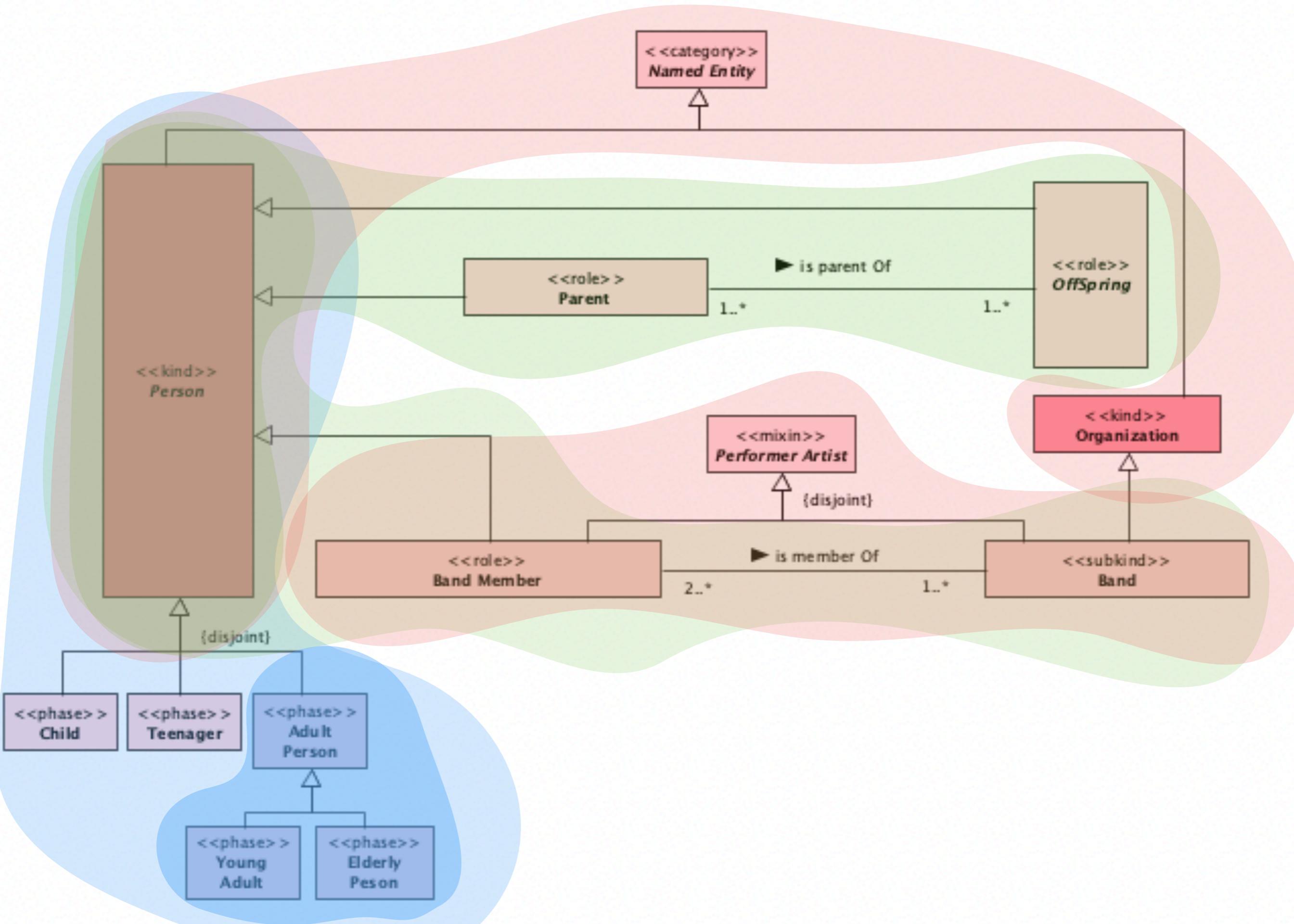












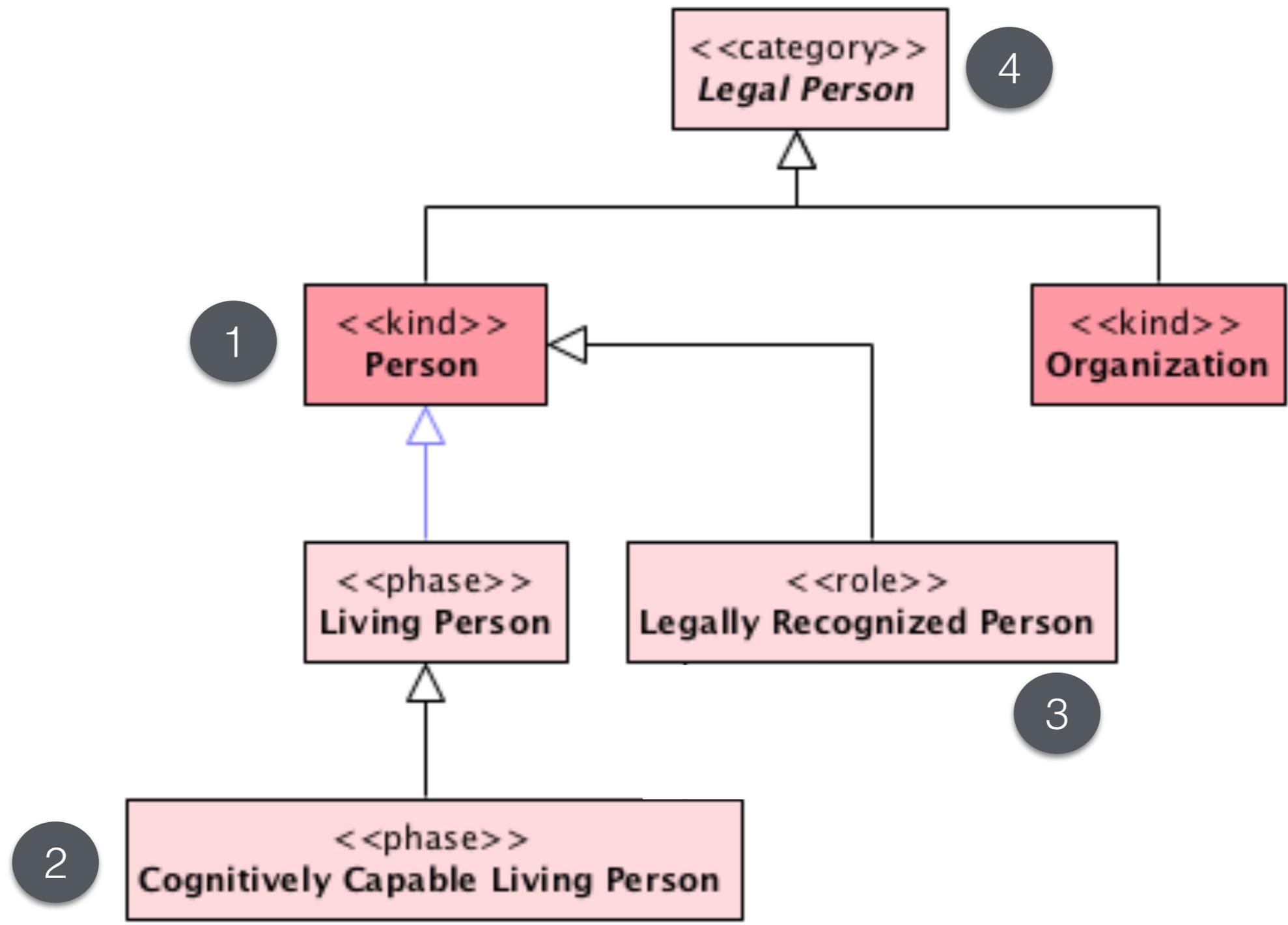
Person?

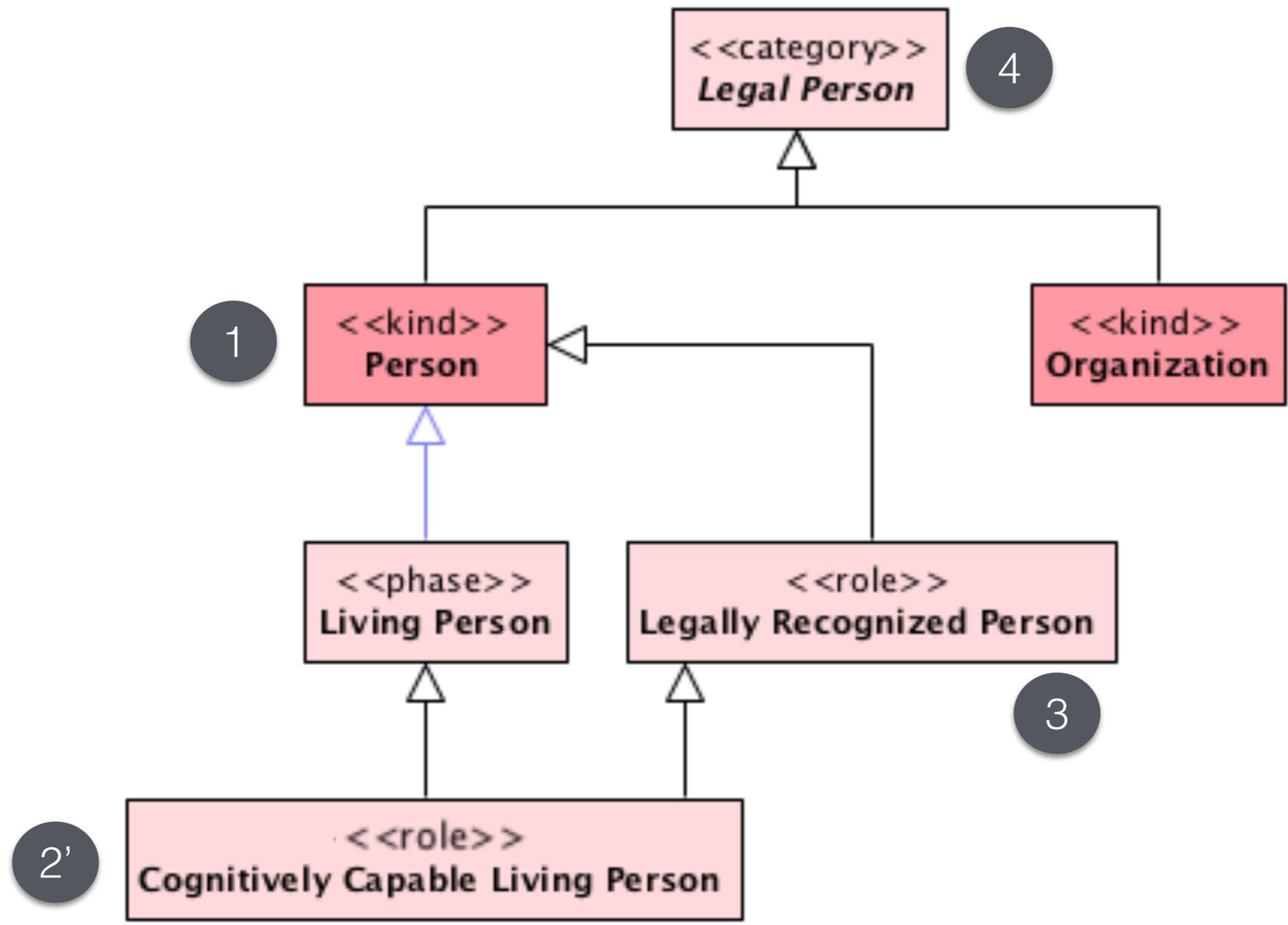
Person?

1. Human Being?
2. Legally Recognized Human Being?
3. Cognitively Capable Human Being?
4. Legal Person?

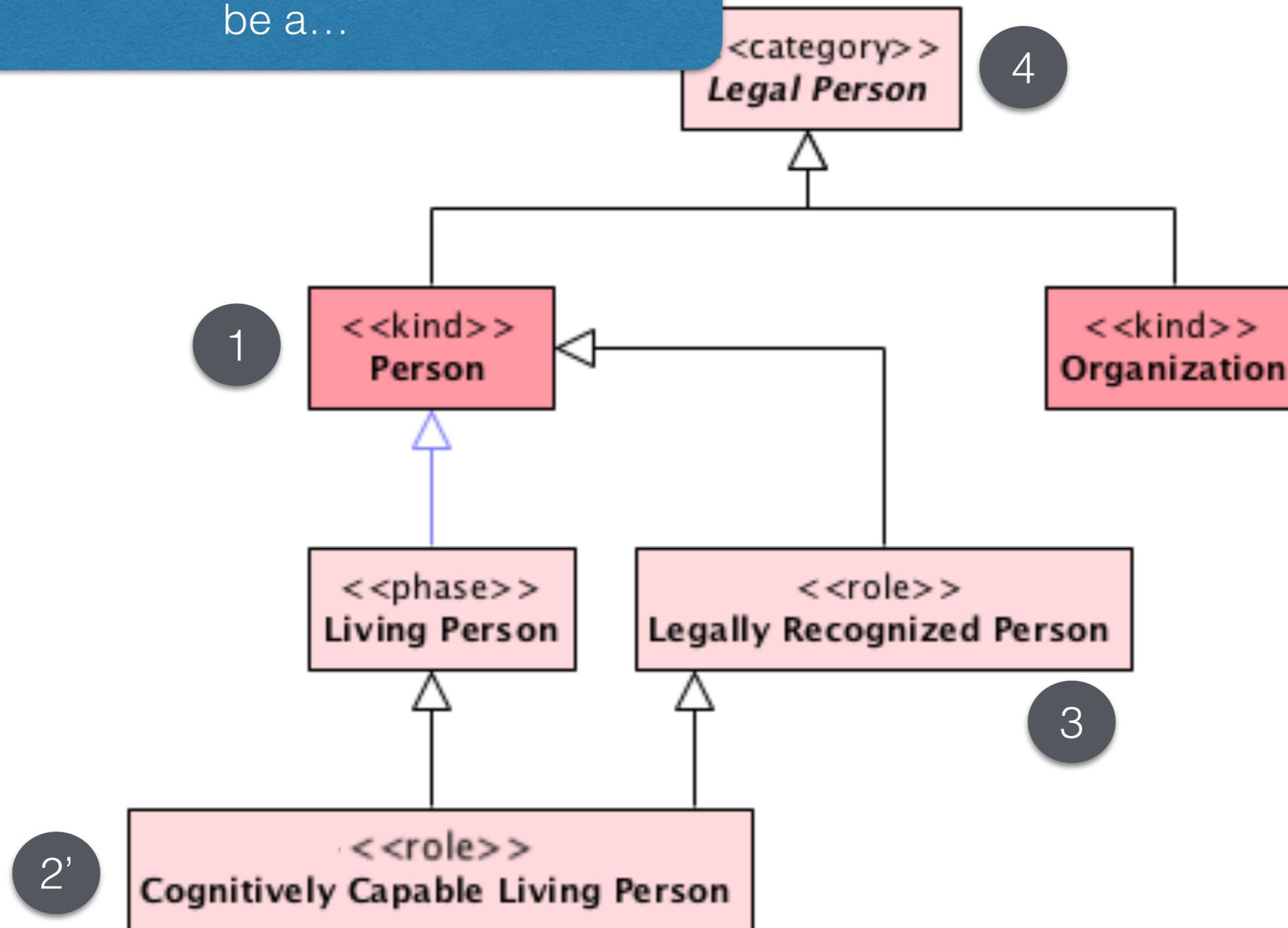
Person?

1. Human Being? **KIND**
2. Legally Recognized Human Being? **ROLE**
3. Cognitively Capable Human Being? **PHASE**
4. Legal Person? **MIXIN**

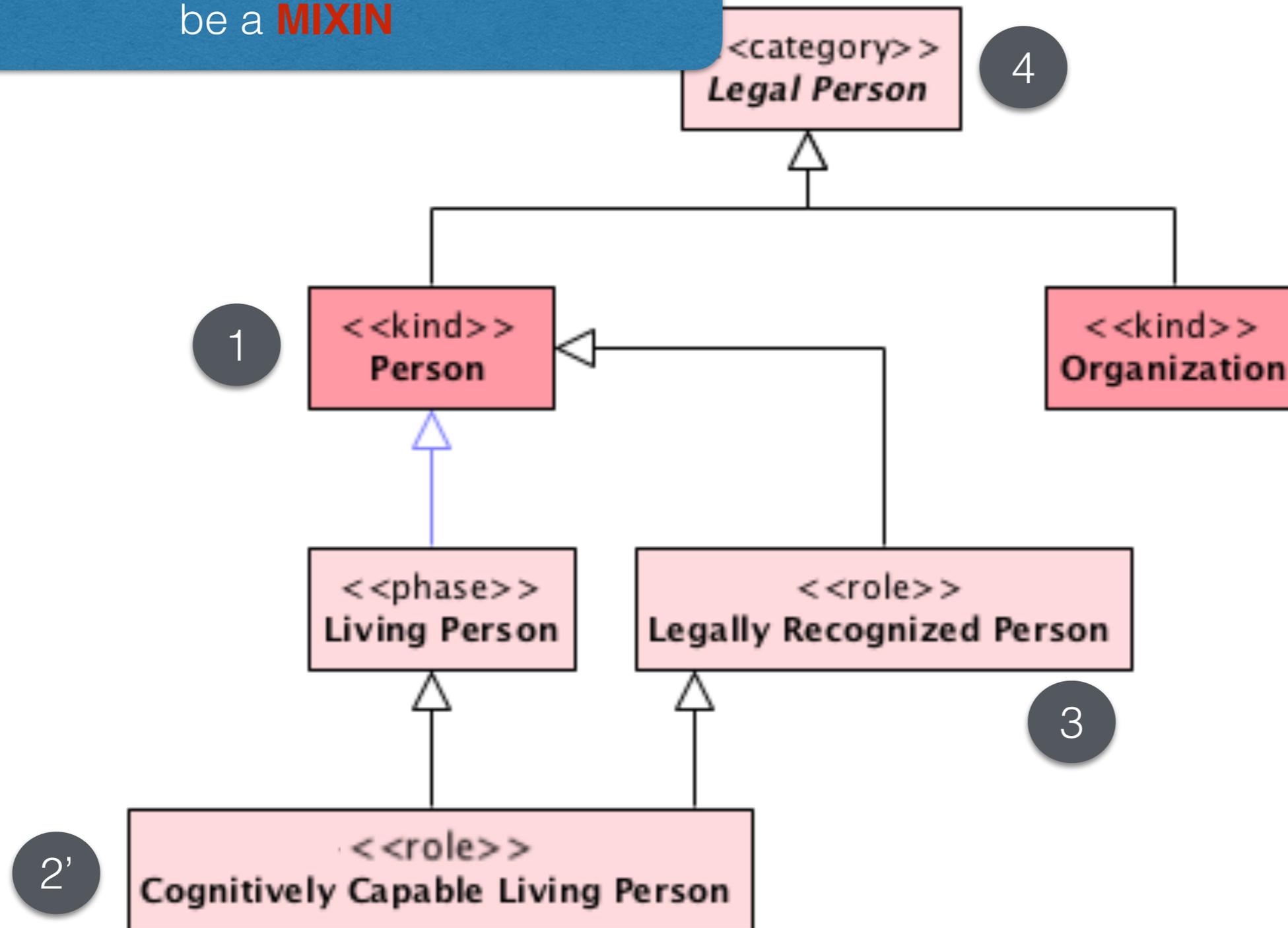


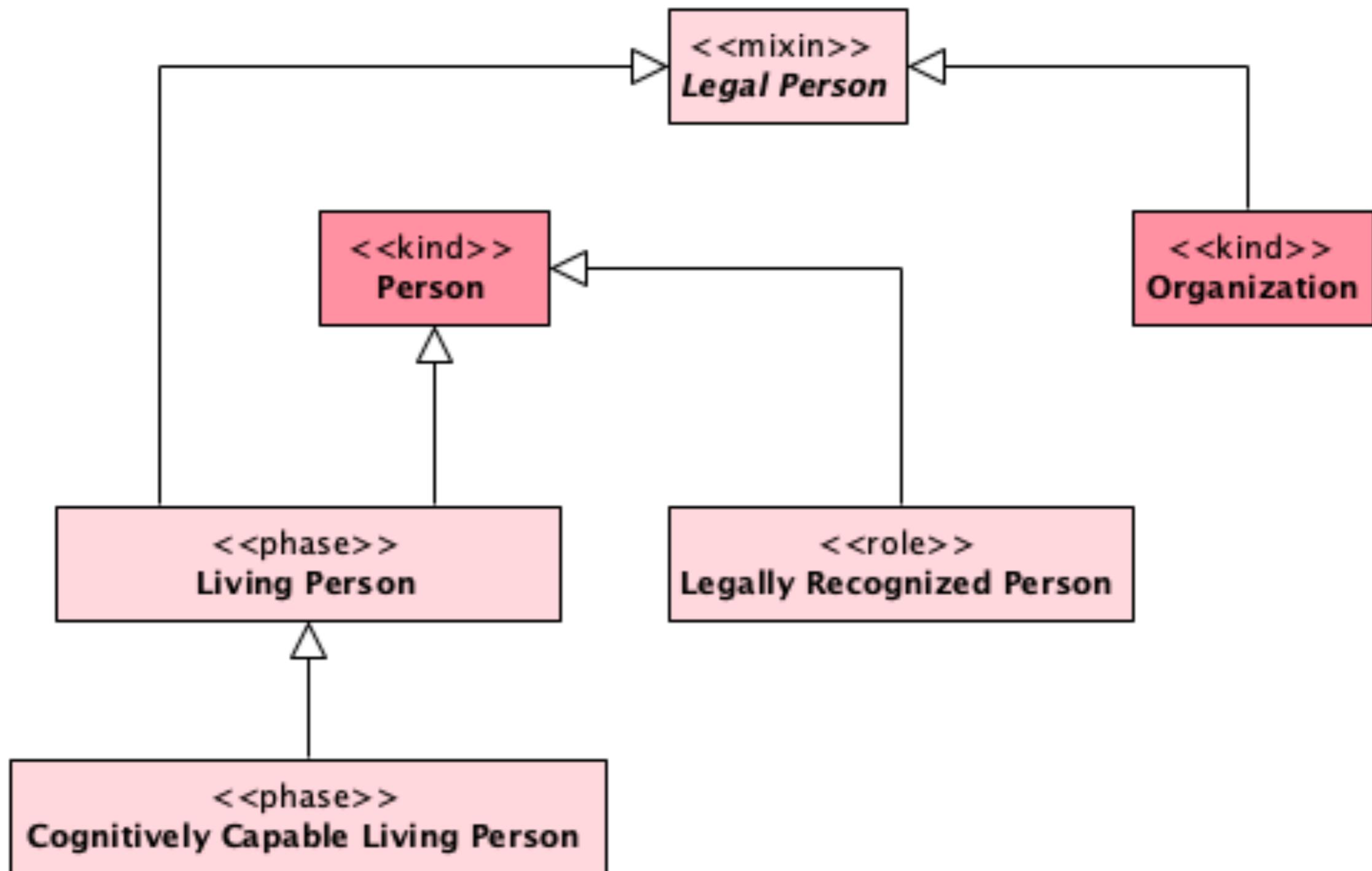


Yet another alternative: Legal Person classifies both organizations and cognitively capable living people. In that case, it would be a...



Yet another alternative: Legal Person classifies both organizations and cognitively capable living people. In that case, it would be a **MIXIN**





3

Relations and Relationships

BBN Report No. 3072
A.I. Report No. 38

ADA022584

WHAT'S IN A LINK:
Foundations for Semantic Networks

W. A. Woods

November 1975

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What is in a **Relationship**?

1. N-tuple?
2. (Directional) Fact?
3. Event?

What is a **Relationship**?

1. N-tuple
2. (Directional) Fact
3. Event
4. **None of the above**

“We need to discuss the *Relationship*”: Revisiting Relationships as Modeling Constructs

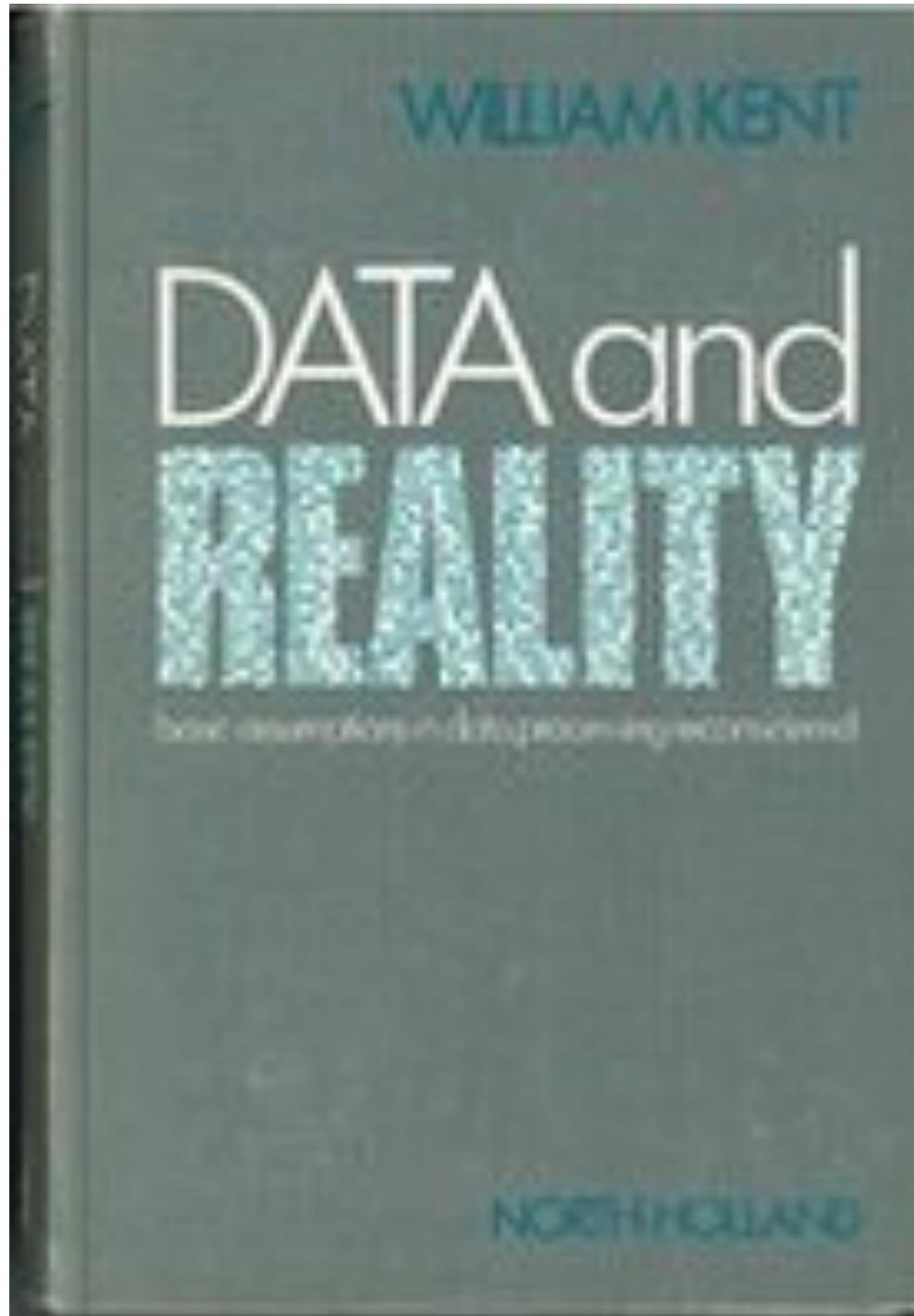
Nicola Guarino¹, Giancarlo Guizzardi^{1,2}

¹Laboratory for Applied Ontology (LOA, ISTC-CNR), Trento, Italy

^{1,2}Computer Science Department, Federal University of Espírito Santo (UFES), Brazil
guarino@loa.istc.cnr.it, gguizzardi@inf.ufes.br

Abstract. This paper advances our long-term research program on ontological foundations for conceptual modeling by addressing one of conceptual modeling’s most fundamental constructs, namely, *relationships*. We investigate the nature of relationships and present an ontological theory of *relationships as endurants* (roughly object-like entities). In this view, and in contrast with the interpretation of relationships as facts or events, relationships can: qualitatively change while maintaining their identity; be the subject of modal properties; be characterized by having both essential and accidental properties. As we demonstrate here, this theory has important consequences to the practice of conceptual modeling. First, regarding the representation of relationship types and their taxonomic structures in conceptual models. Second, as methodological support for understanding the relation between relationships and events and for guiding the choices involved in the modeling and interpretation of reified relationships.

1978



Contents

PREFACE TO THE SECOND EDITION.....	xv
PREFACE.....	xix
1 ENTITIES	1
1.1 One Thing	2
1.2 How Many Things Is It?	7
1.3 Change	10
1.4 The Murderer and the Butler.....	13
1.5 Categories (What Is It?).....	14
1.6 Existence.....	18
2 THE NATURE OF AN INFORMATION SYSTEM.....	23
2.1 Organization.....	23
2.2 Data Description	25
2.3 What is "In the System"?.....	33
2.4 Existence Tests In Information Systems	37
2.5 Records and Representatives	40
3 NAMING	47
3.1 How Many Ways?.....	47
3.2 What is Being Named?	54
3.3 Uniqueness, Scope, and Qualifiers	55
3.4 Scope of Naming Conventions	60
3.5 Changing Names.....	61
3.6 Versions.....	62
3.7 Names, Symbols, Representations	63
3.8 Why Separate Symbols and Things?	63
3.9 Sameness (Equality)	69

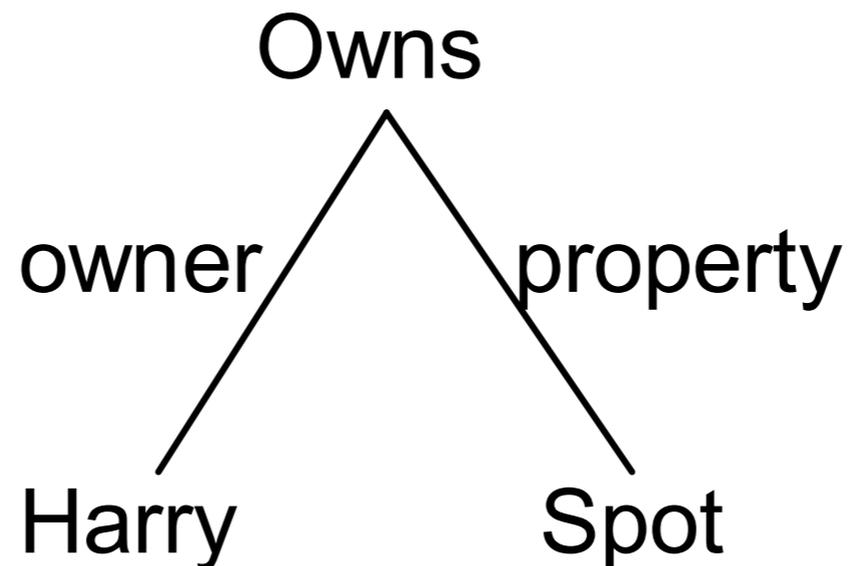
4.5 Relationships and Instances Are Entities

Instances of relationships are things themselves, about which we may have information in the system.

They have attributes. Just as you have an age, so does your association with your department, your spouse, and your car. For a given part (type) stocked in a given warehouse, there is a certain quantity on hand.

They can be related to other things. The storing of a certain part in a certain warehouse is approved by a certain manager.

Instances of relationships can be related to each other (illustrated in section 10.2).



BBN Report No. 3072
A.I. Report No. 38

ADA022584

WHAT'S IN A LINK:

Foundations for Semantic Networks

W. A. Woods

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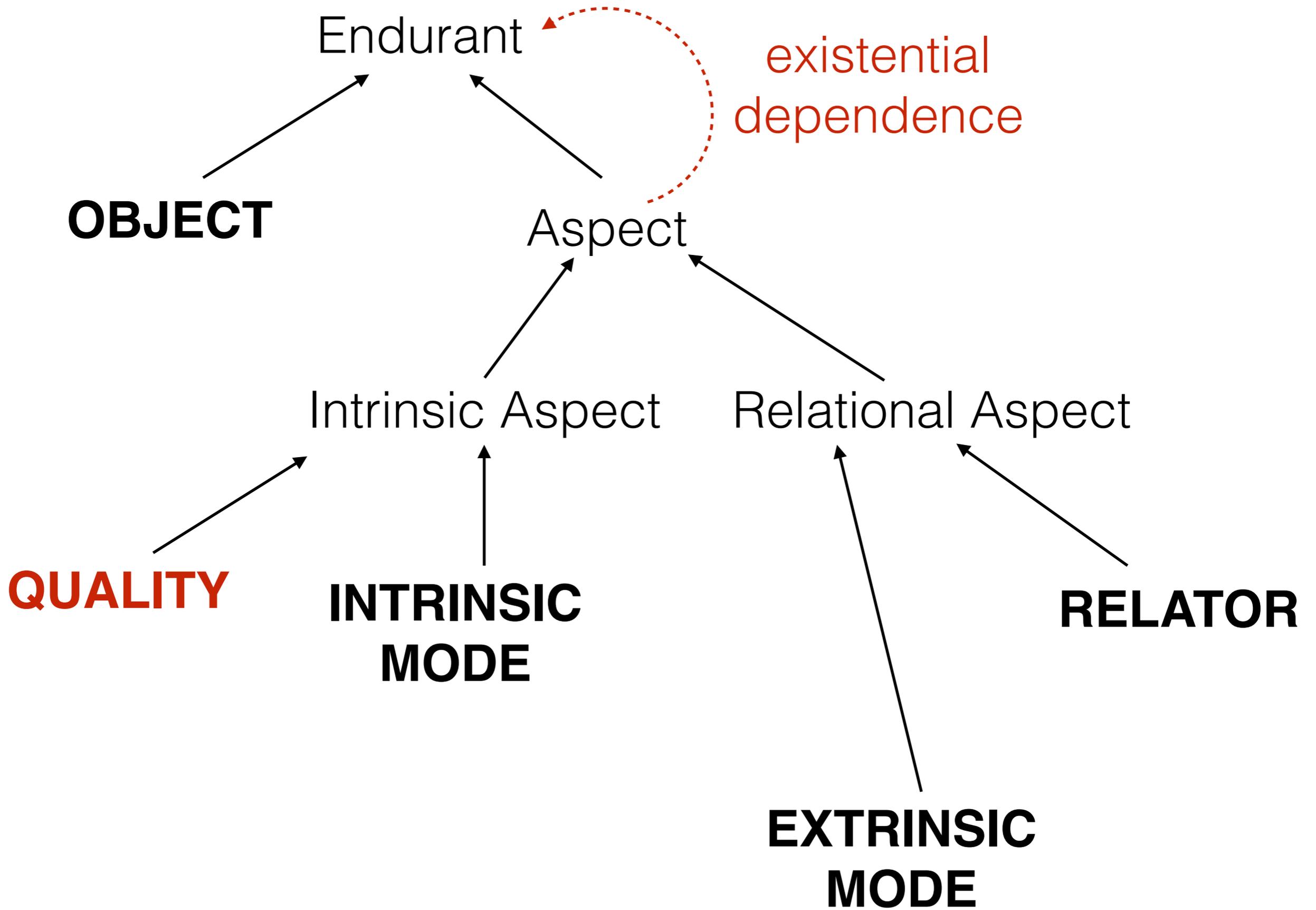
of today's semantic networks. Facts about an object can frequently be stored on a "property list" of the object by specifying such attribute-value pairs as HEIGHT : 6 FEET, HAIRCOLOR : BROWN, OCCUPATION : SCIENTIST, etc. (Such lists are provided, for example, for all atoms in the LISP programming language.) One way of thinking of these pairs is that the attribute name (i.e., the first element of the pair) is the name of a "link" or "pointer" which points to the "value" of the attribute (i.e., the second element of the pair). Such a description of a person named John might be laid out graphically as:

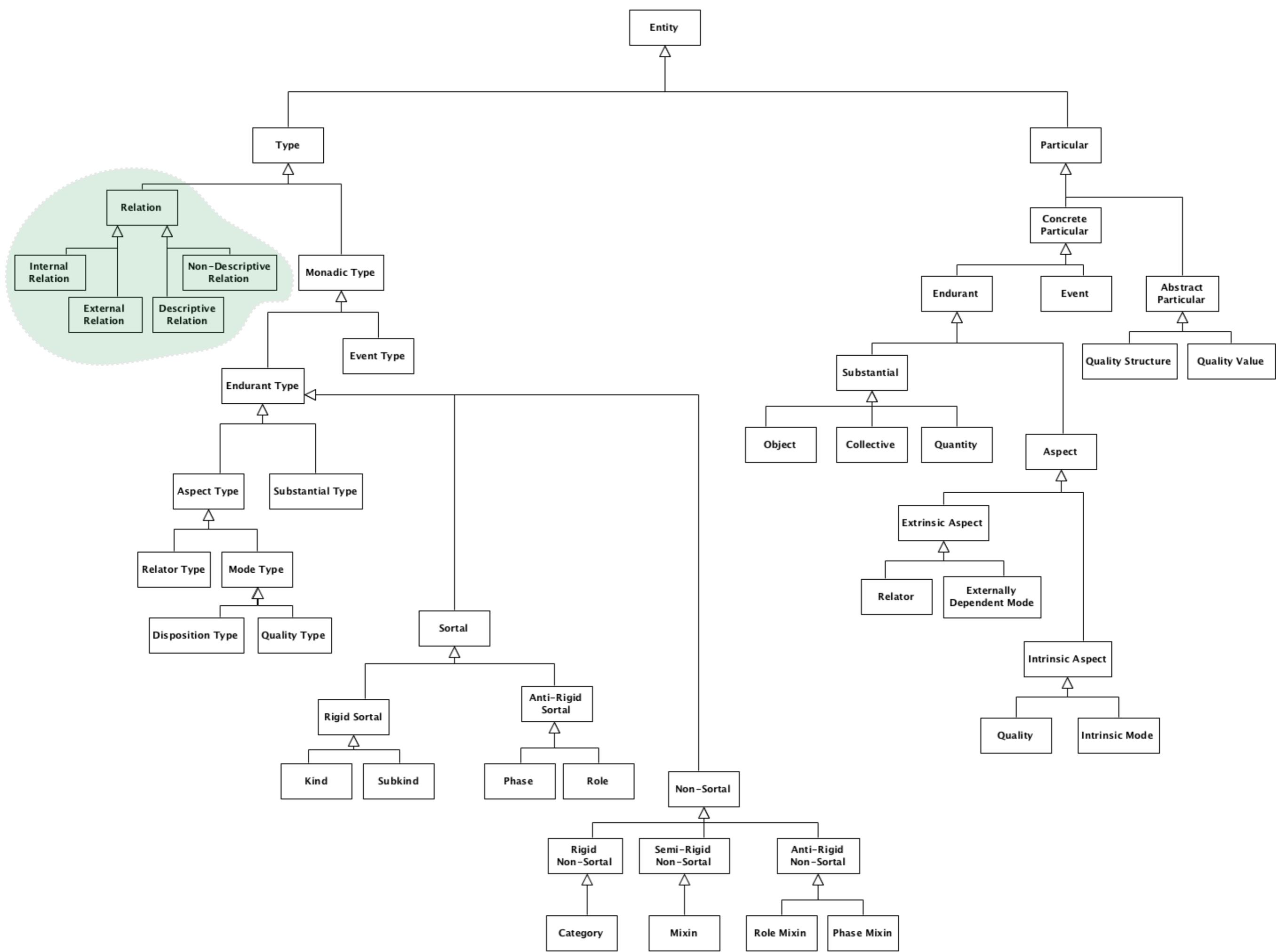
JOHN

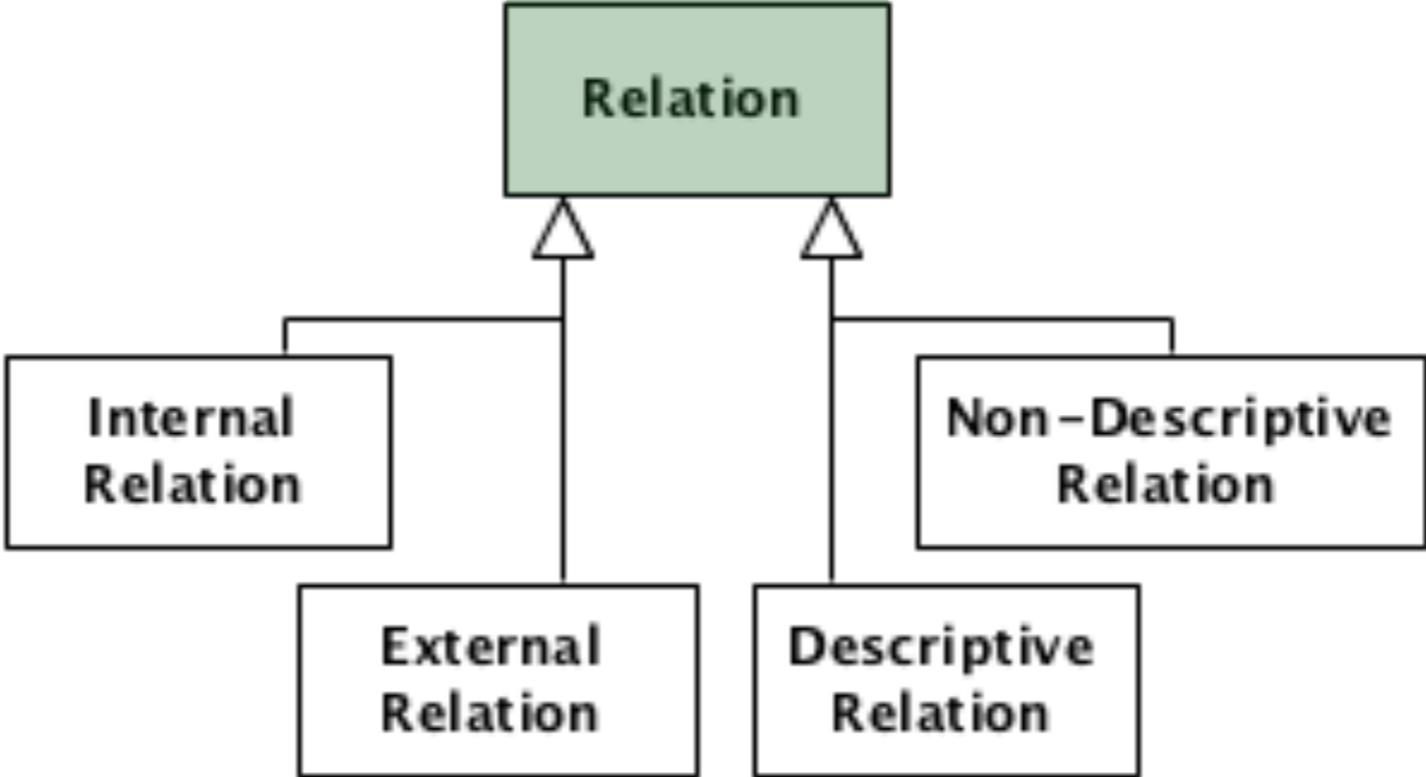
HEIGHT	6 FEET
HAIRCOLOR	BROWN
OCCUPATION	SCIENTIST

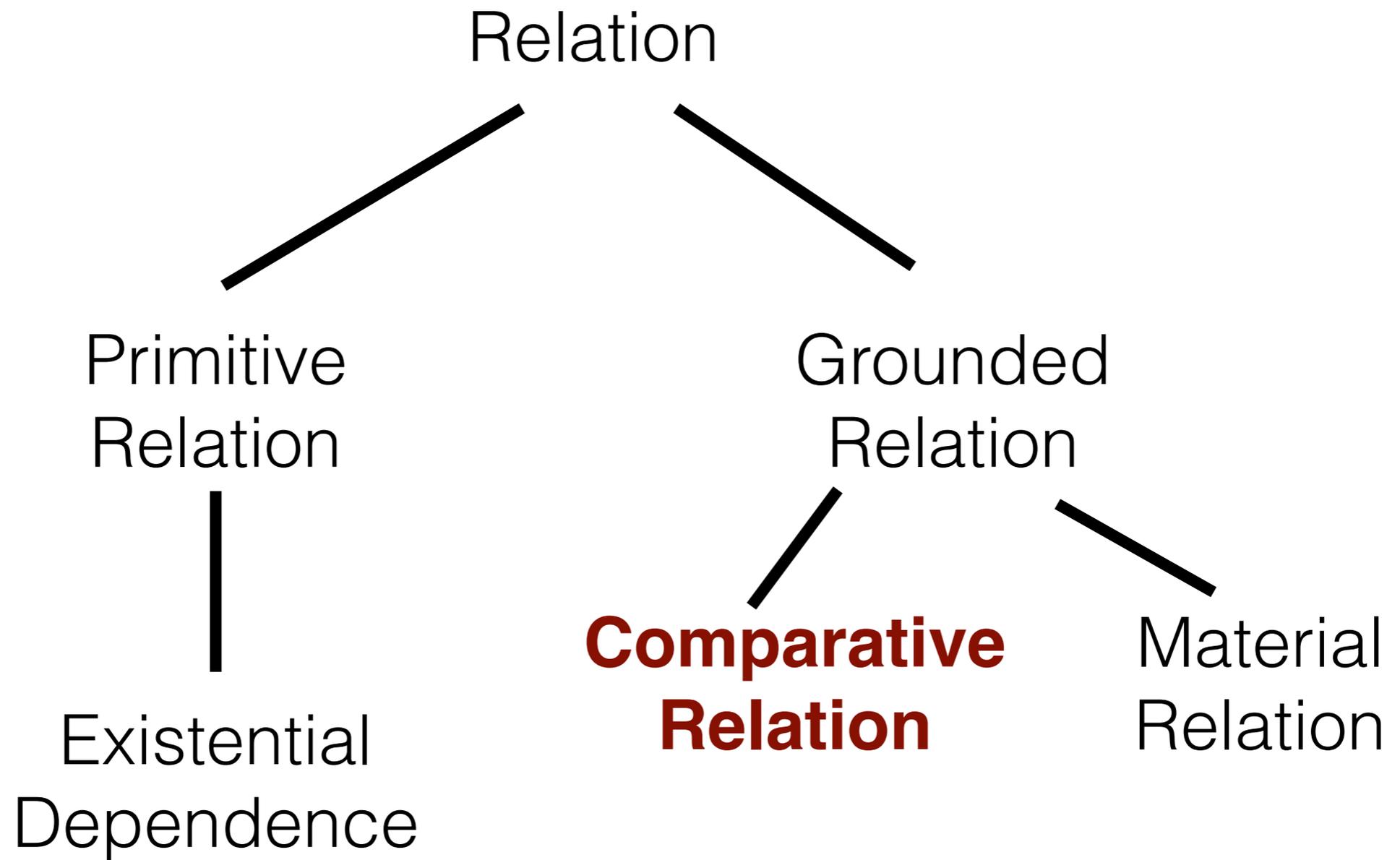
Let us consider now another example -- "John's height is greater than Sue's". We now have a new set of problems. We can still think of a link named HEIGHT pointing from JOHN to a predicate whose interpretation is "greater than Sue's height", but what does the reference to Sue's height inside this predicate have to do with the way that we represented John's height? In a functional form we would simply

but that is departing completely from the notion of attribute-value links. There is another possible interpretation of the thing at the end of the HEIGHT link which would be capable of dealing with this type of situation. That is, the HEIGHT link can point from JOHN to a node which represents the intensional object "John's height". In a similar way, we can have a link named HEIGHT from SUE to a node which represents "Sue's height" and then we can establish a relation GREATER between these two intensional nodes. (Notice that even if the heights were the same, the two intensional objects would be different,











Paul

George





George

Paul

taller-than (Paul, George)?

taller-than (Paul,George)?

Paul

George



hp



Hg

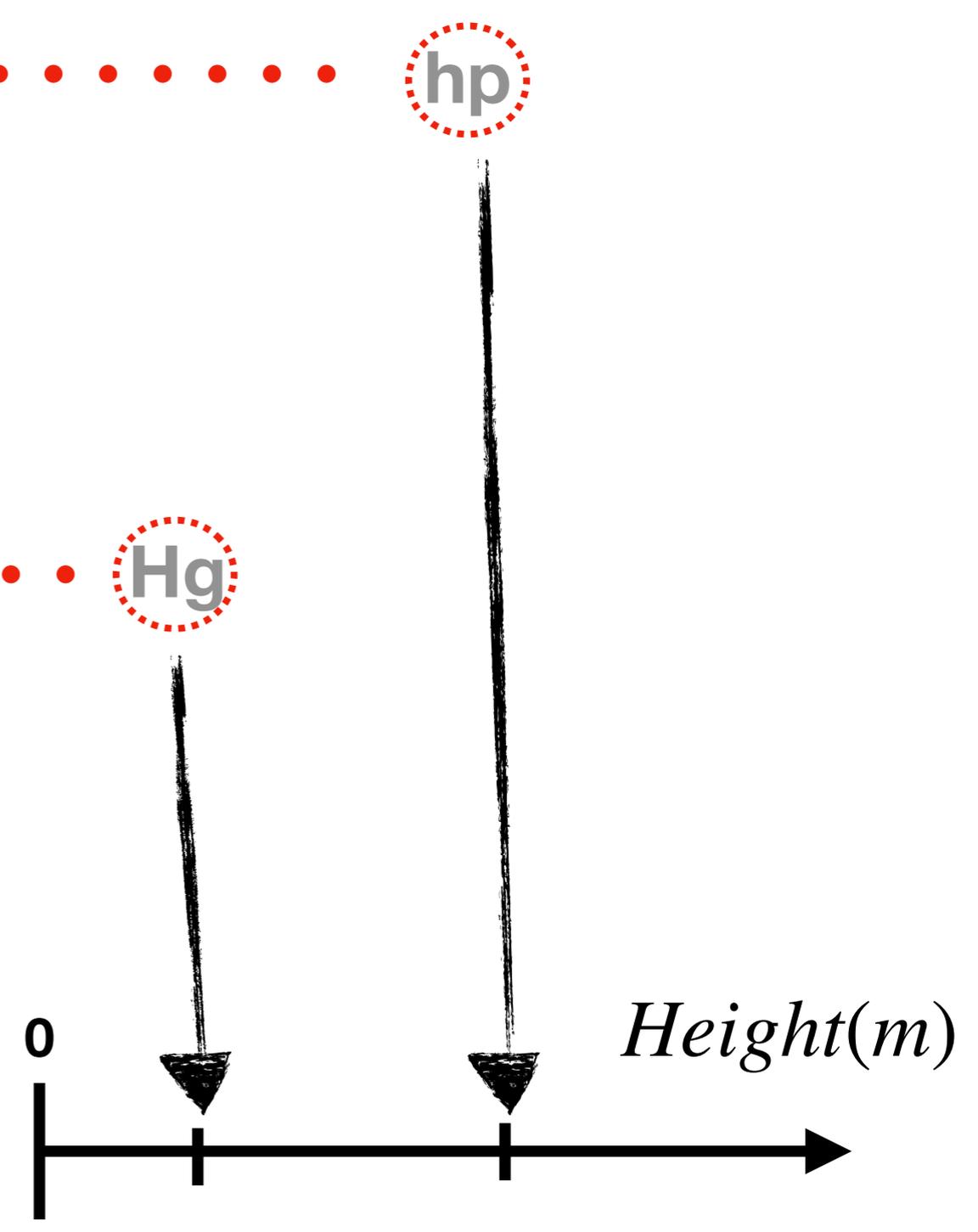




George

Paul

taller-than (Paul, George)?

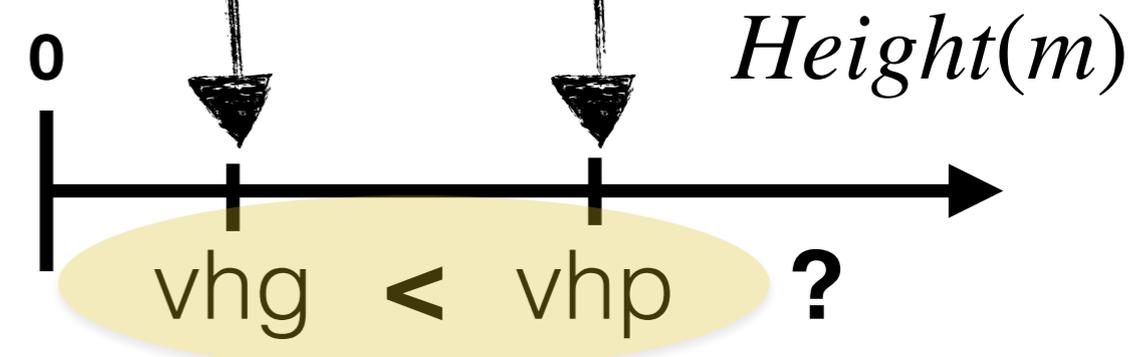




George

Paul

taller-than (Paul, George)?





George

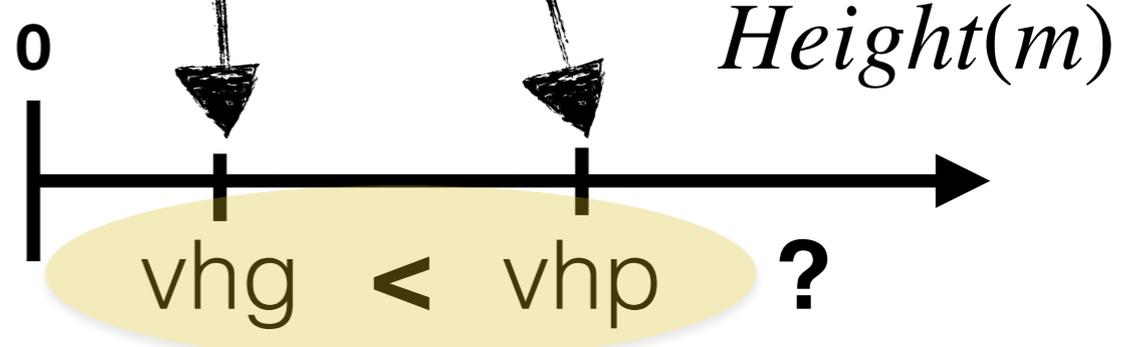
Paul

taller-than (Paul, George)?

Totally Ordered
(Non-reflexive
Asymmetric
Transitive
Total)

hp

Hg





George

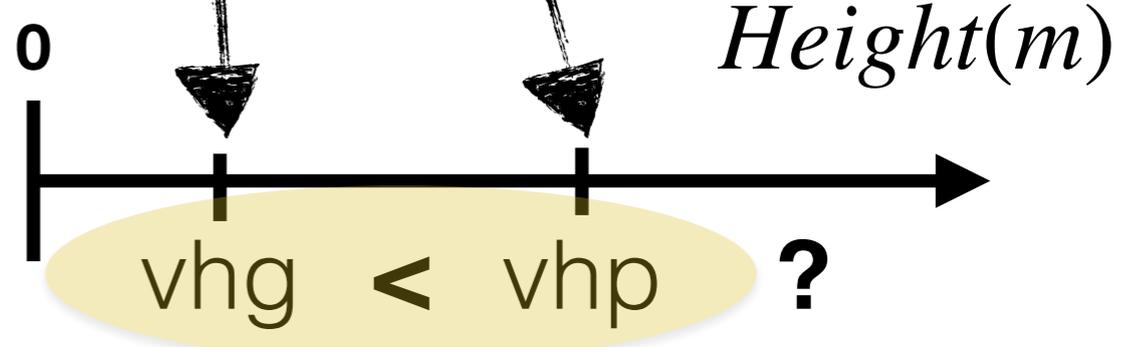
Paul

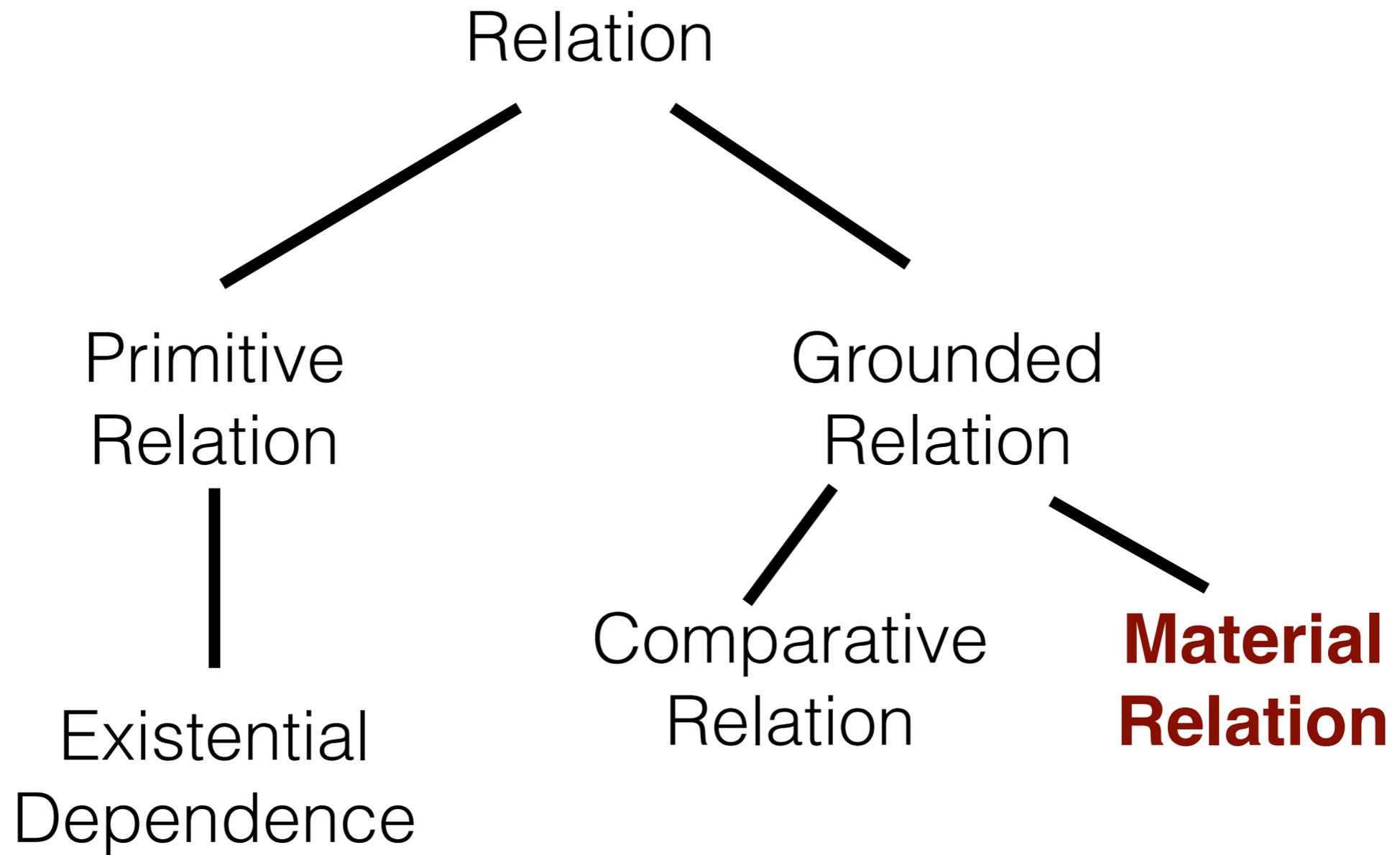
taller-than (Paul, George)?

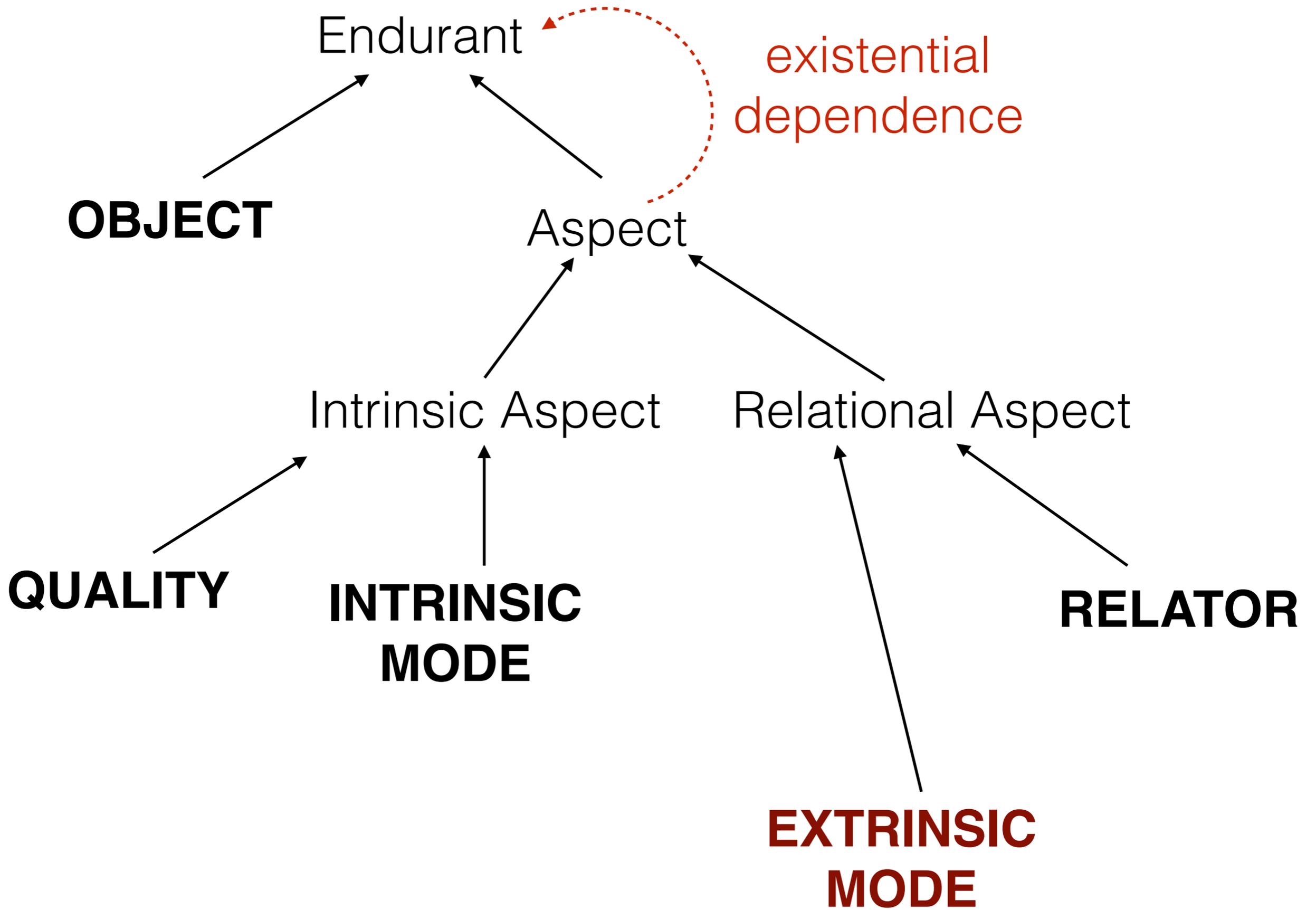
hp

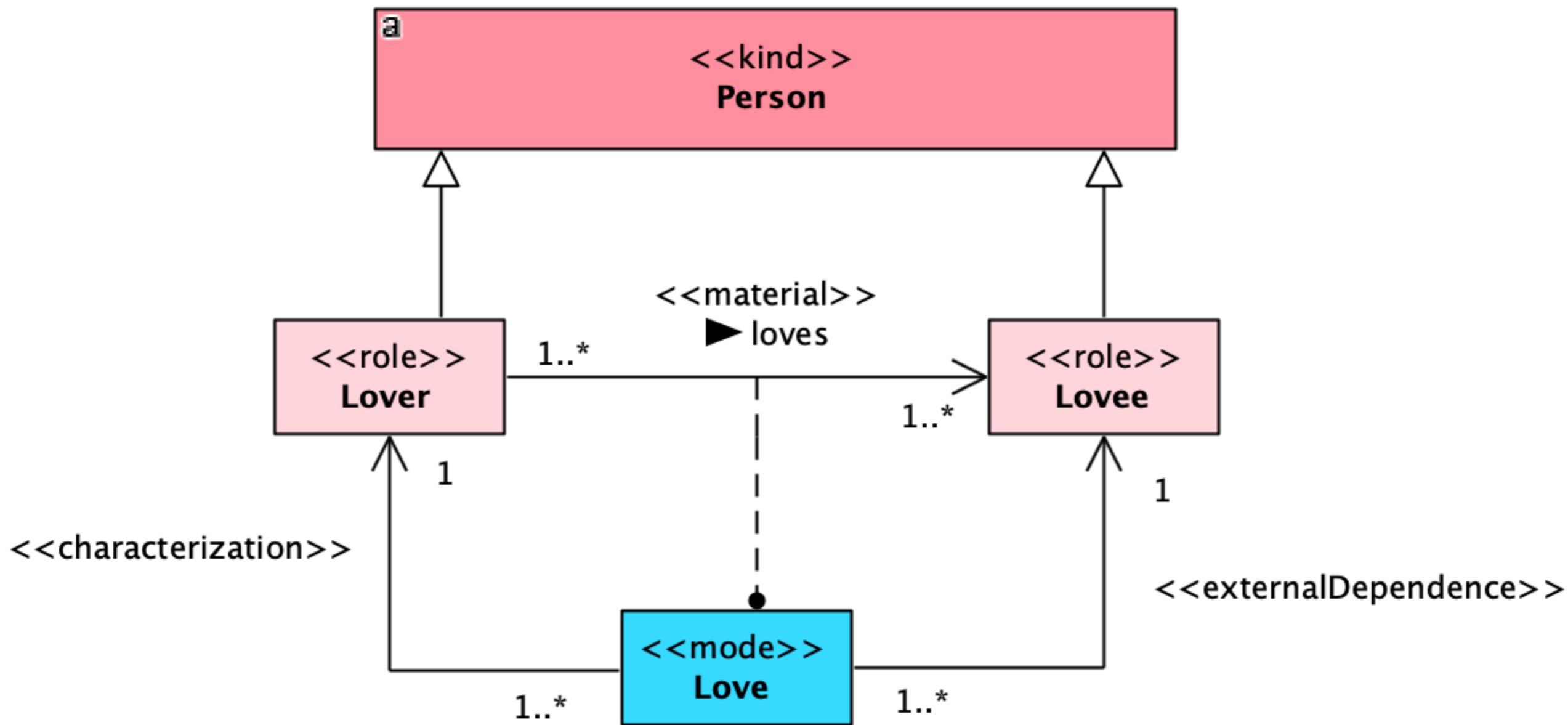
Hg

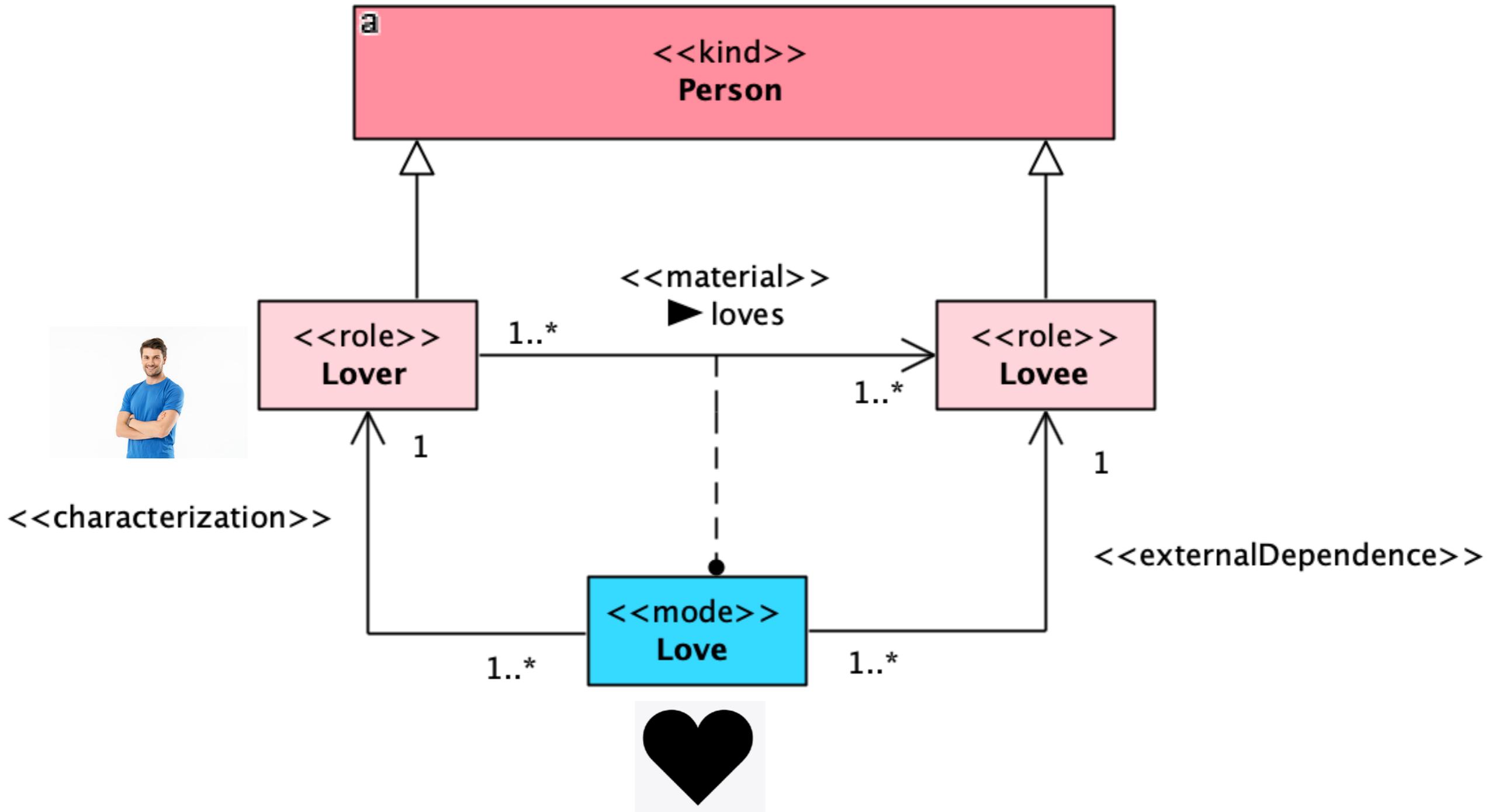
Totally Ordered
(Non-reflexive
Asymmetric
Transitive
Total)

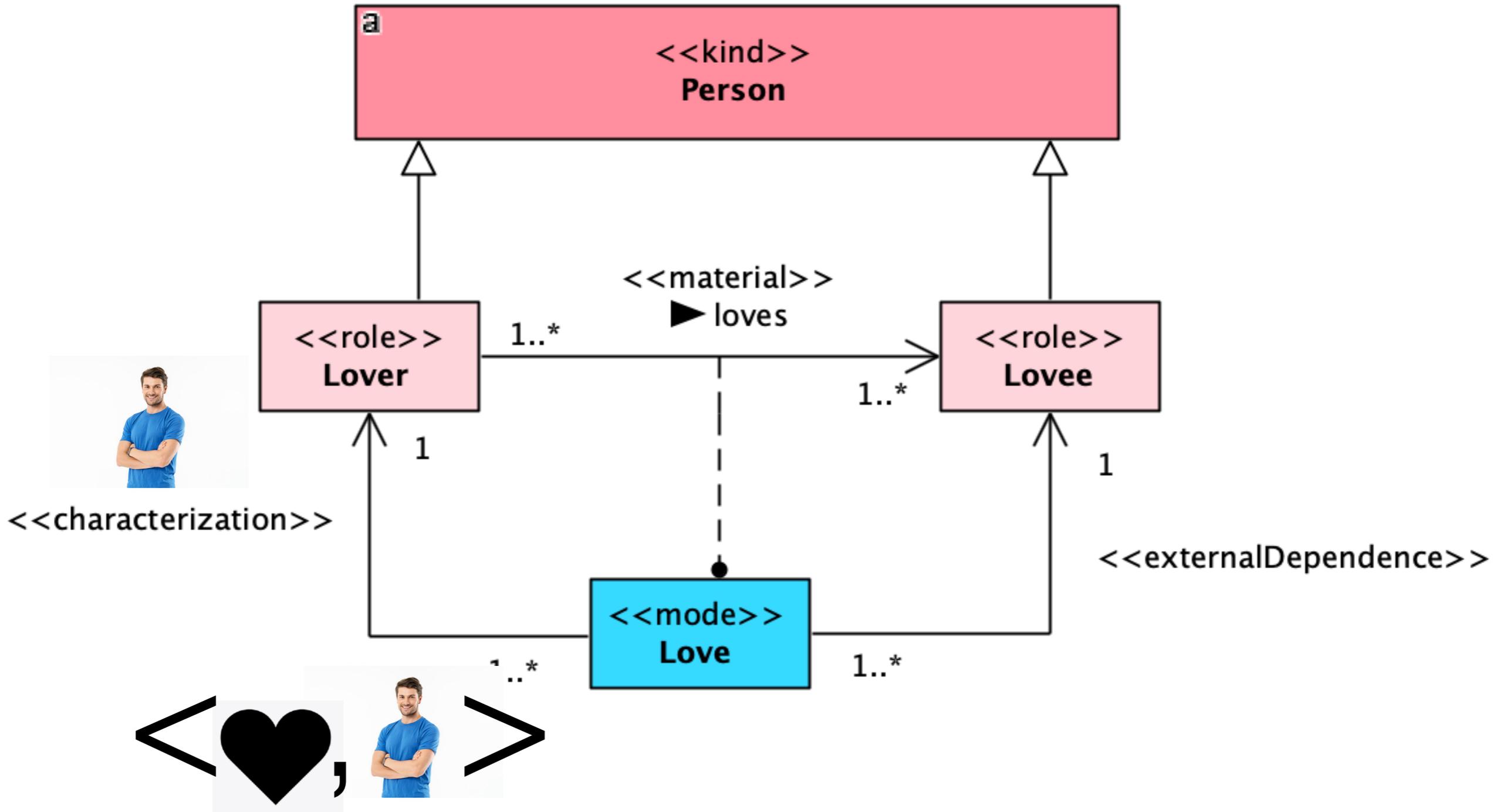


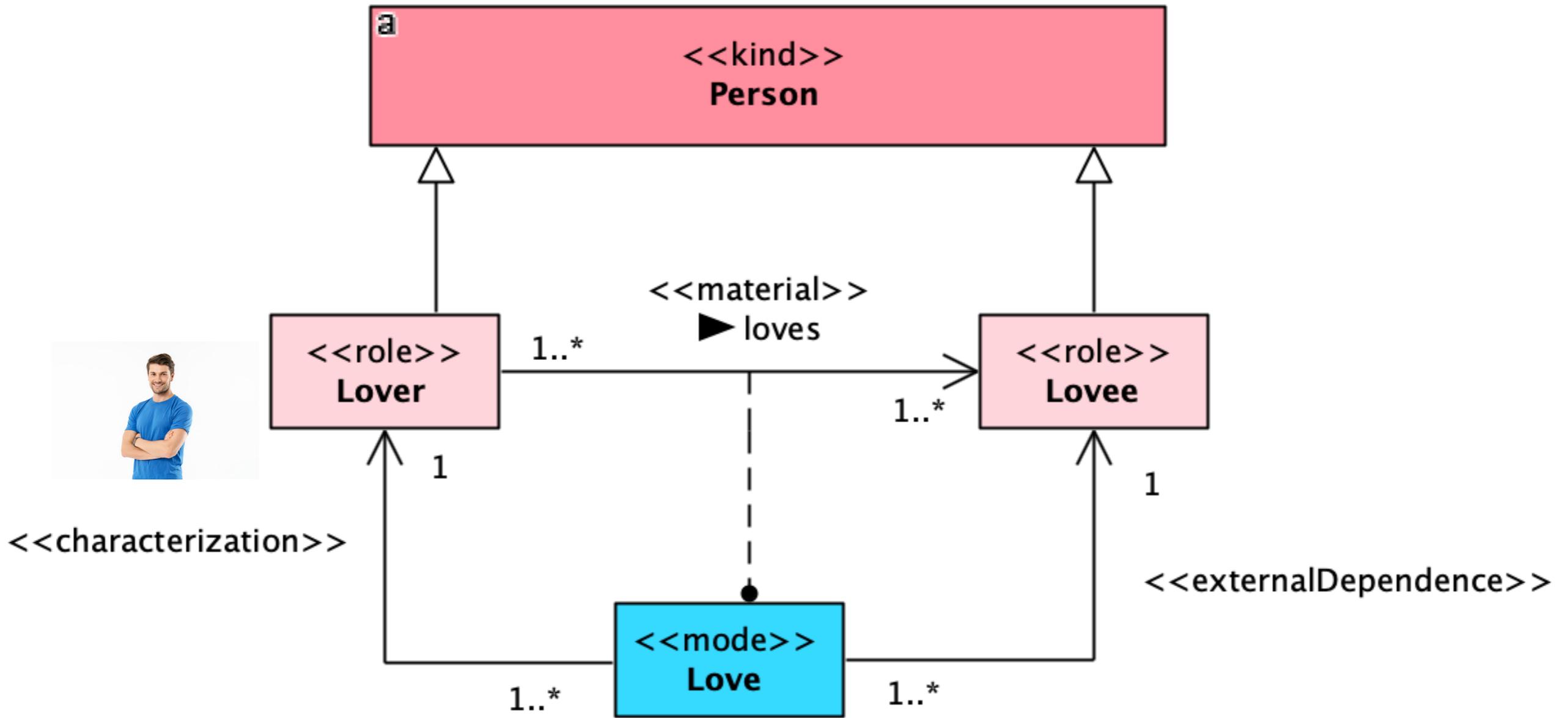


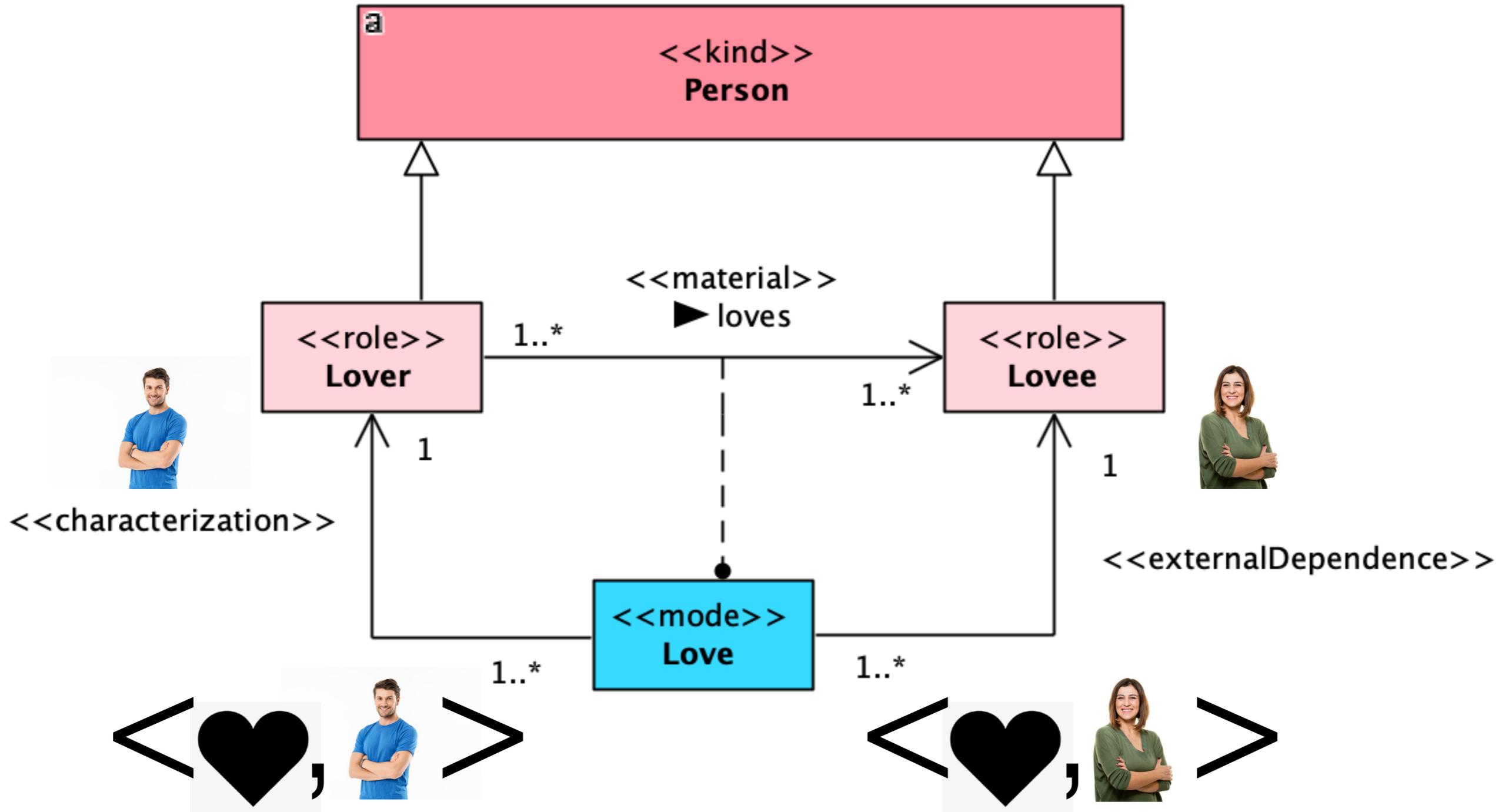


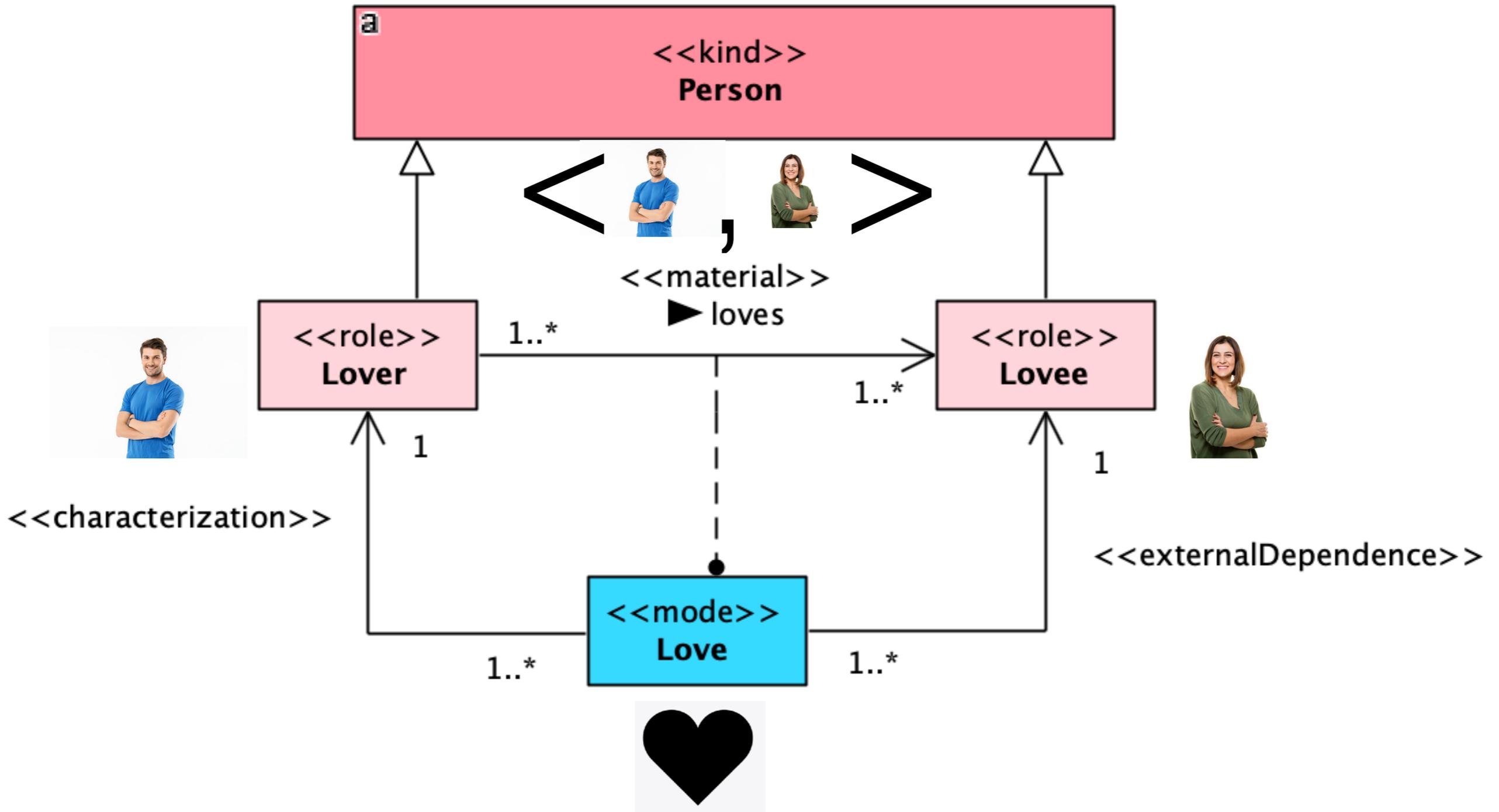


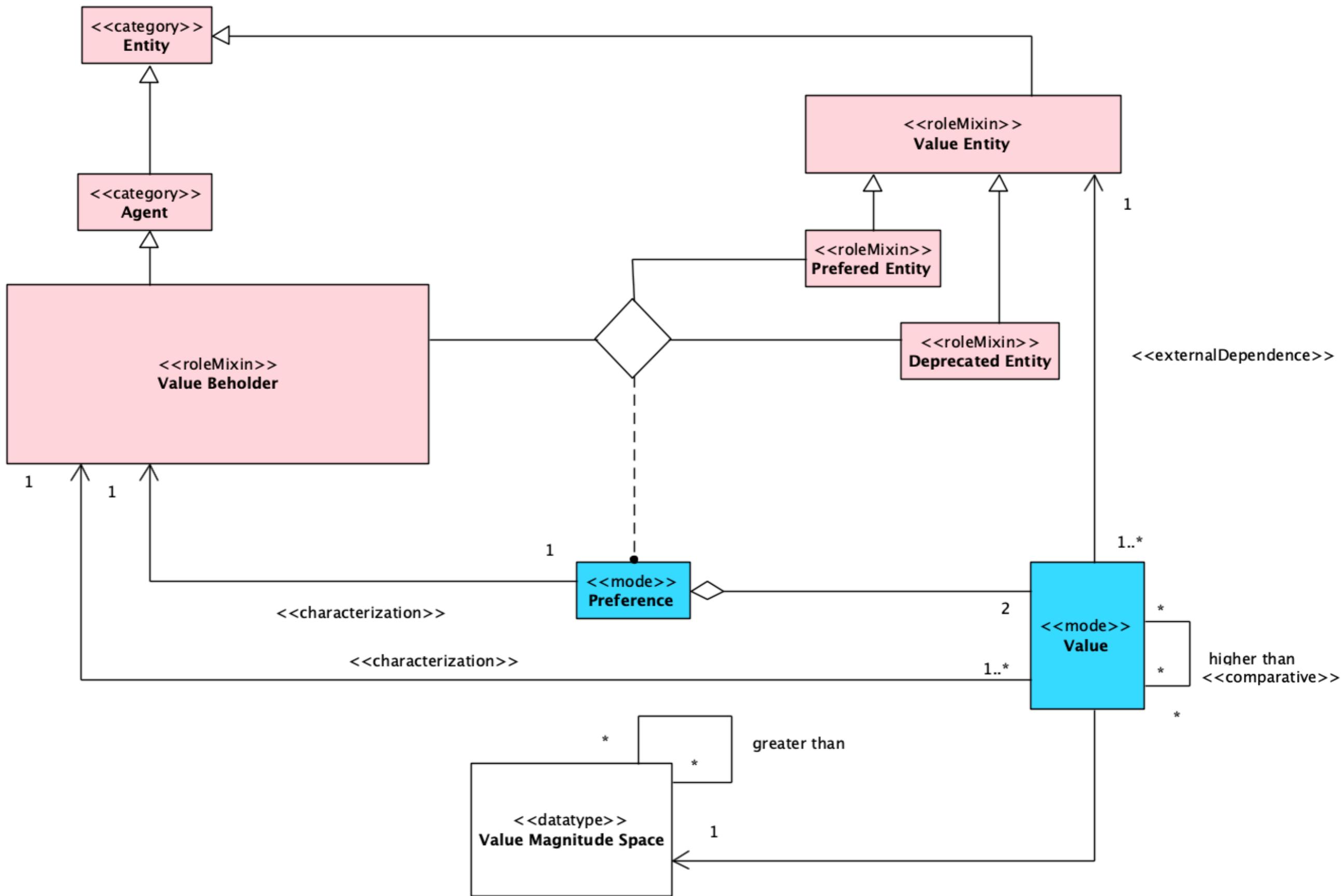


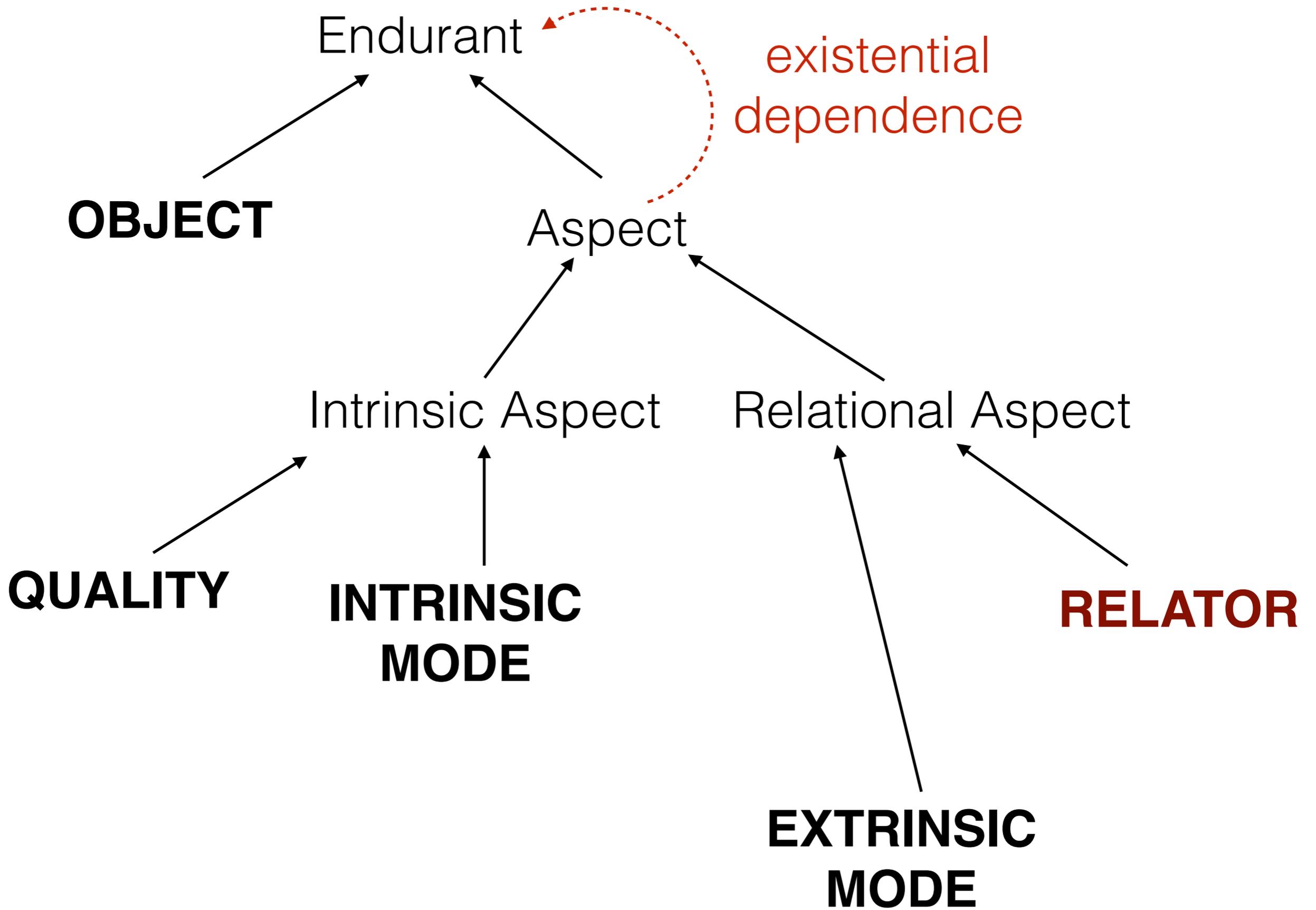


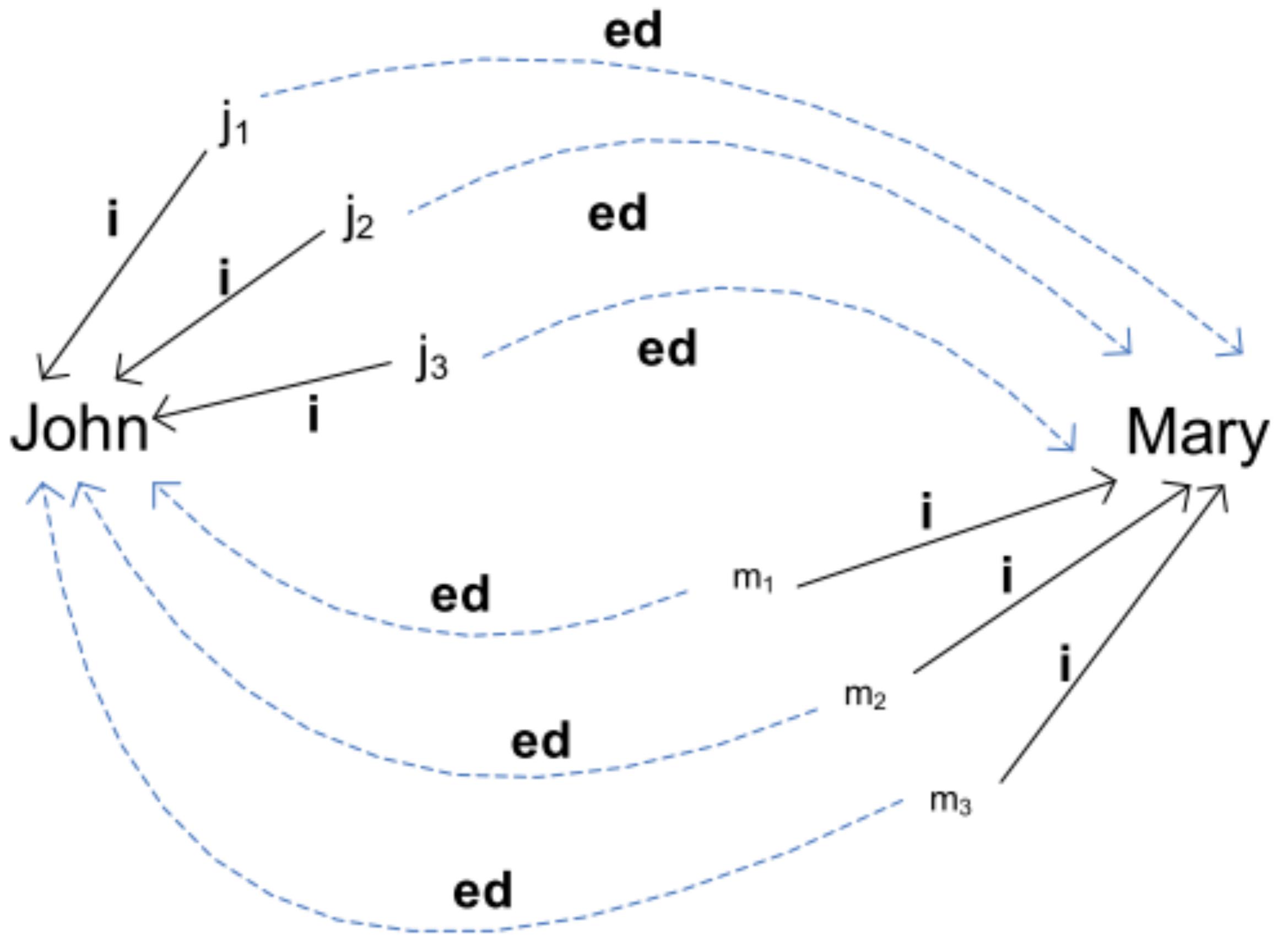




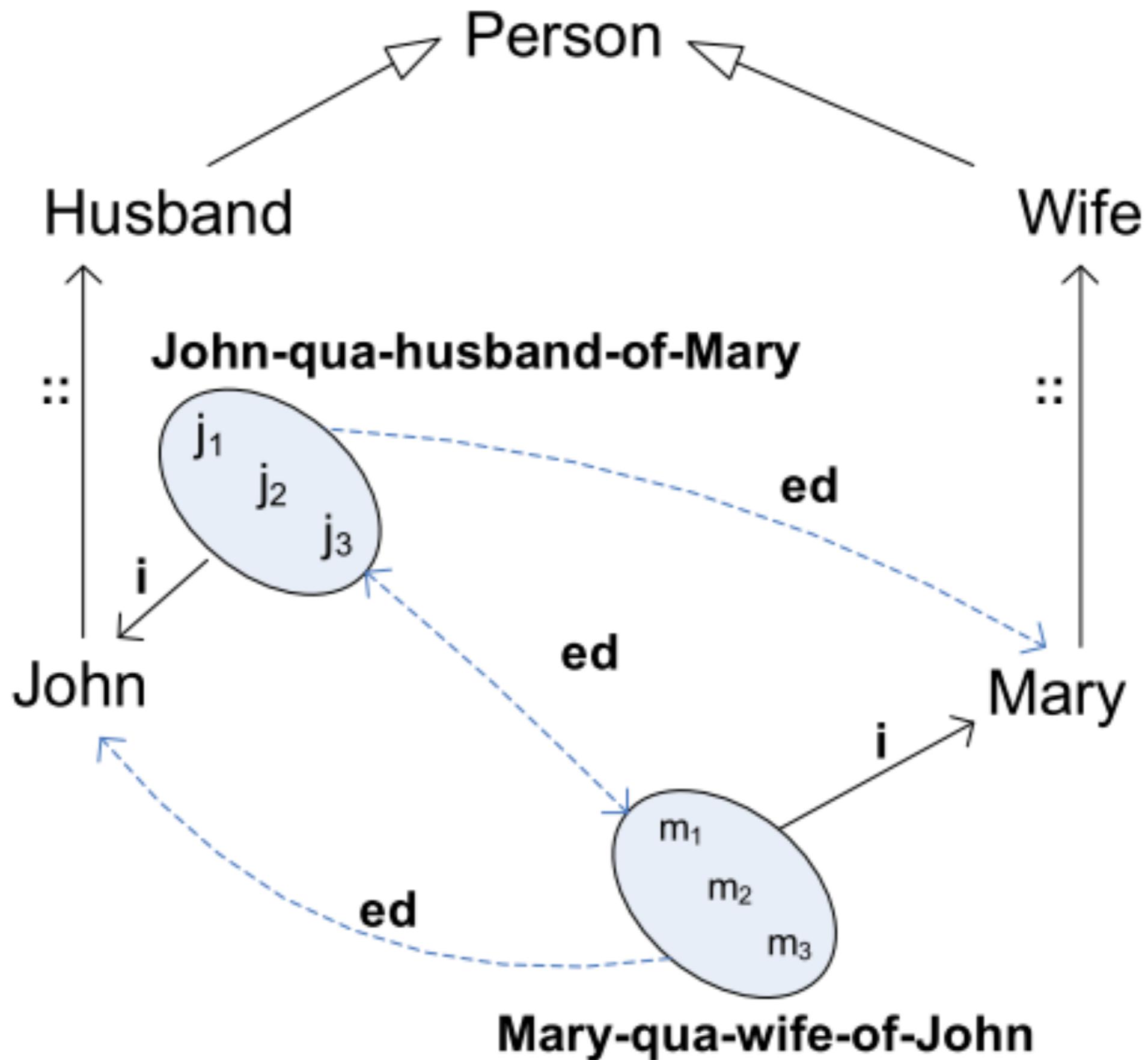


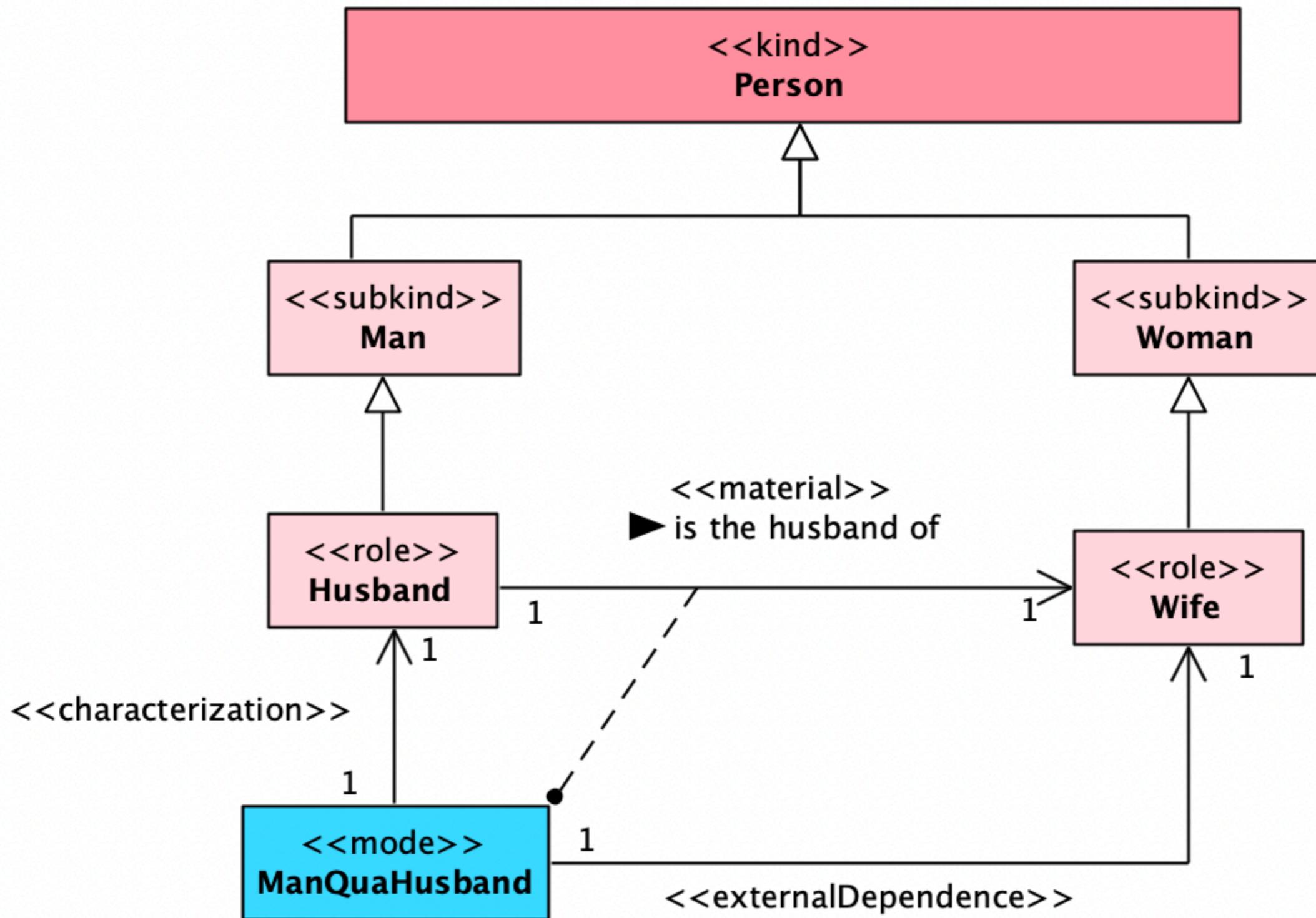


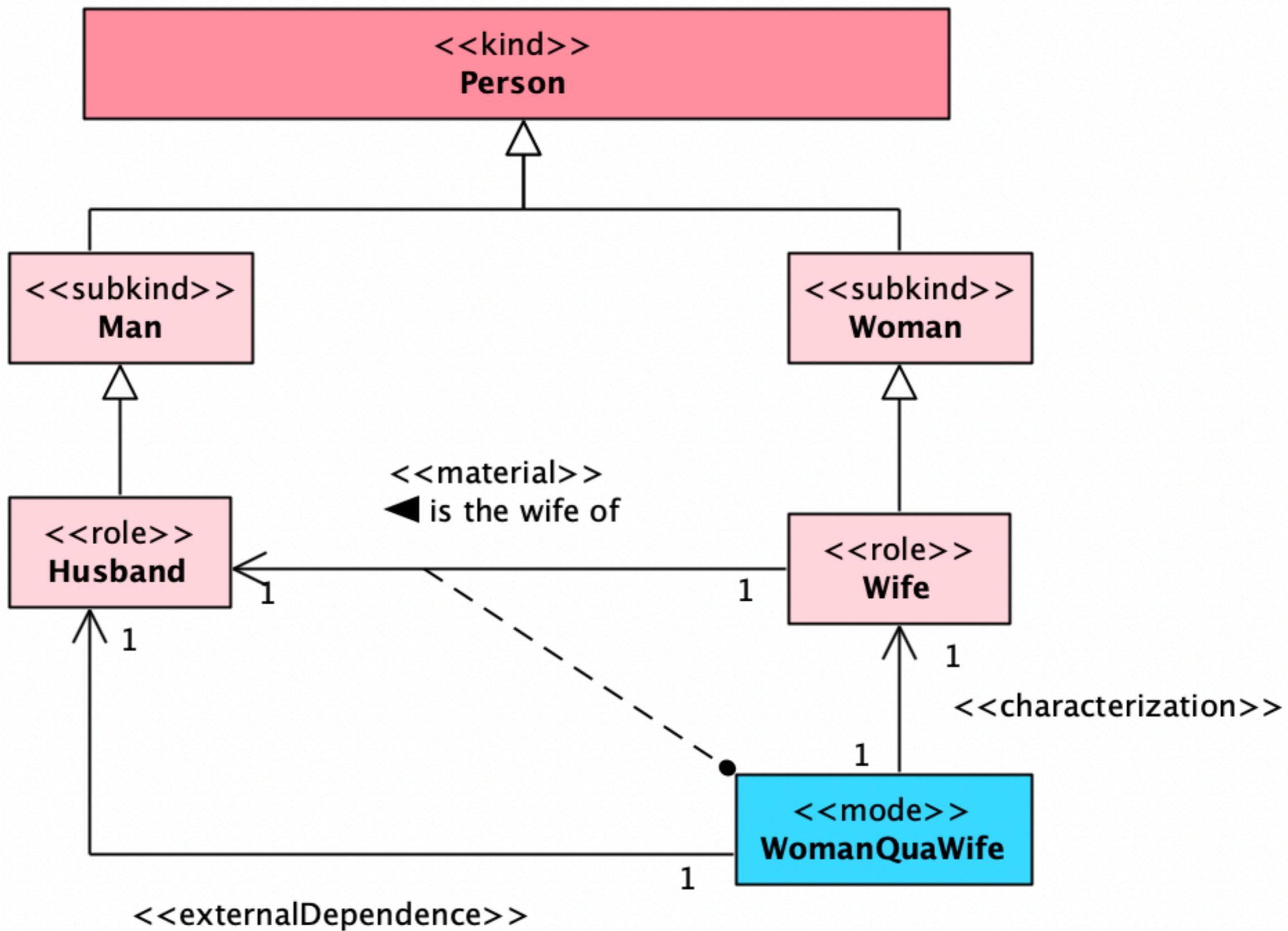


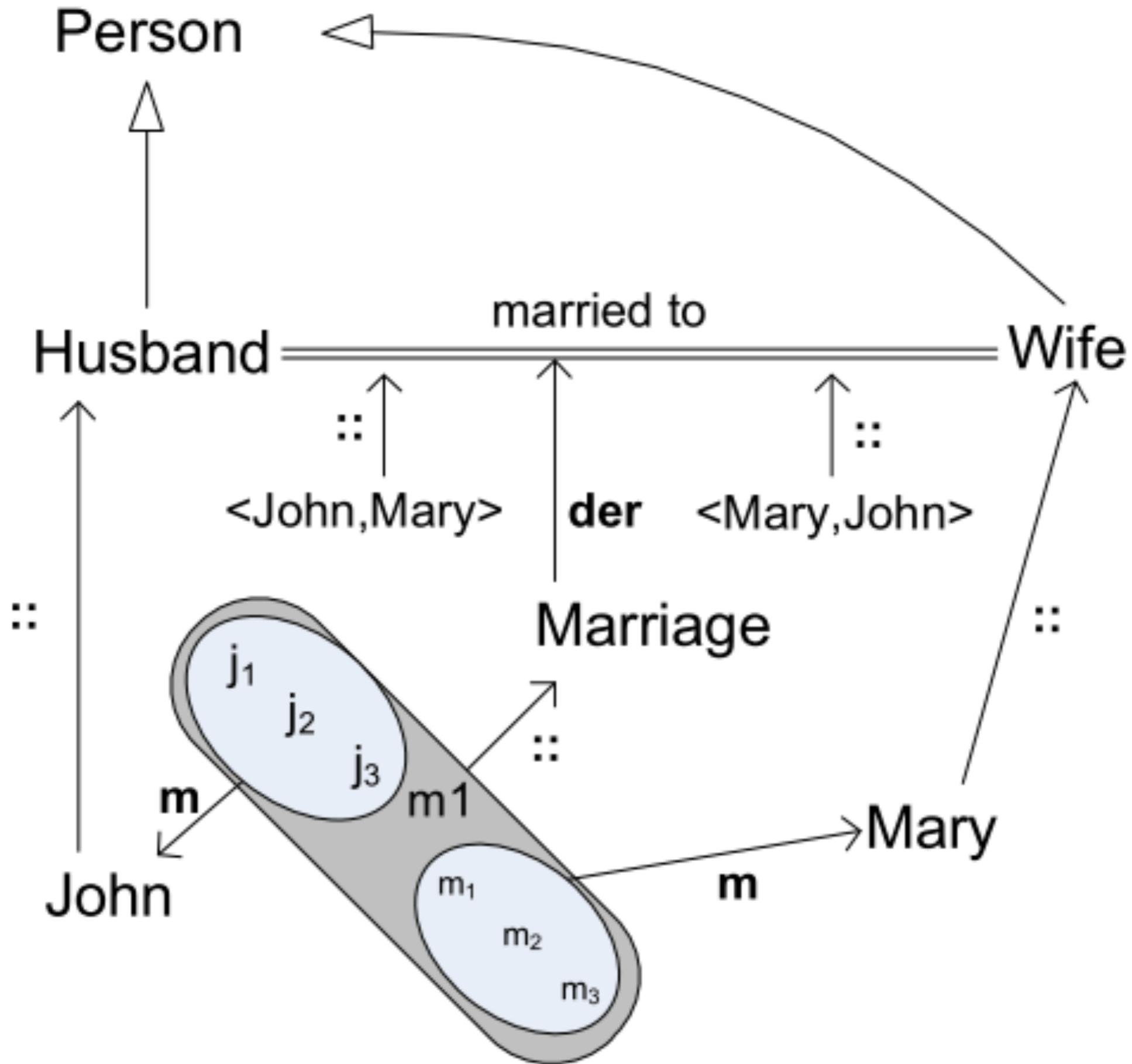


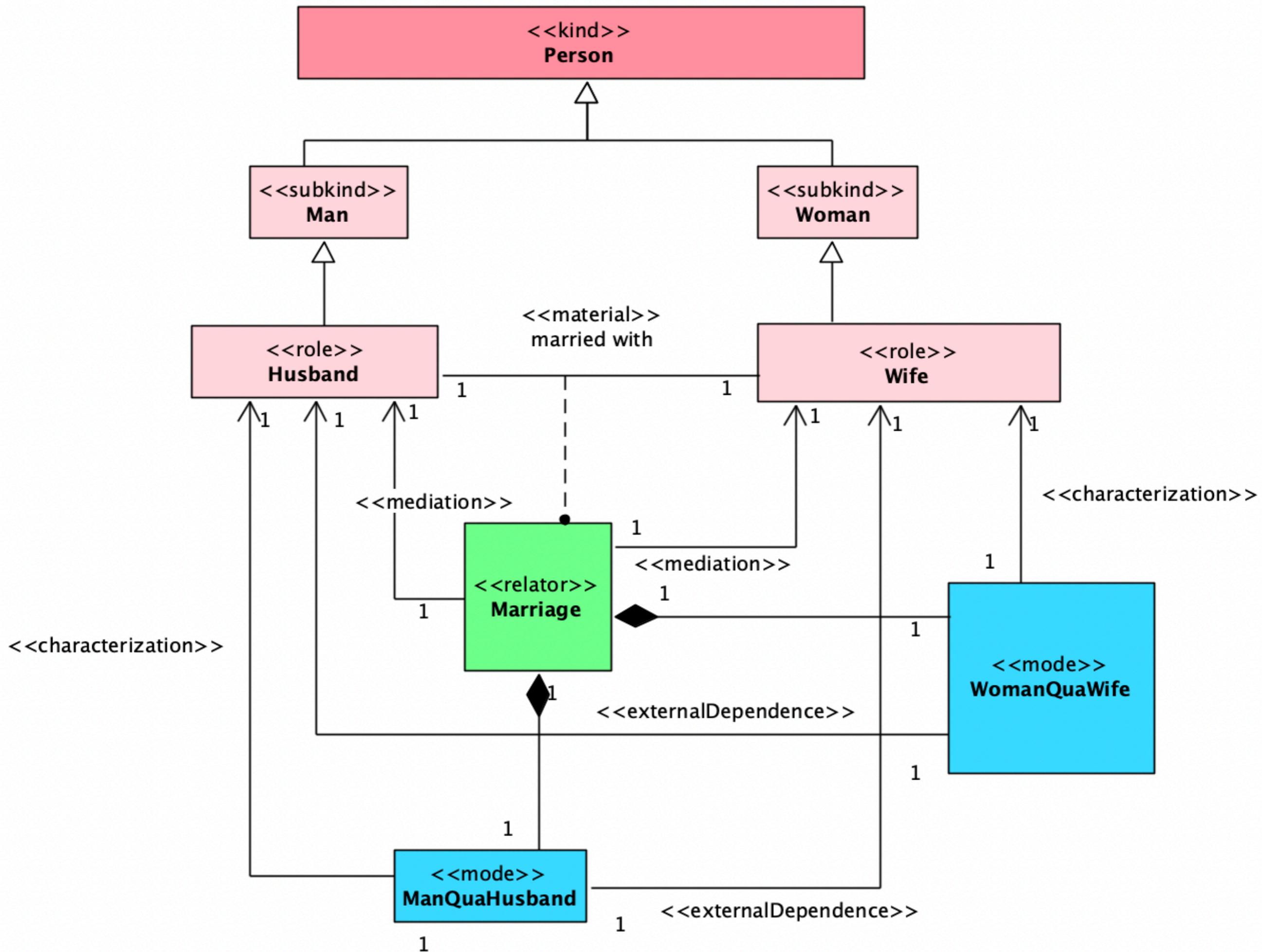
Suppose John marries Mary

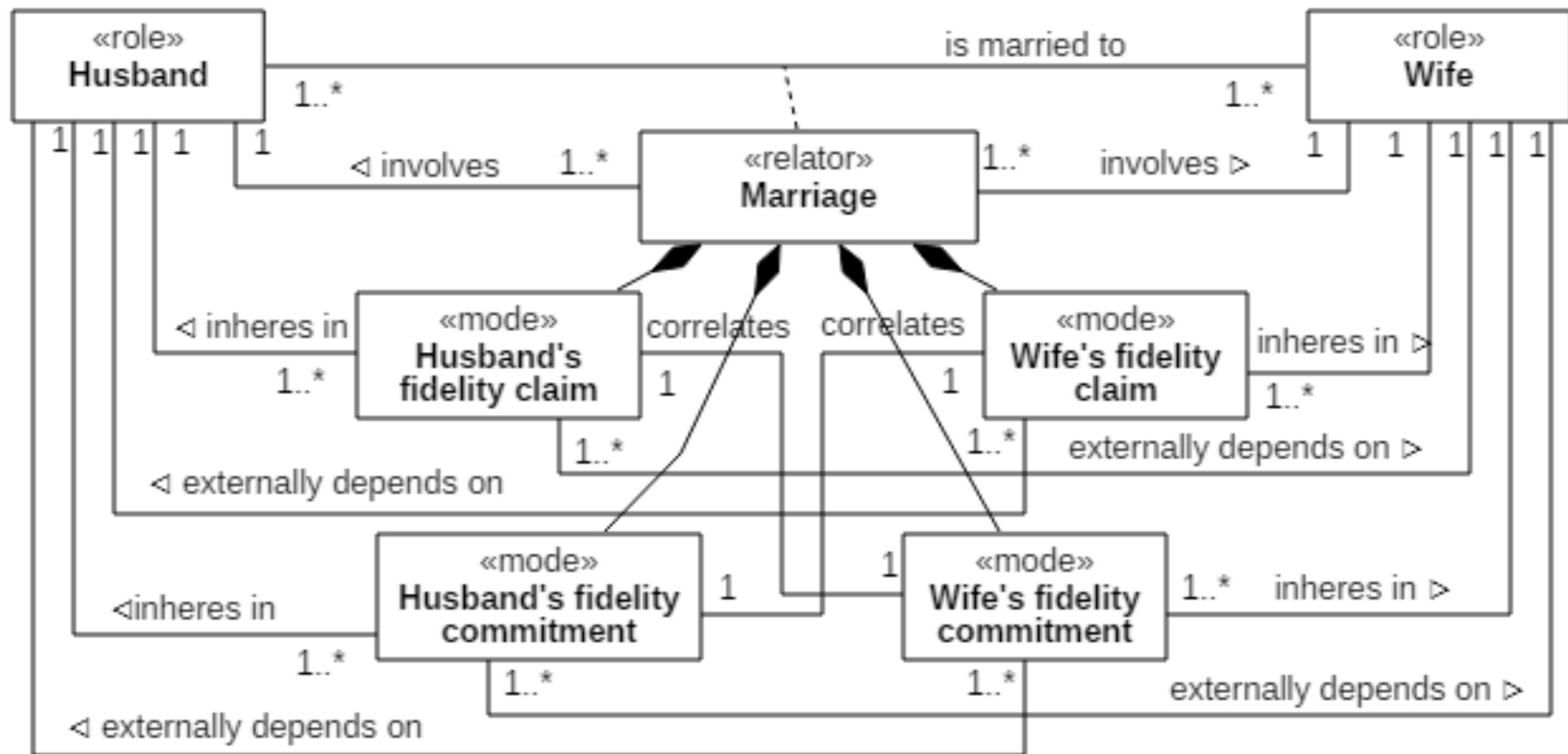






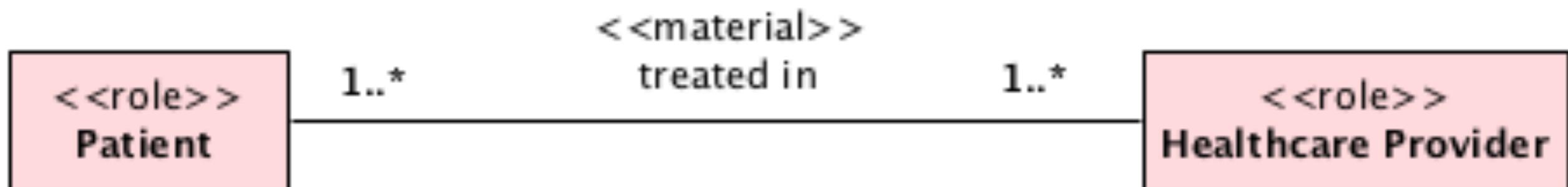






What does that buy us?

1. Identification and Individuation of events
2. Delimiting the scope of transitivity of parthood
3. Subsetting, Specialization, Redefinition
4. Incompatible Predication
5. The Counting Problem
6. Intentional versus Extensional Meta-Properties
7. The Collapse of Cardinality Constraints
8. Modularization
9. The Representation of Anadyc Relations



How to interpret 1..* ?

- Given a treatment, there is **exactly one patient, exactly one healthcare provider** but **both** patient and healthcare provider **can participate in many treatments**

How to interpret 1..* ?

- Given a treatment, there is **exactly one patient, exactly one healthcare provider** but **both** patient and healthcare provider **can participate in many treatments**
- Given a treatment, there are **possibly many patients, exactly one healthcare provider** but **both** patient and healthcare provider **can participate in many treatments**

How to interpret 1..* ?

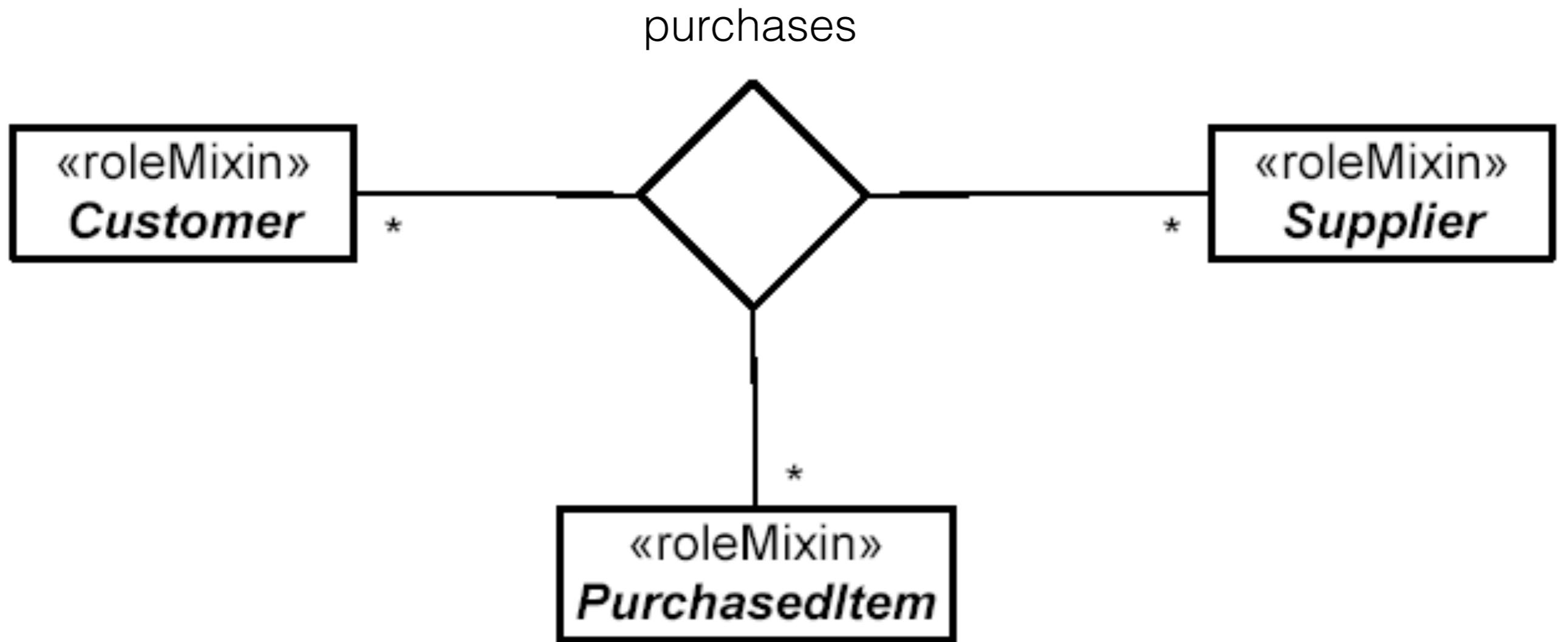
- Given a treatment, there is **exactly one patient, exactly one healthcare provider** but **both** patient and healthcare provider **can participate in many treatments**
- Given a treatment, there are **possibly many patients, exactly one healthcare provider** but **both** patient and healthcare provider **can participate in many treatments**
- Given a treatment, there is **exactly one patient, possibly many healthcare providers** but **both** patient and healthcare provider **can participate in many treatments**

How to interpret 1..* ?

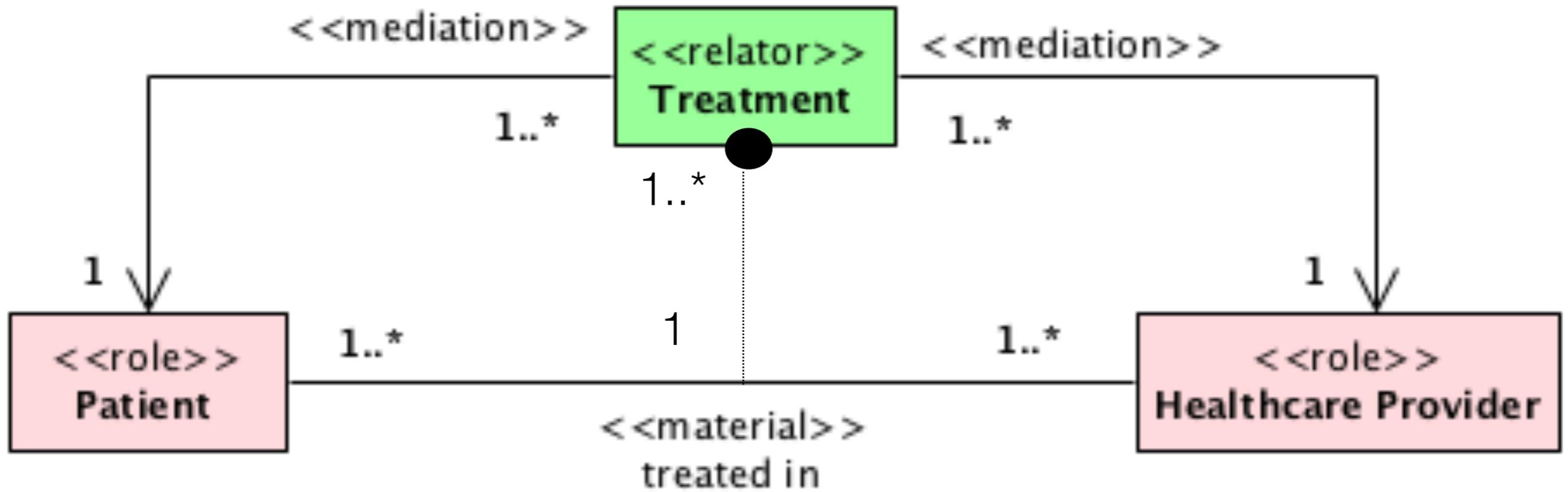
- Given a treatment, there is **exactly one patient, exactly one healthcare provider** but **both** patient and healthcare provider **can participate in many treatments**
- Given a treatment, there are **possibly many patients, exactly one healthcare provider** but **both** patient and healthcare provider **can participate in many treatments**
- Given a treatment, there is **exactly one patient, possibly many healthcare providers** but **both** patient and healthcare provider **can participate in many treatments**
- Given a treatment, there are **possibly many patients, possibly many healthcare providers** and **both** patient and healthcare provider **can participate in many treatments**

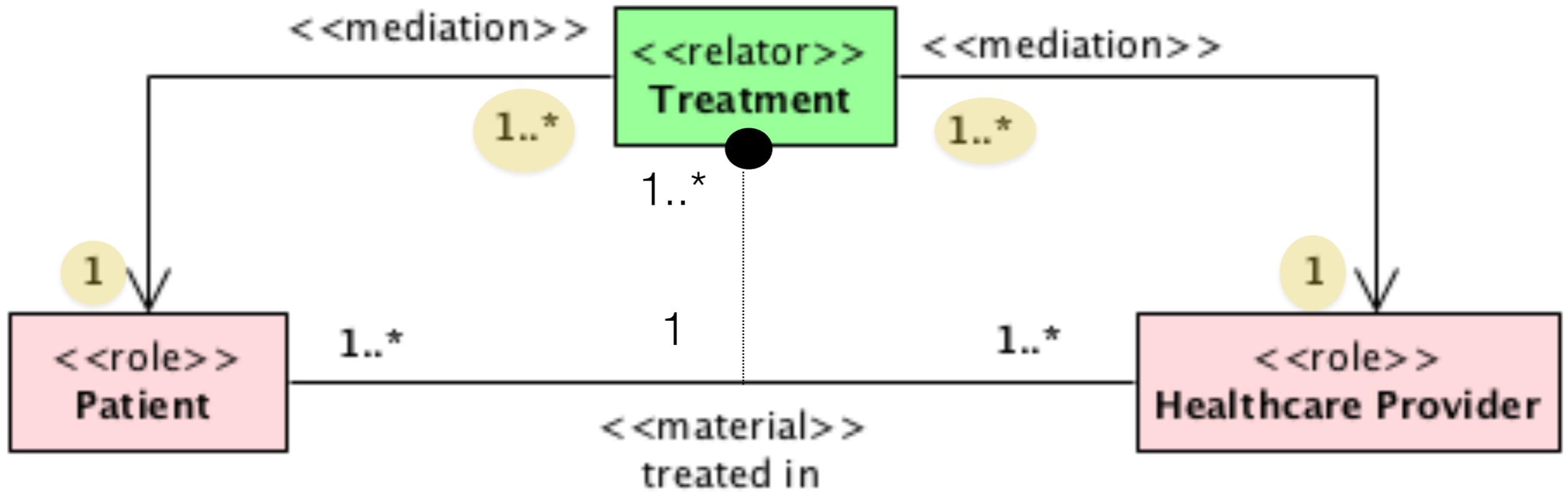
How to interpret 1..* ?

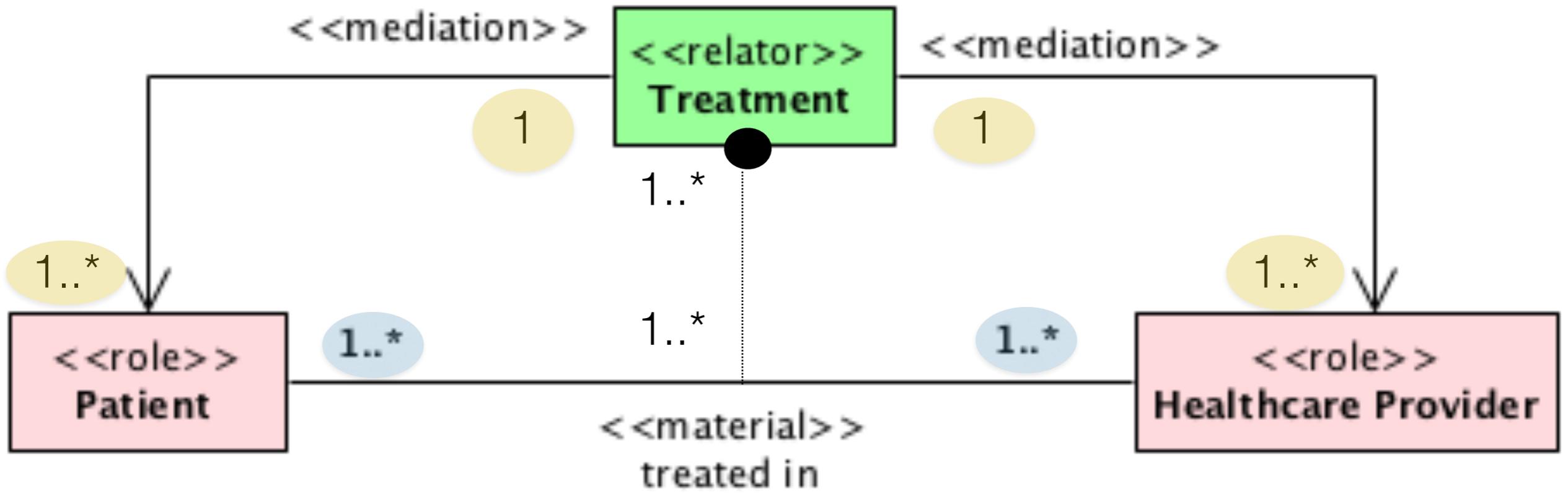
- Given a treatment, there is **exactly one patient, exactly one healthcare provider** but **both** patient and healthcare provider **can participate in many treatments**
- Given a treatment, there are **possibly many patients, exactly one healthcare provider** but **both** patient and healthcare provider **can participate in many treatments**
- Given a treatment, there is **exactly one patient, possibly many healthcare providers** but **both** patient and healthcare provider **can participate in many treatments**
- Given a treatment, there are **possibly many patients, possibly many healthcare providers** and **both** patient and healthcare provider **can participate in many treatments**
- Given a treatment, there are **possibly many patients, possibly many healthcare providers** and **both** patient and healthcare provider **can participate in exactly one treatment**
- ...

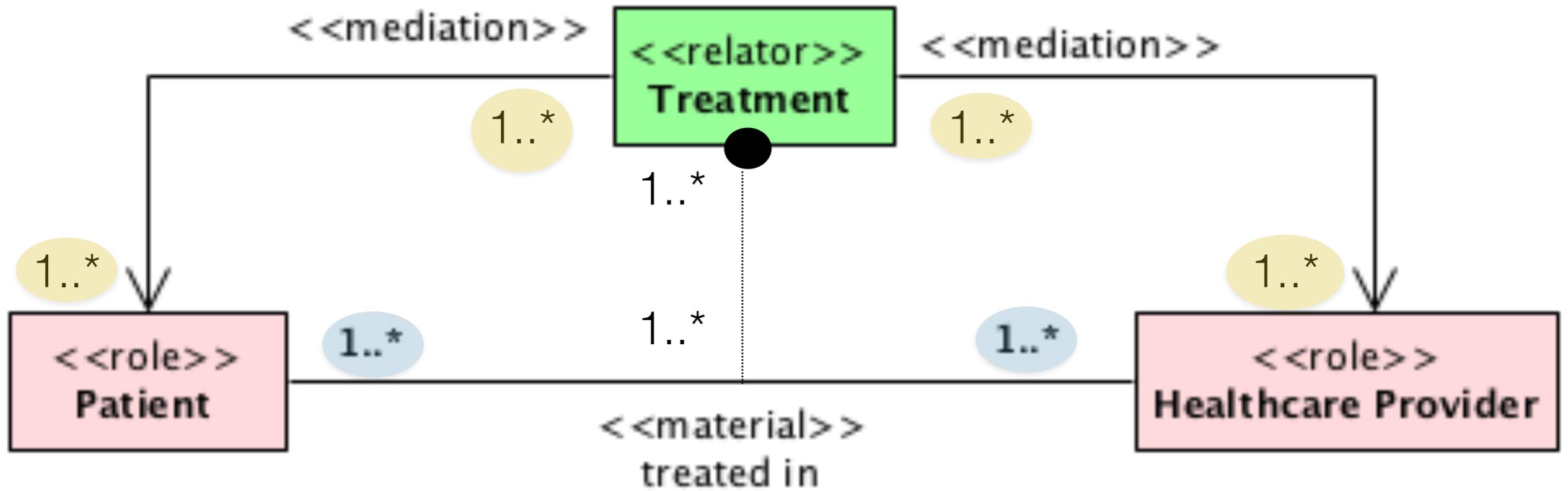


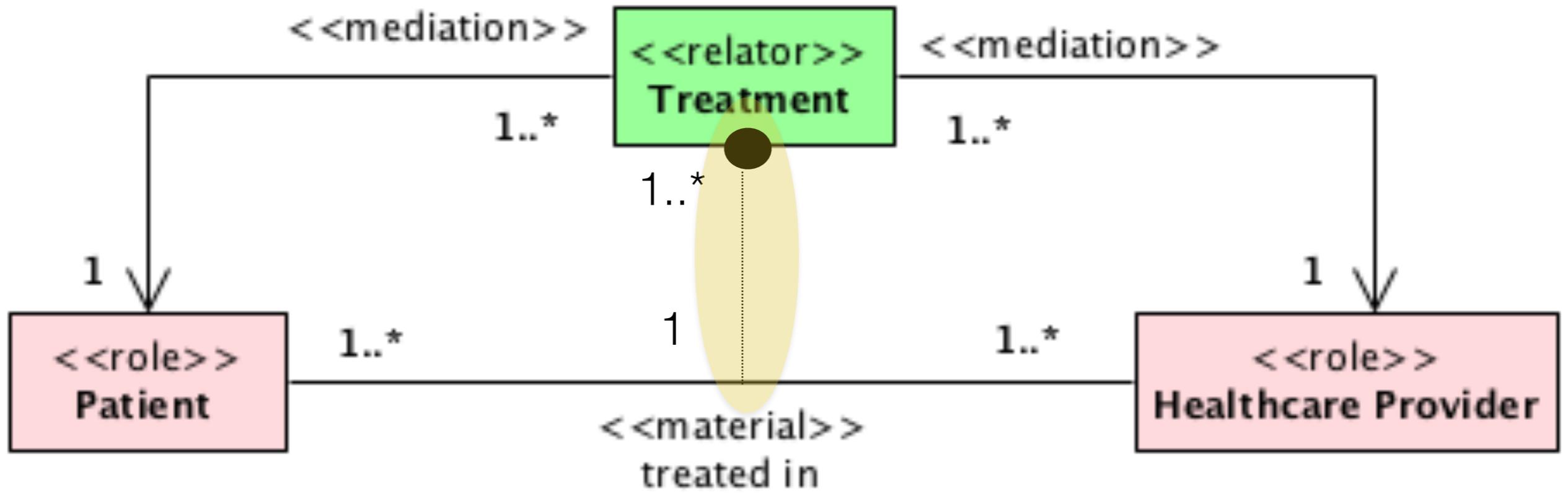
1. In a given purchase, a Customer participates by buying many items from many Suppliers and a customer can participate in several purchases;
2. In a given purchase, many Customers participate by buying many items from many Suppliers, and a customer can participate in only one purchase;
3. In given purchase, a Customer participates by buying many items from a Supplier, and a customer can participate in several purchases;
4. In given purchase, many Customers participate by buying many items from a Supplier, and a customer can participate in several purchases
5. ...

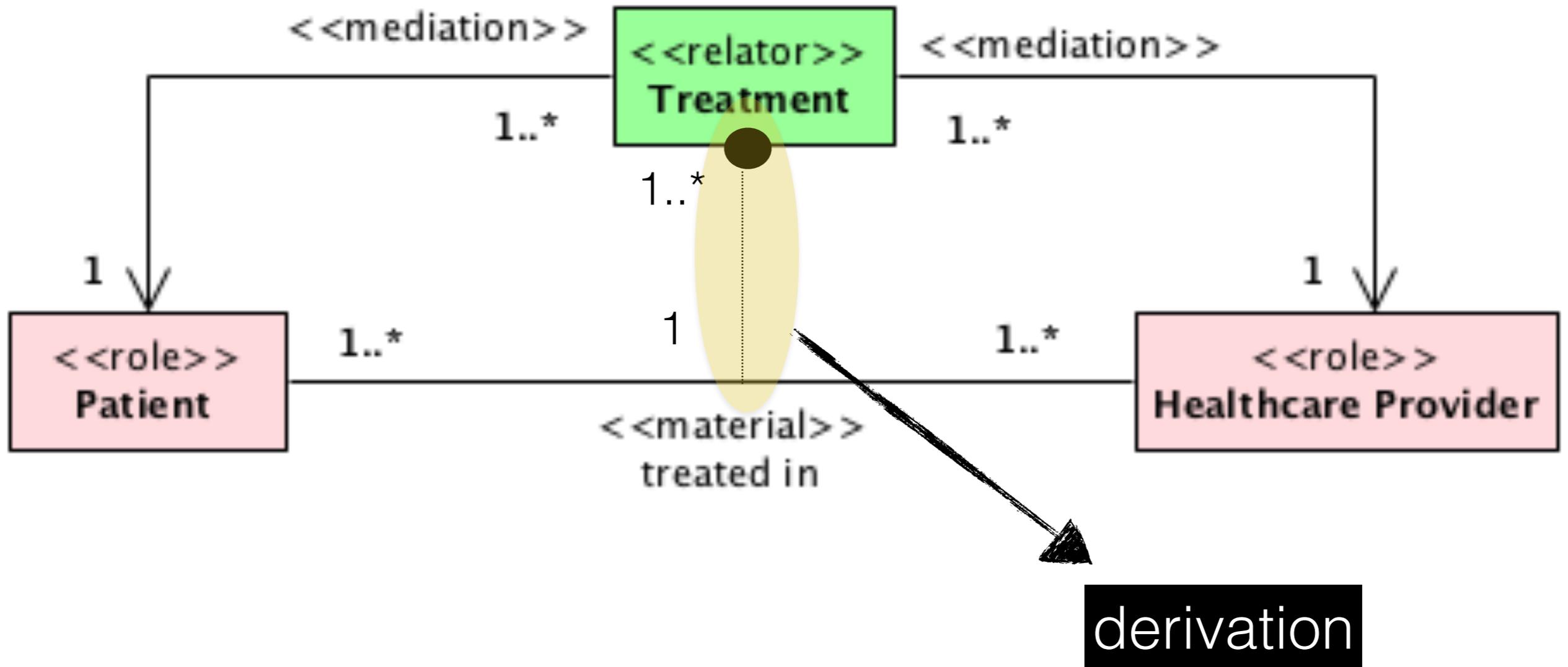


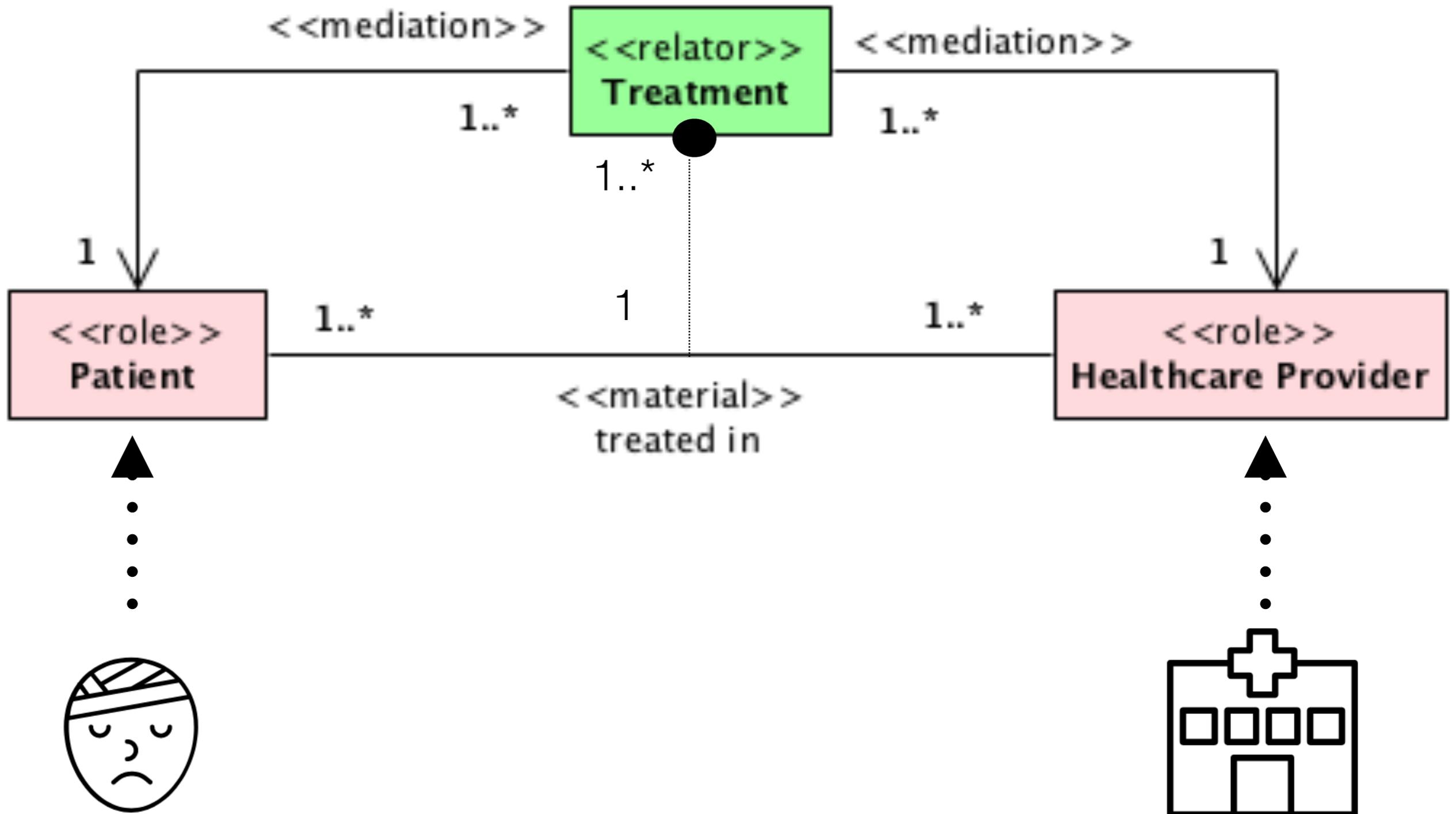


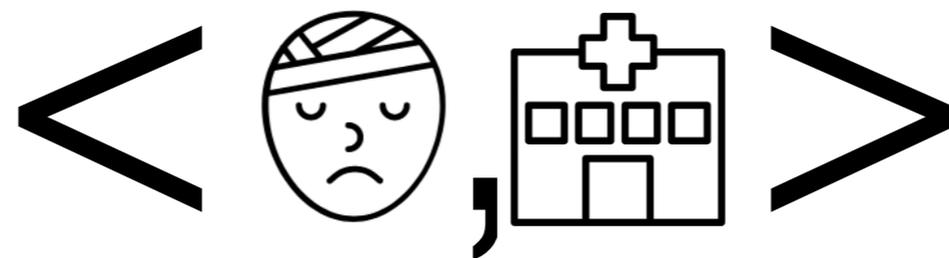
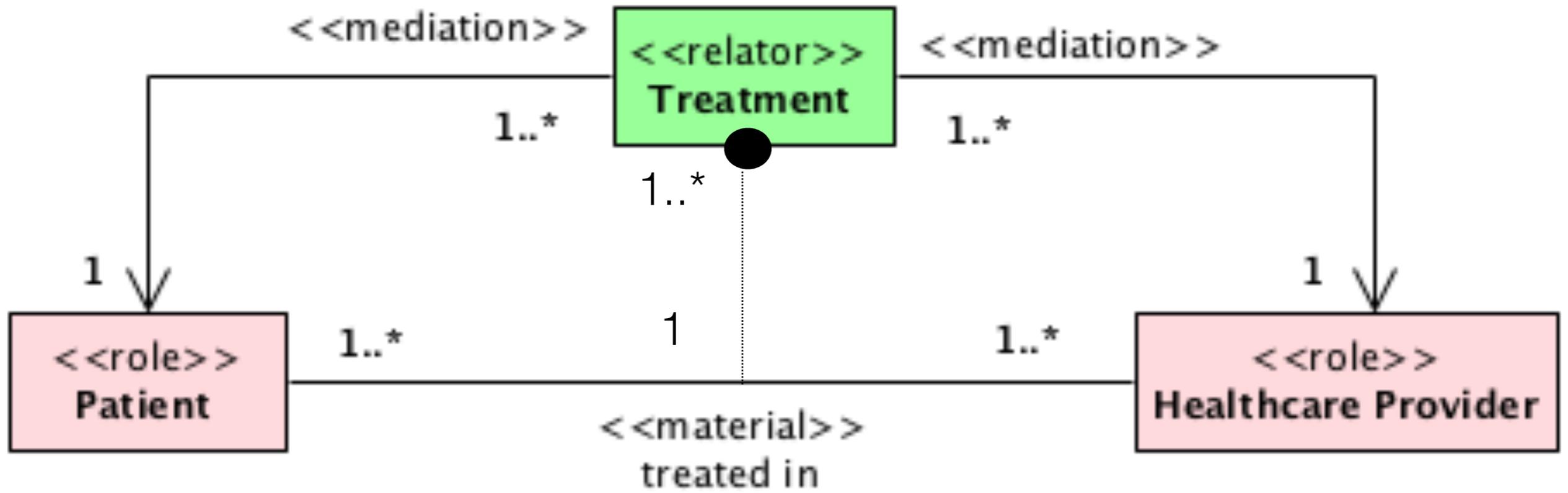




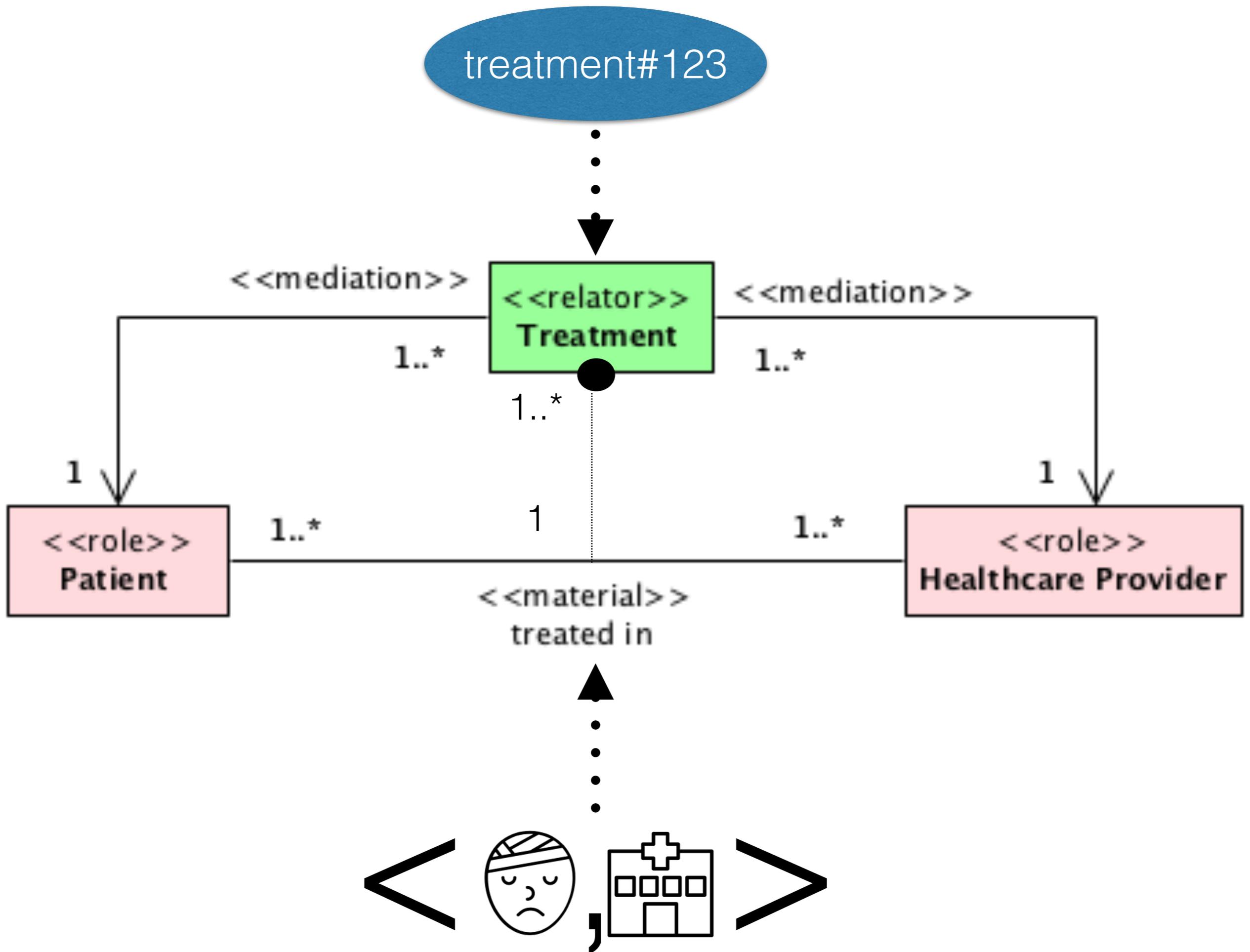


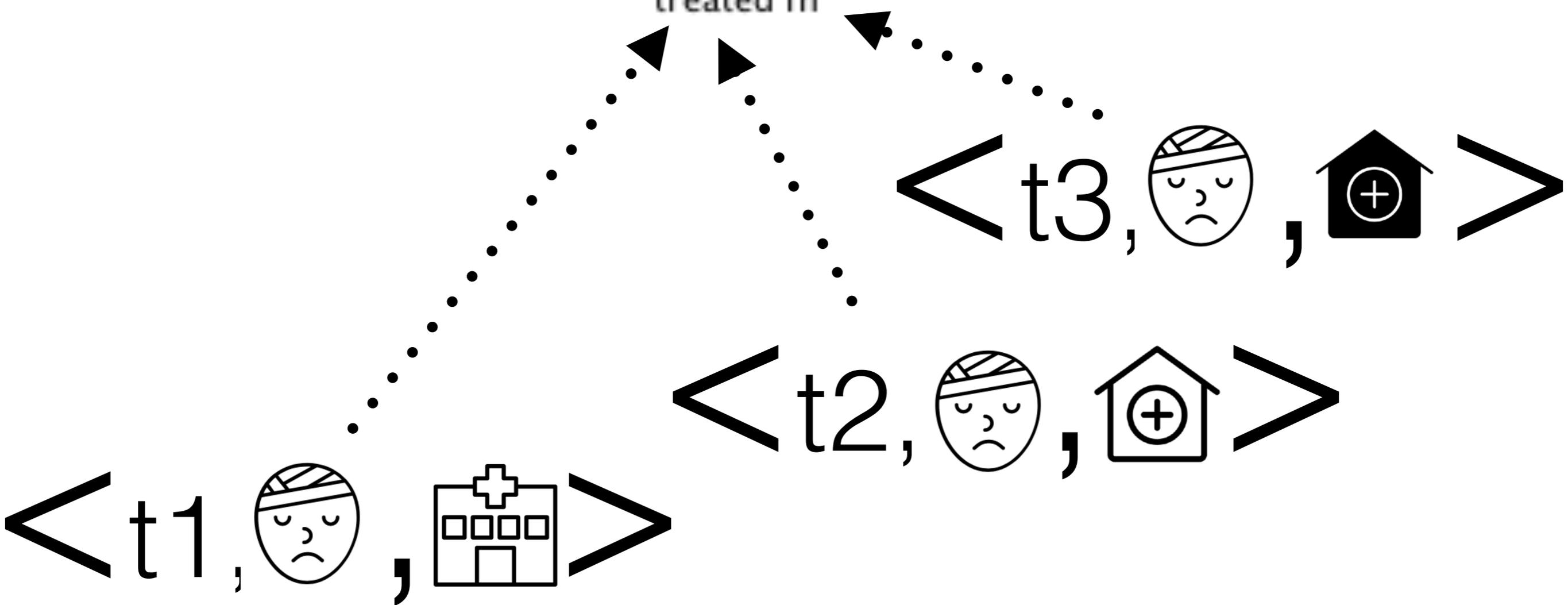
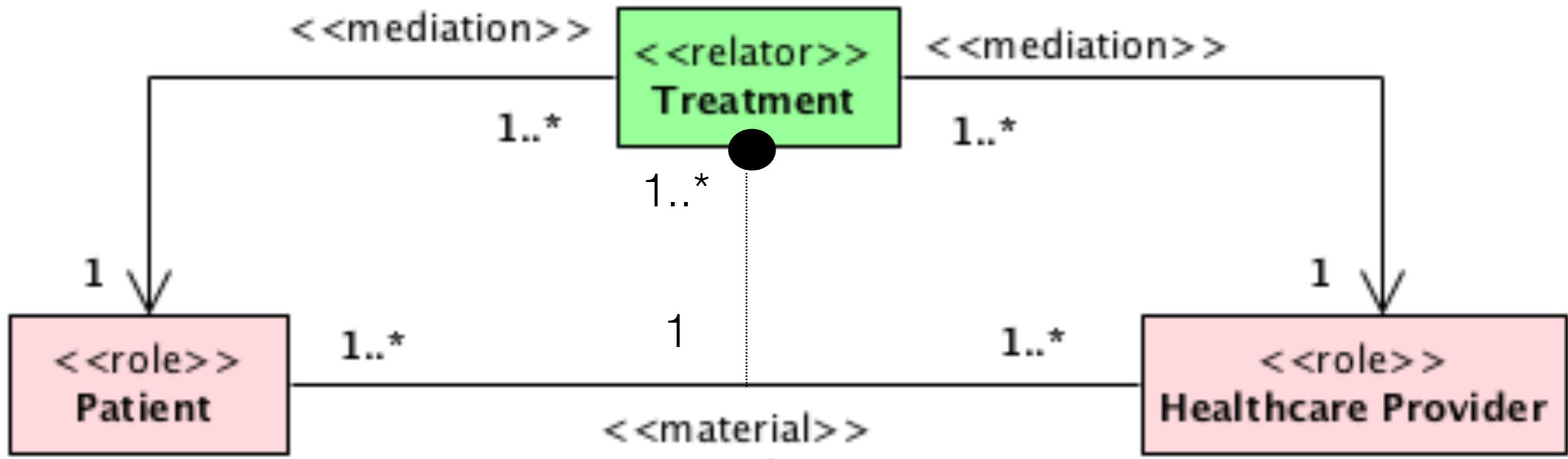


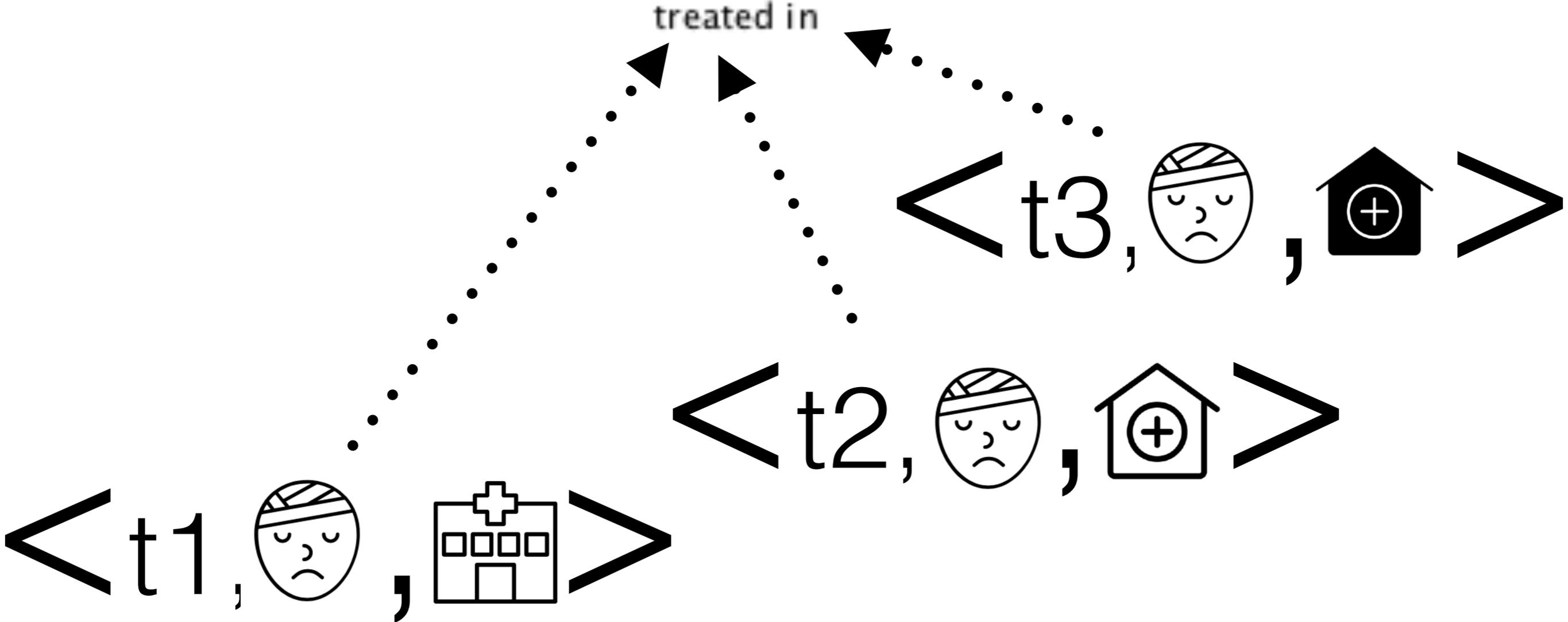
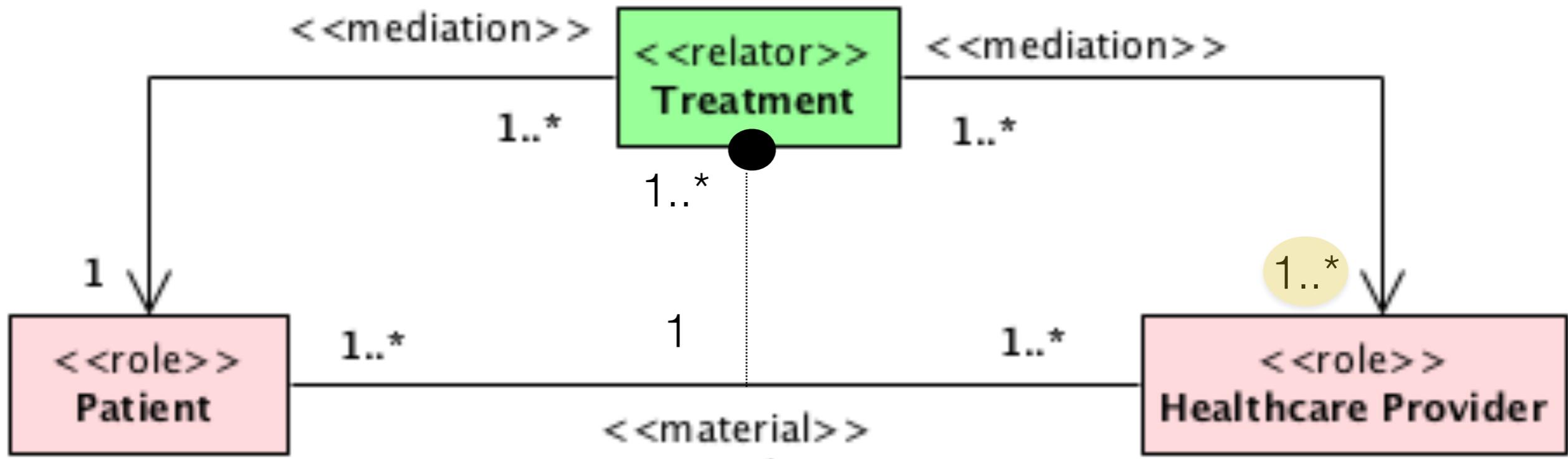




treatment#123







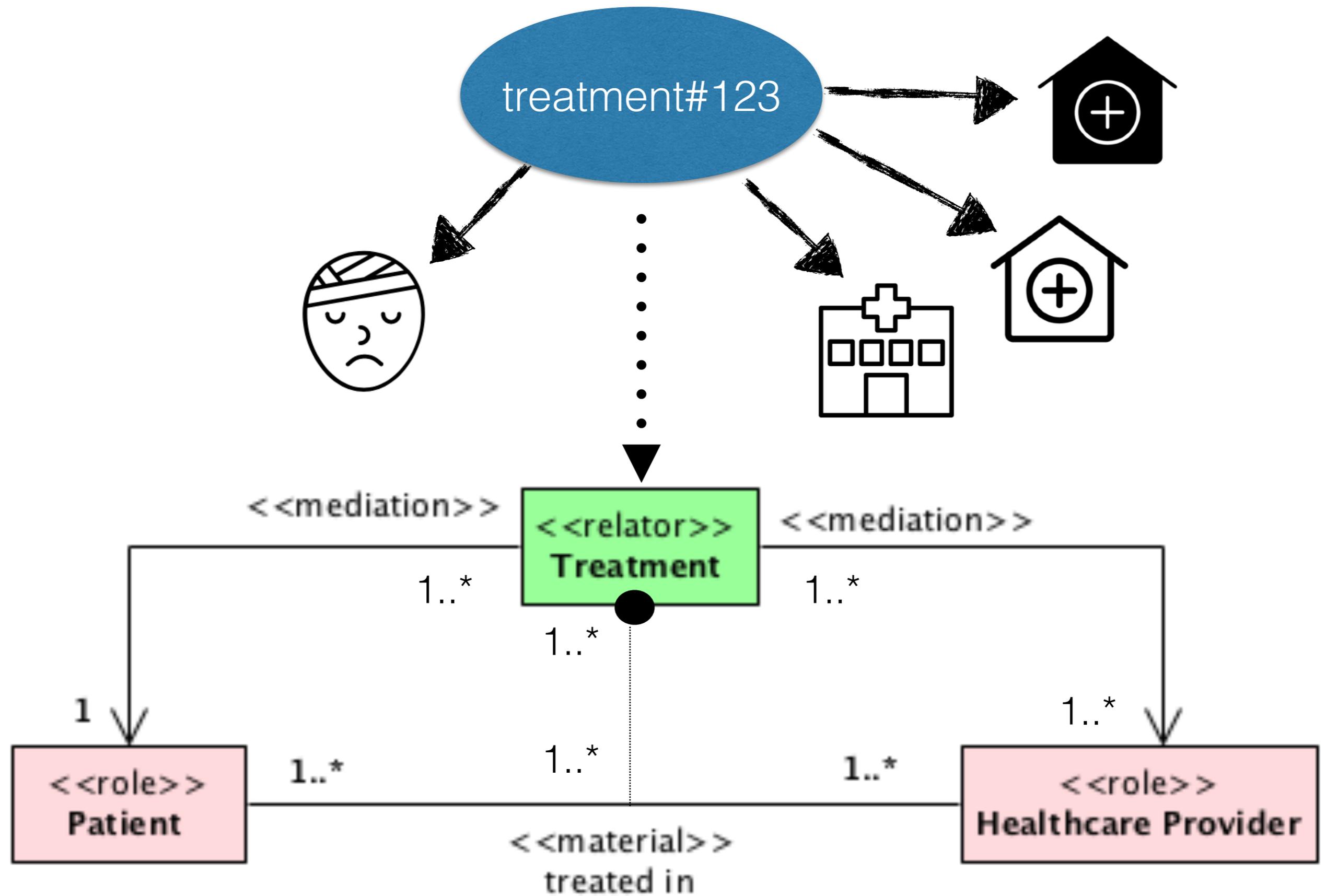
Anadyc Relations

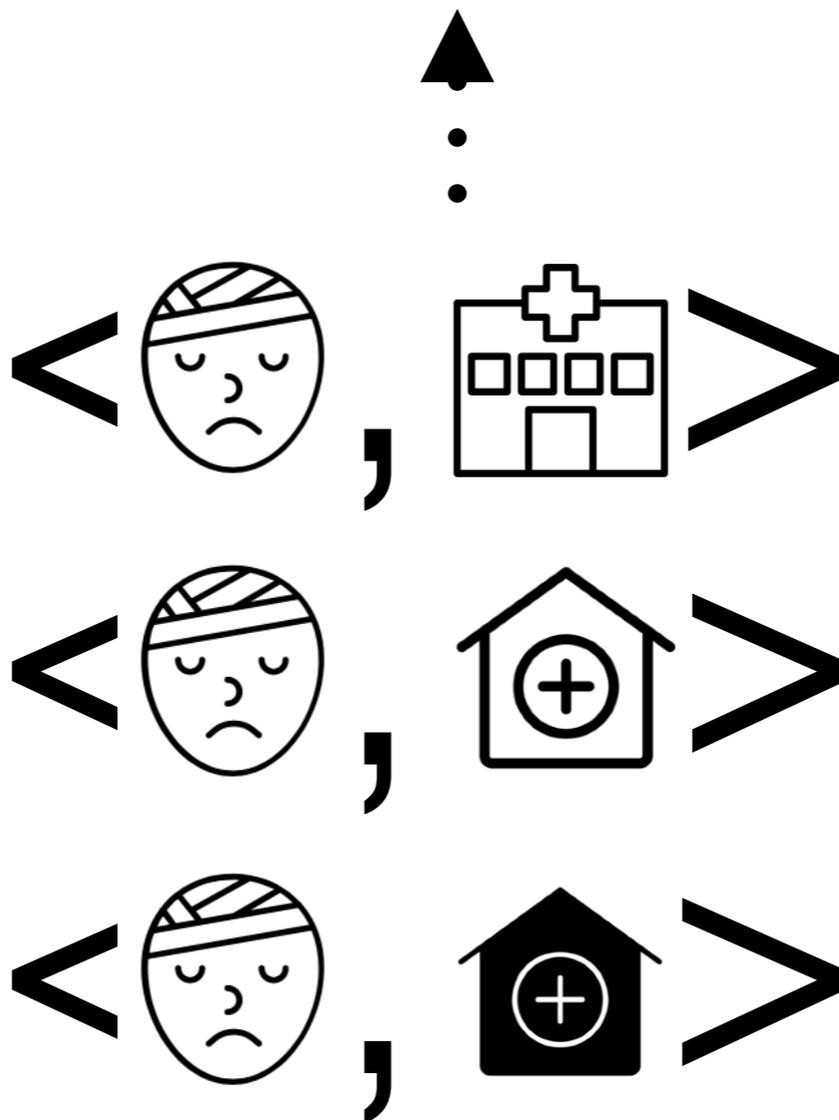
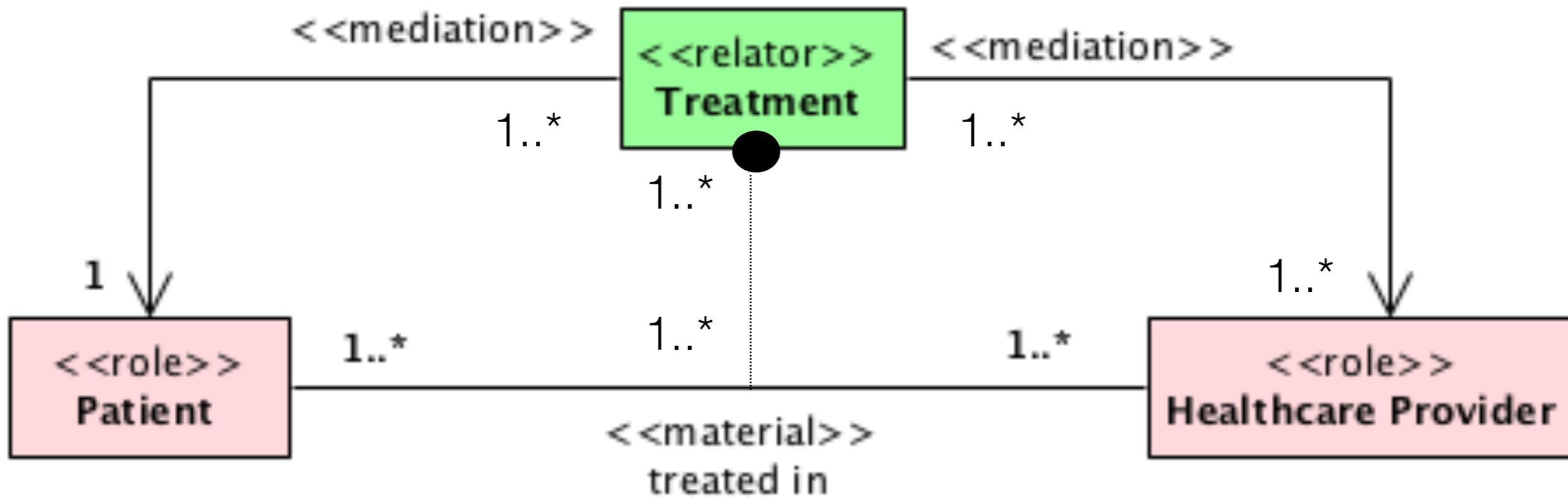
play-with(John,Paul)

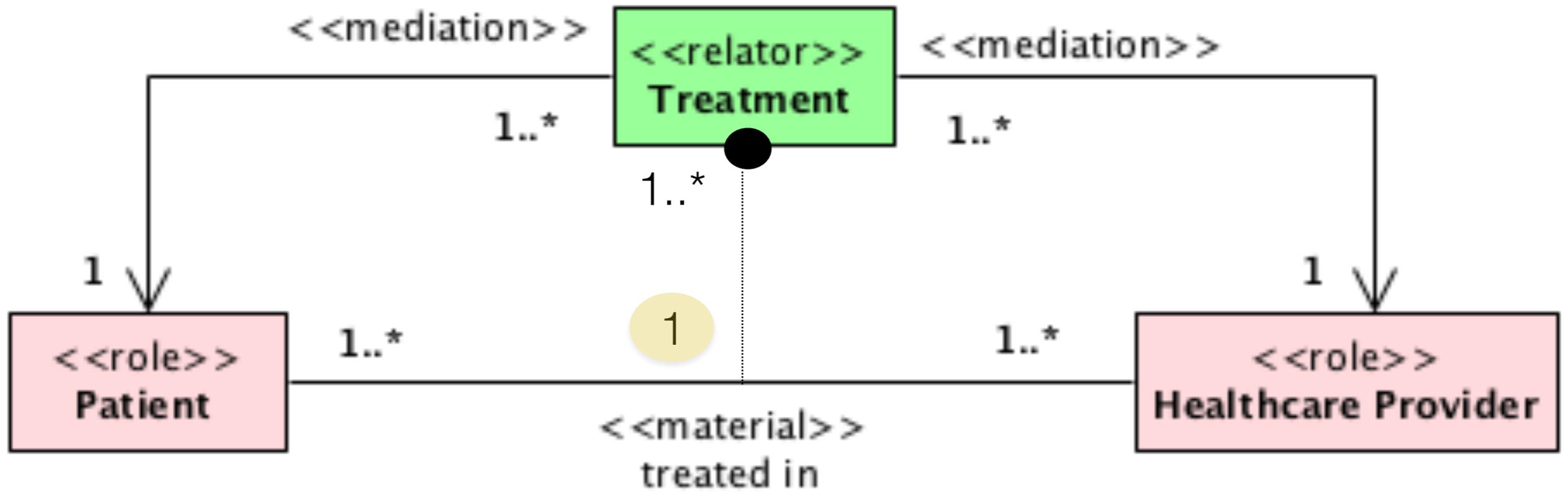
play-with(John,Paul,George)

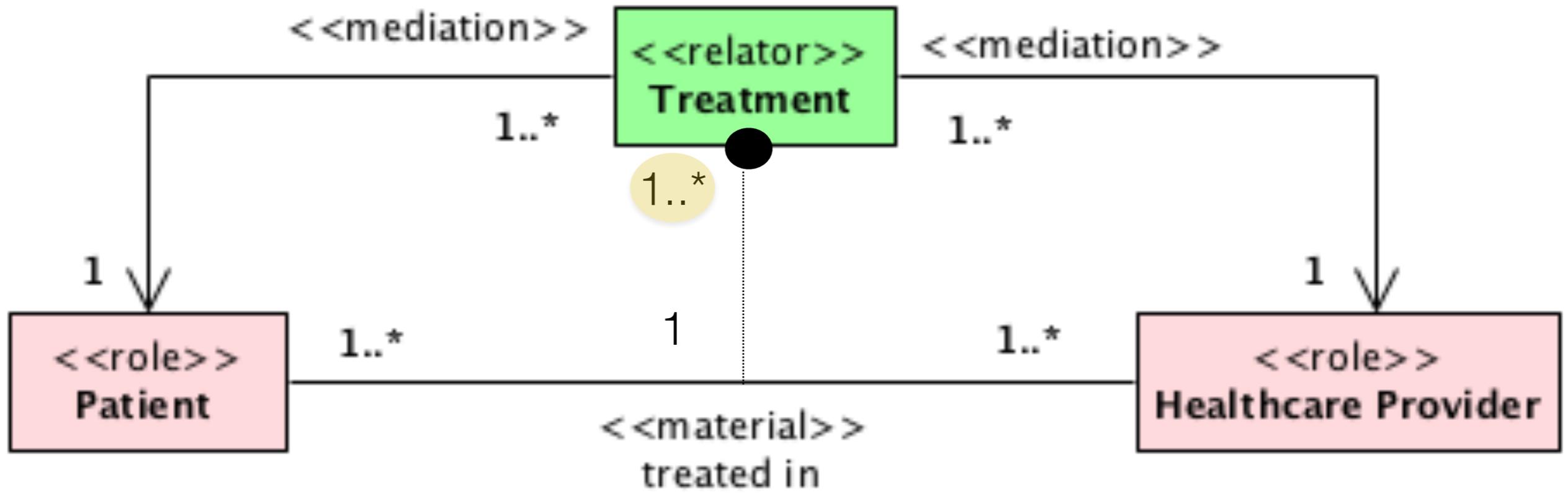
play-with(John,Paul,George,Ringo)

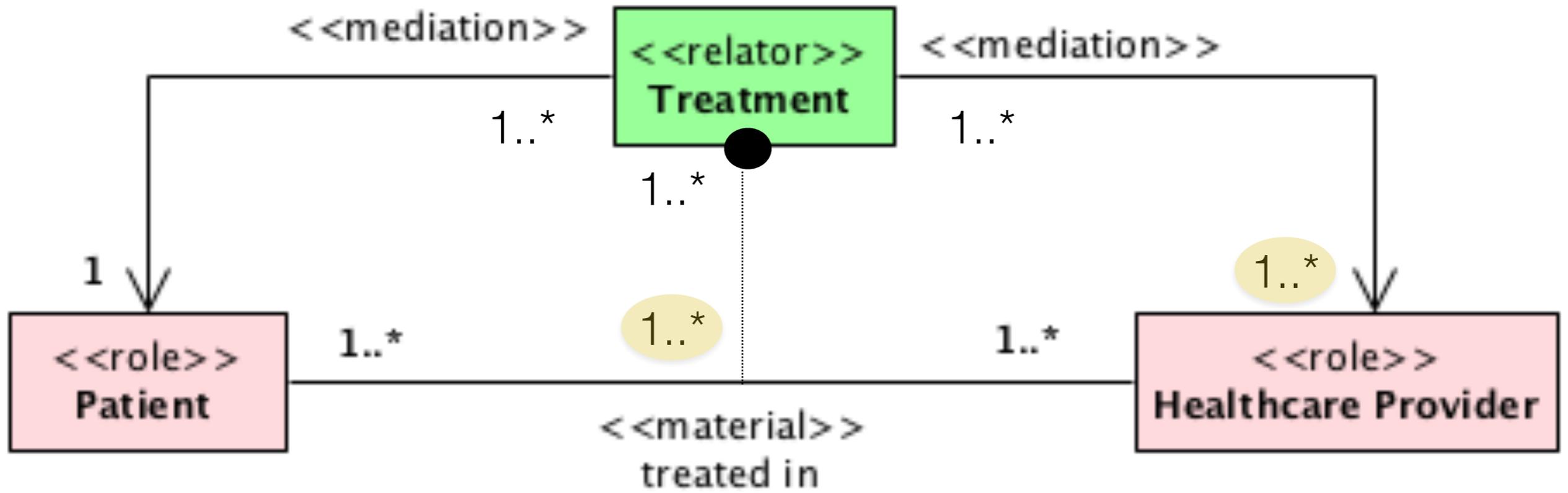
play-with(John,Paul,George,Ringo,Yoko)

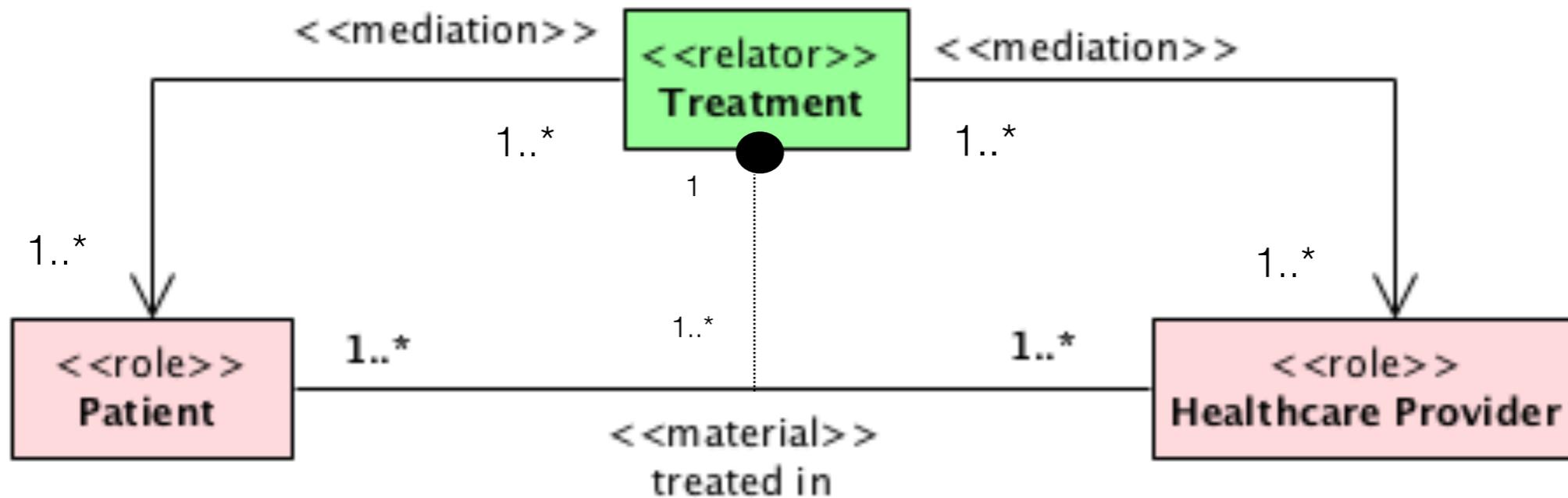
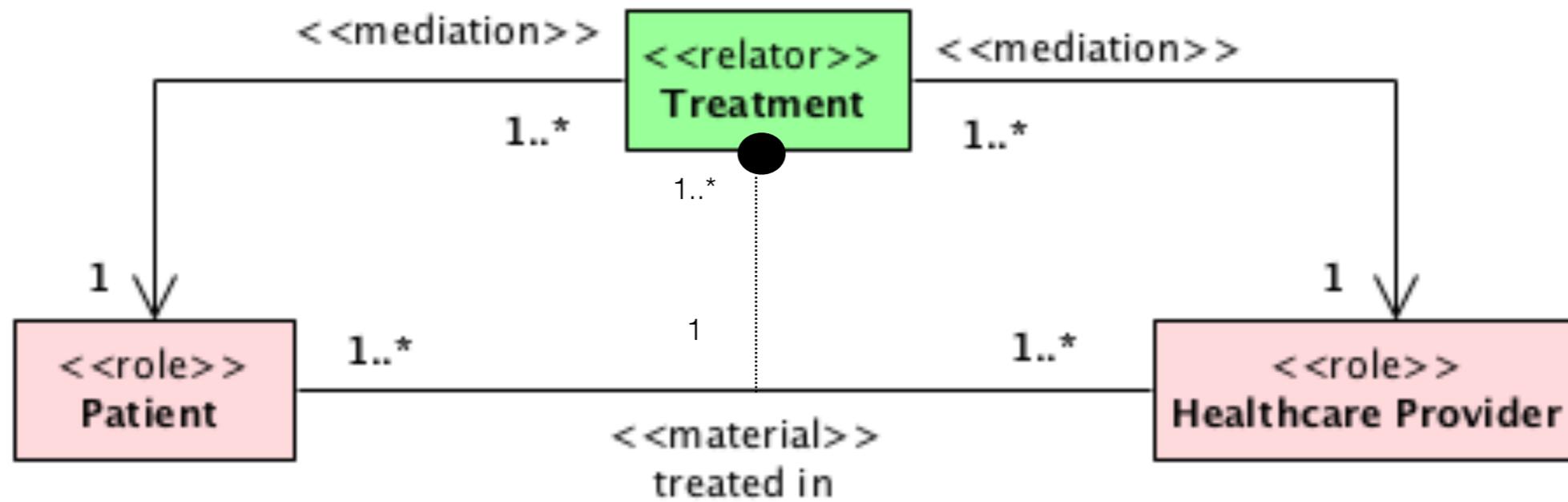


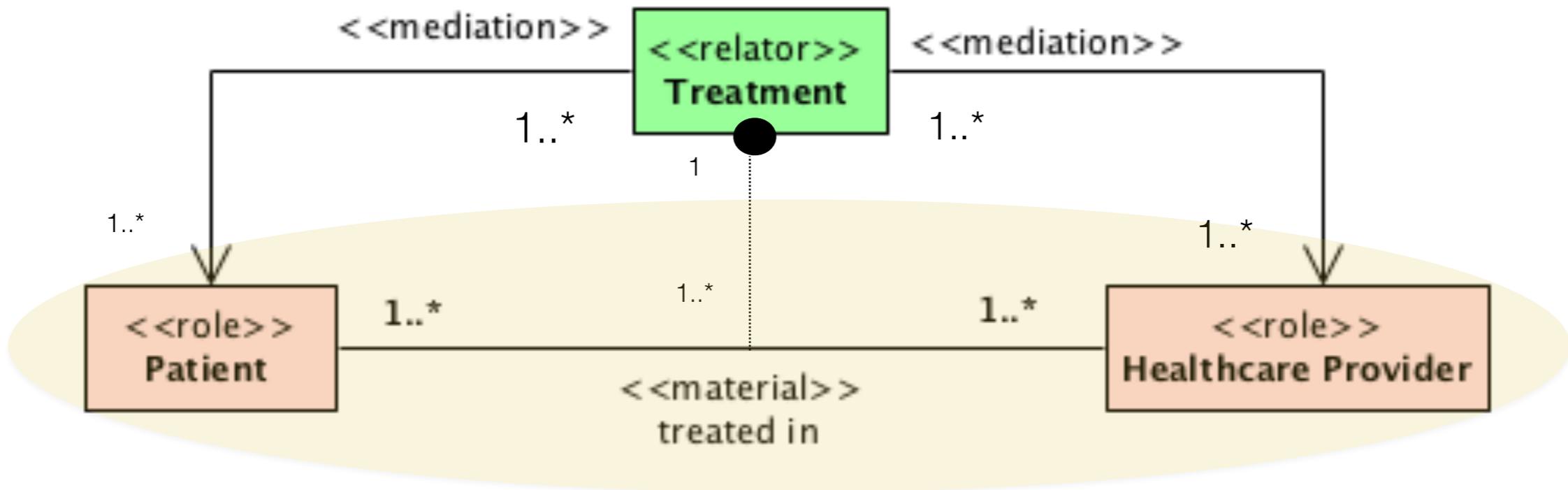
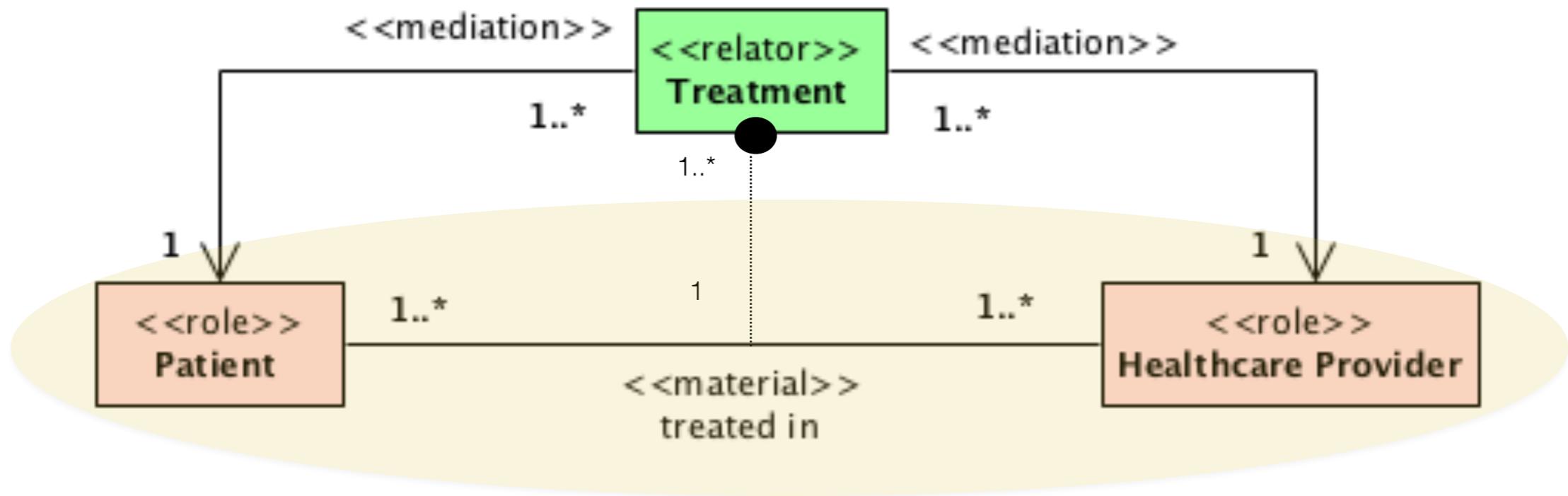


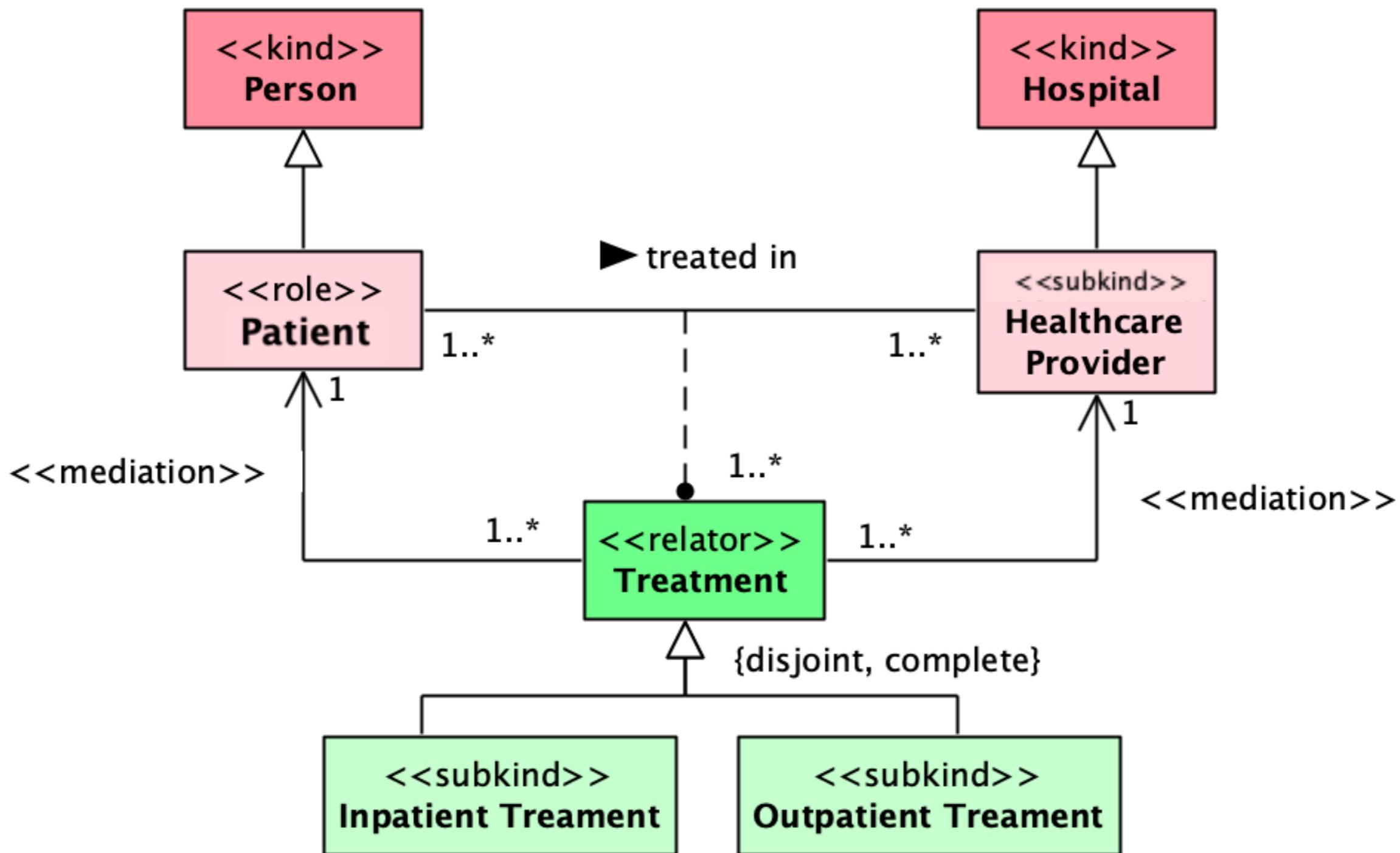


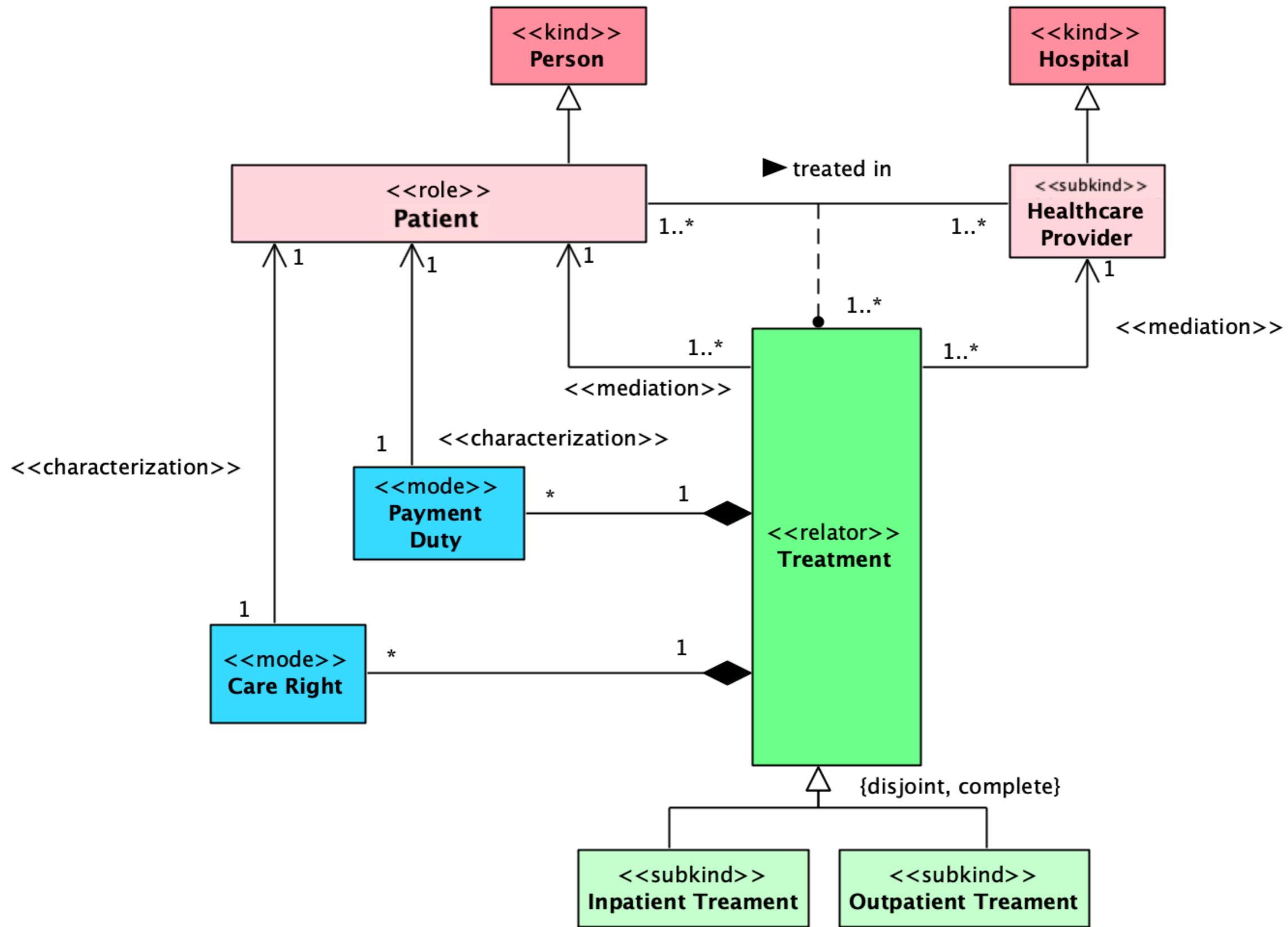


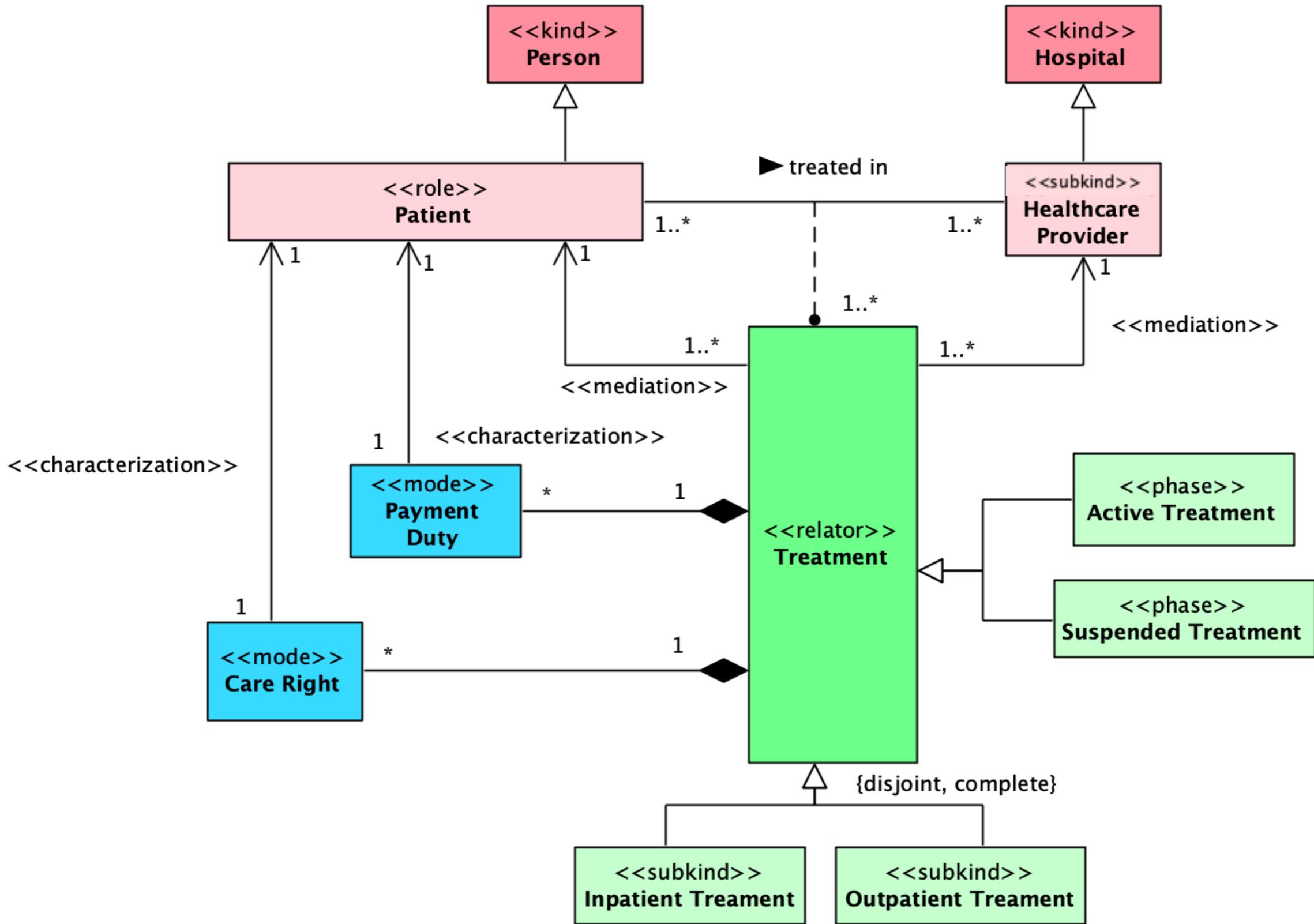


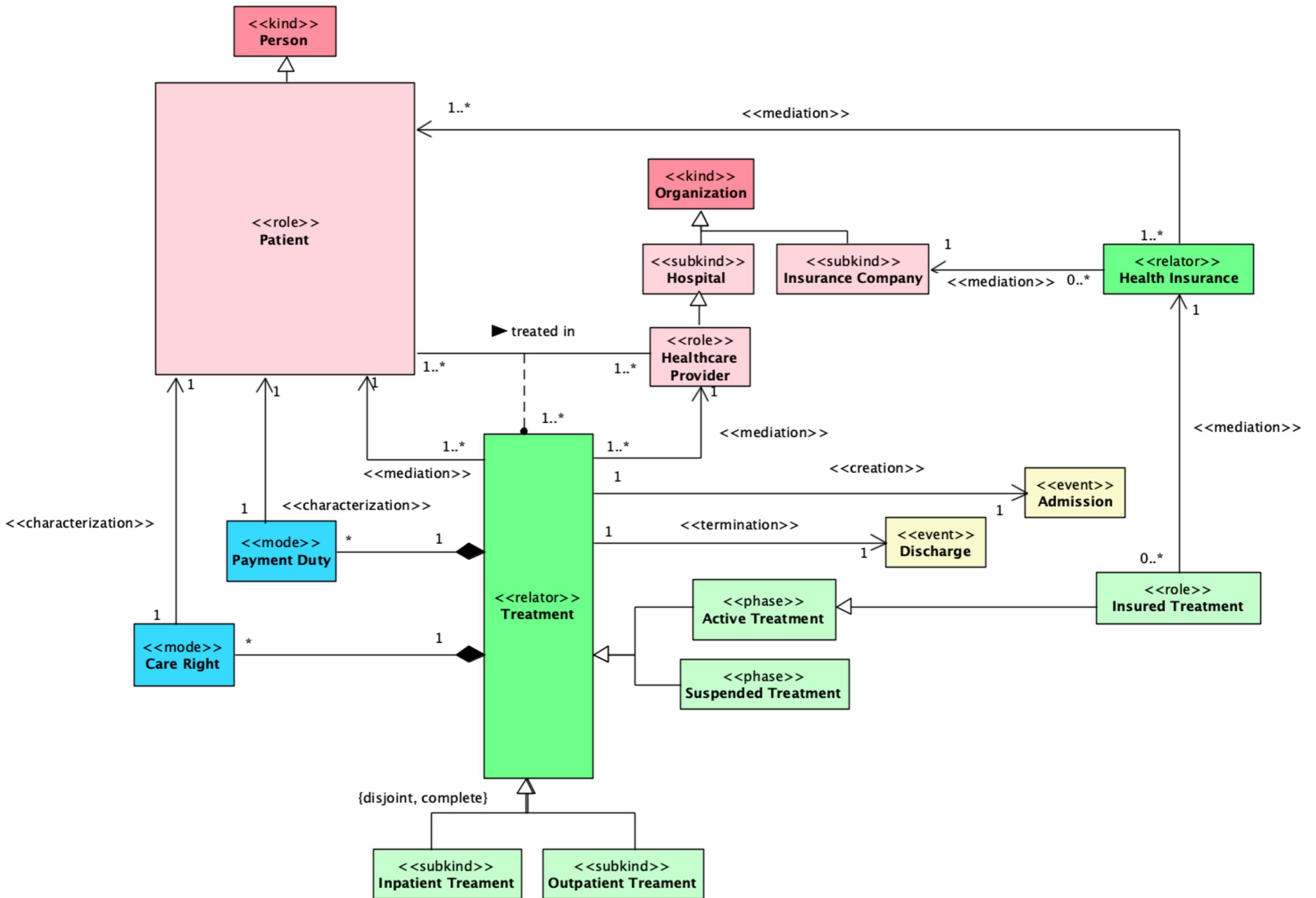


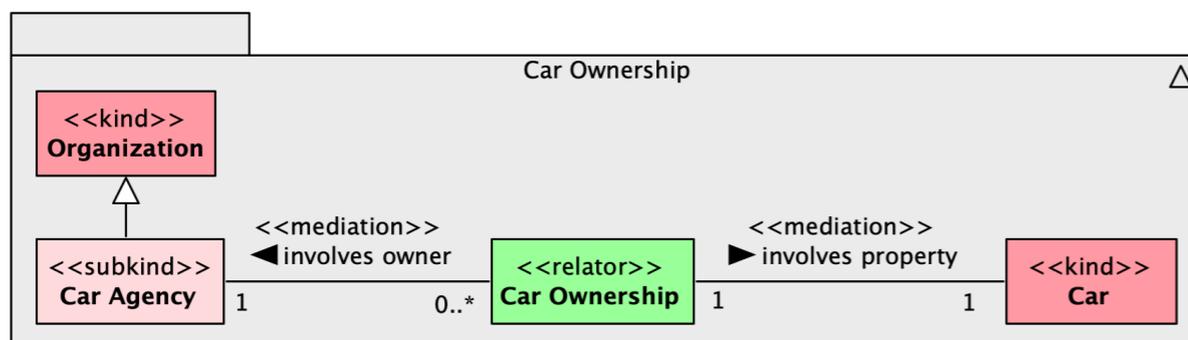
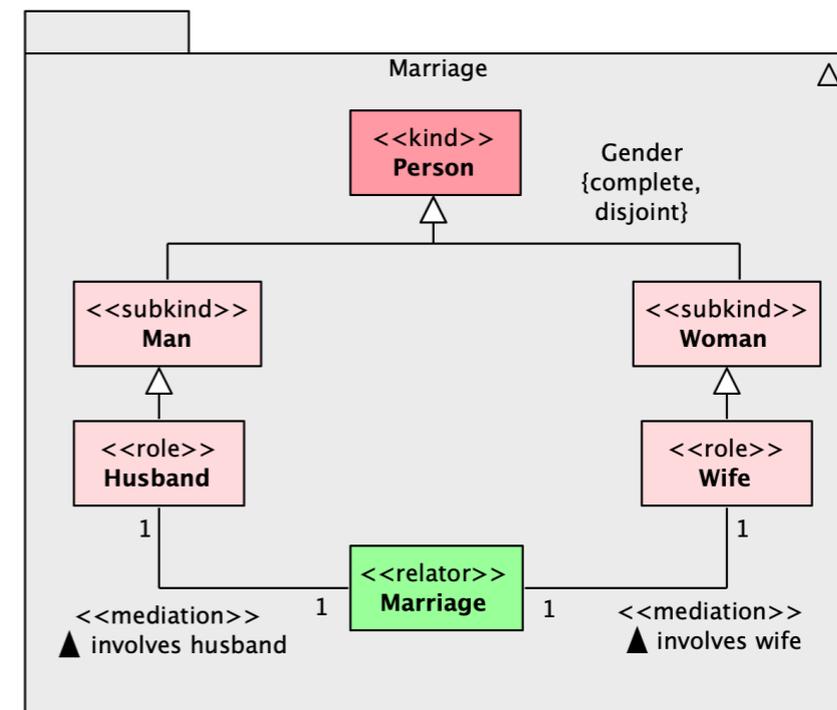
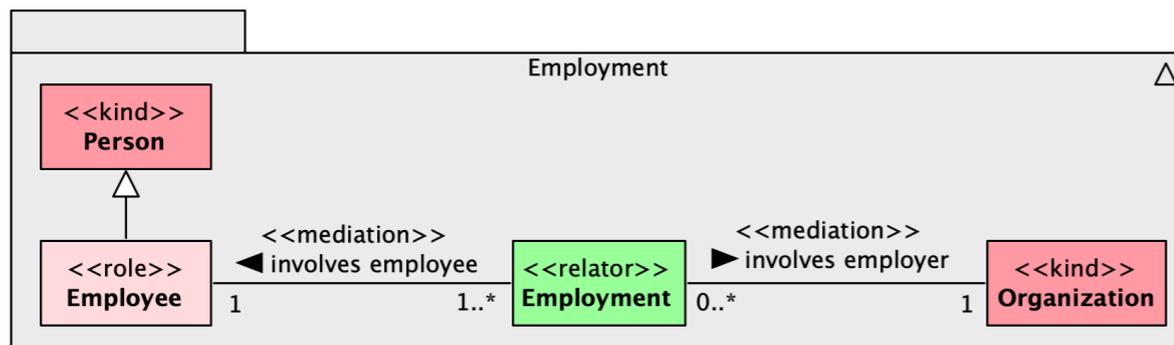
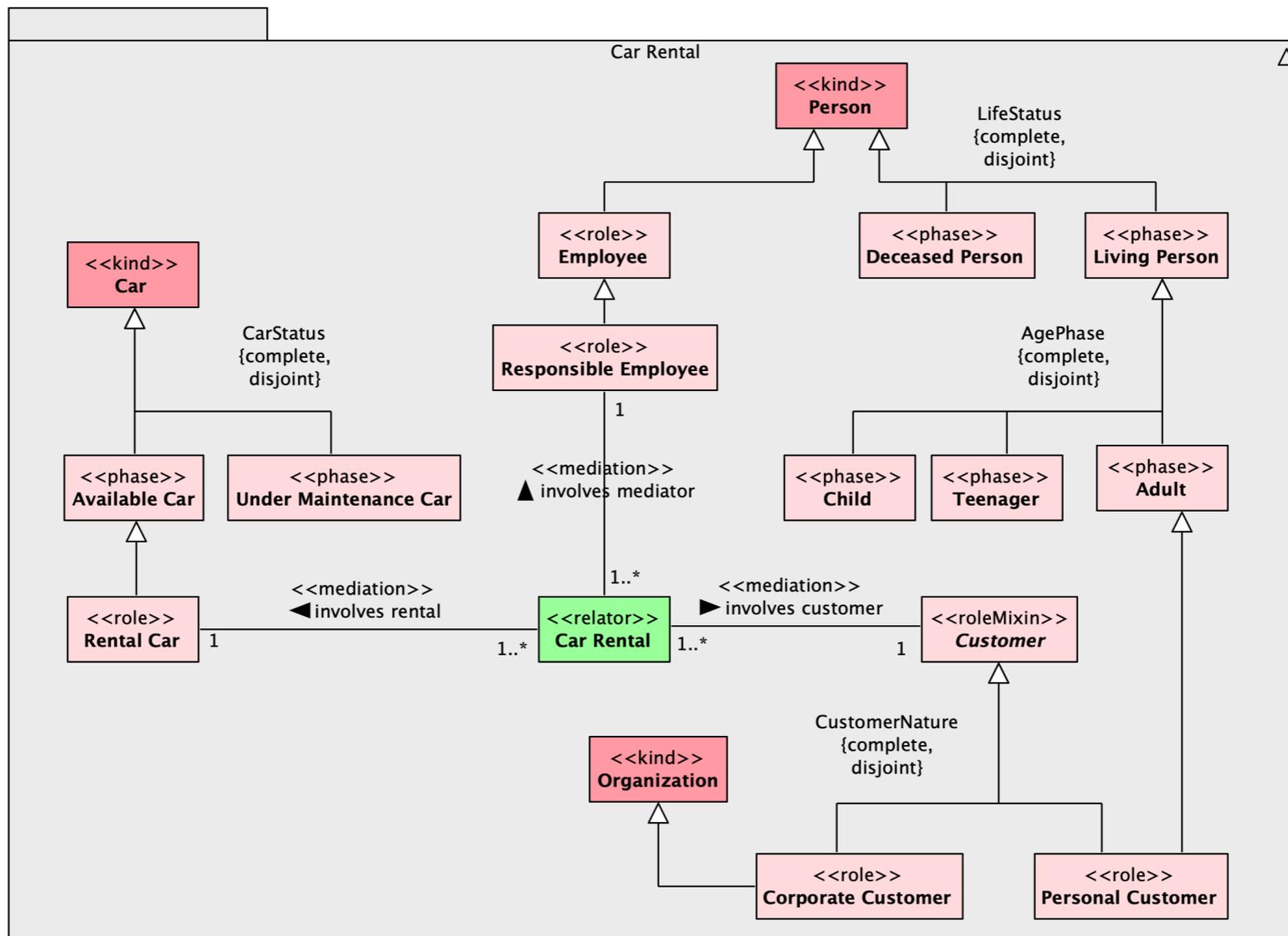






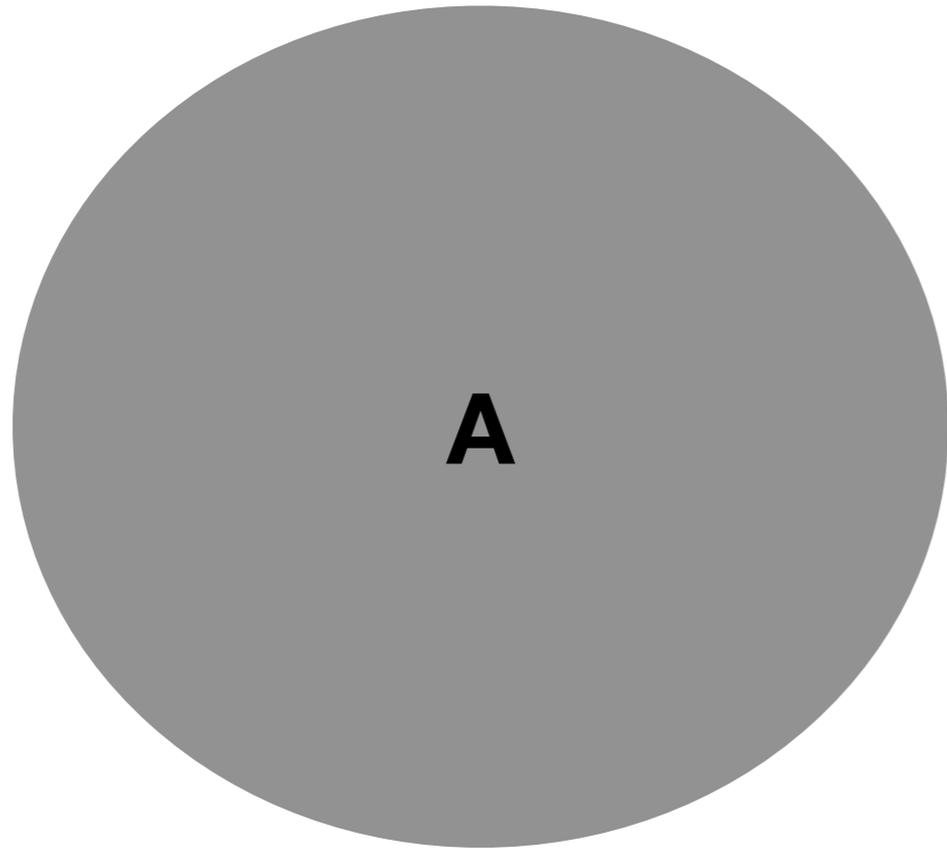




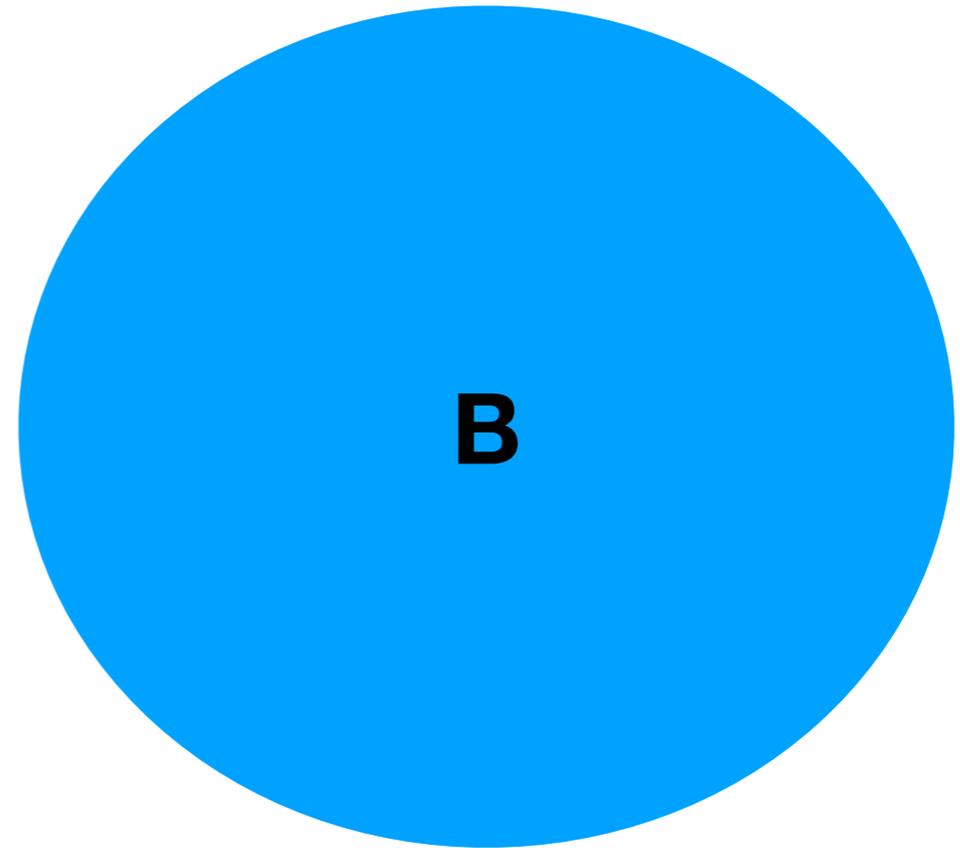


What does that buy us?

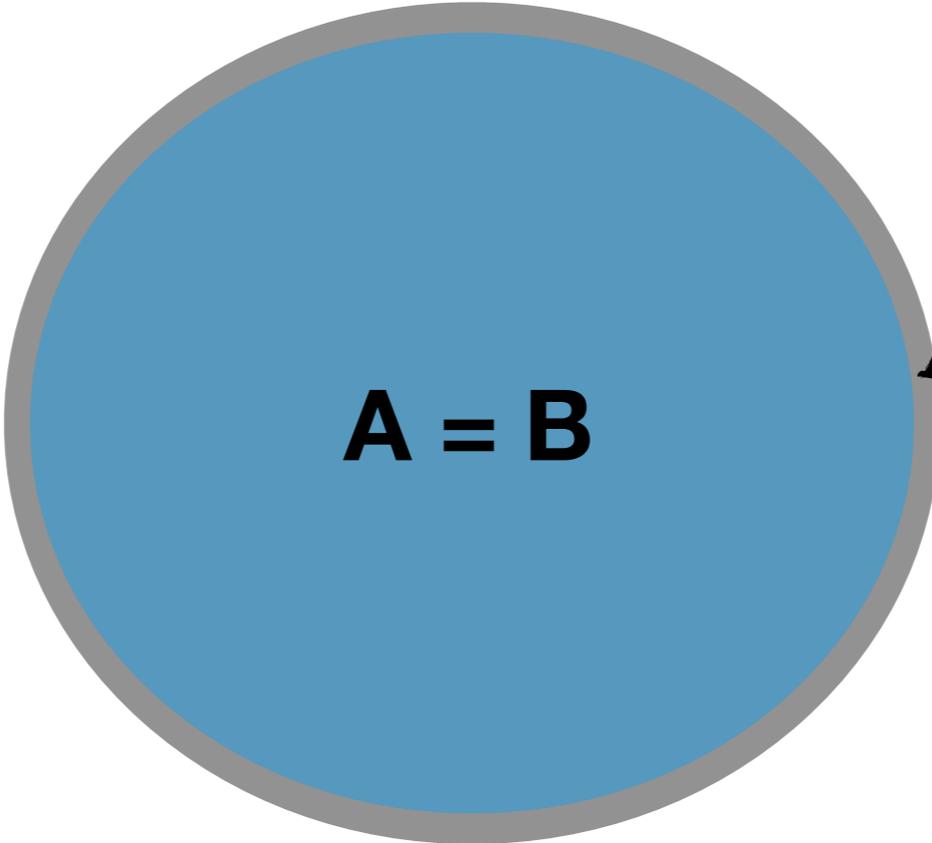
1. Truthmaking and Explanation
2. Makes justice to the complexity of the relational phenomena (**Precision**)
3. Helps to elicit tacit knowledge that would otherwise remain tacit (**Completeness**)
4. Disambiguation (**Semantic Clarity**)



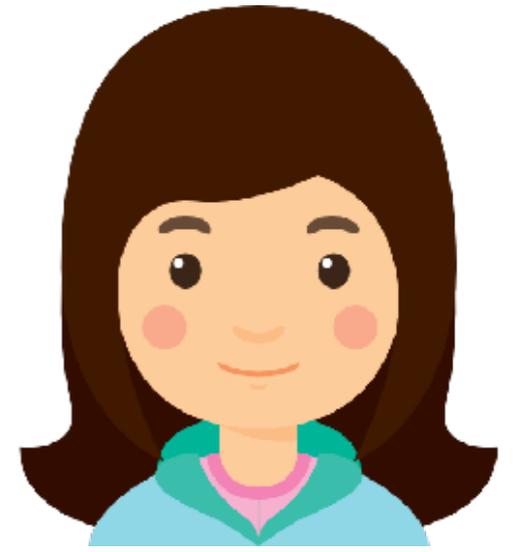
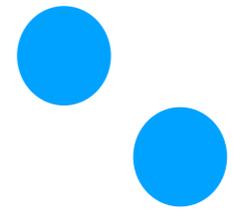
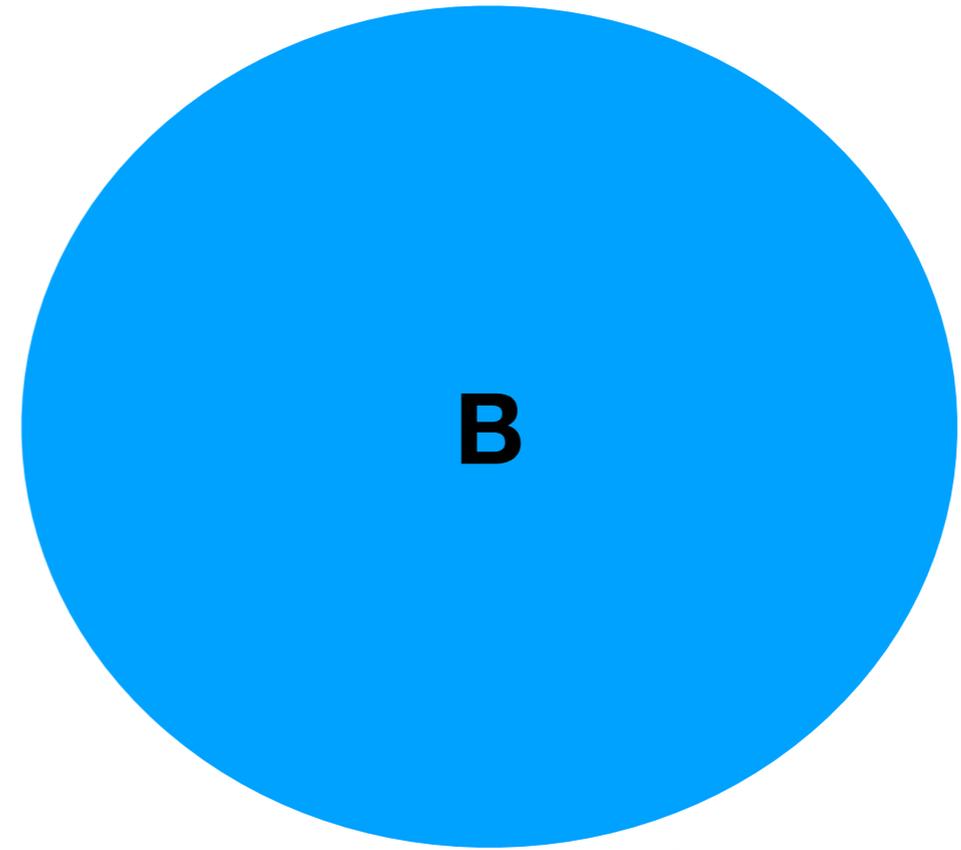
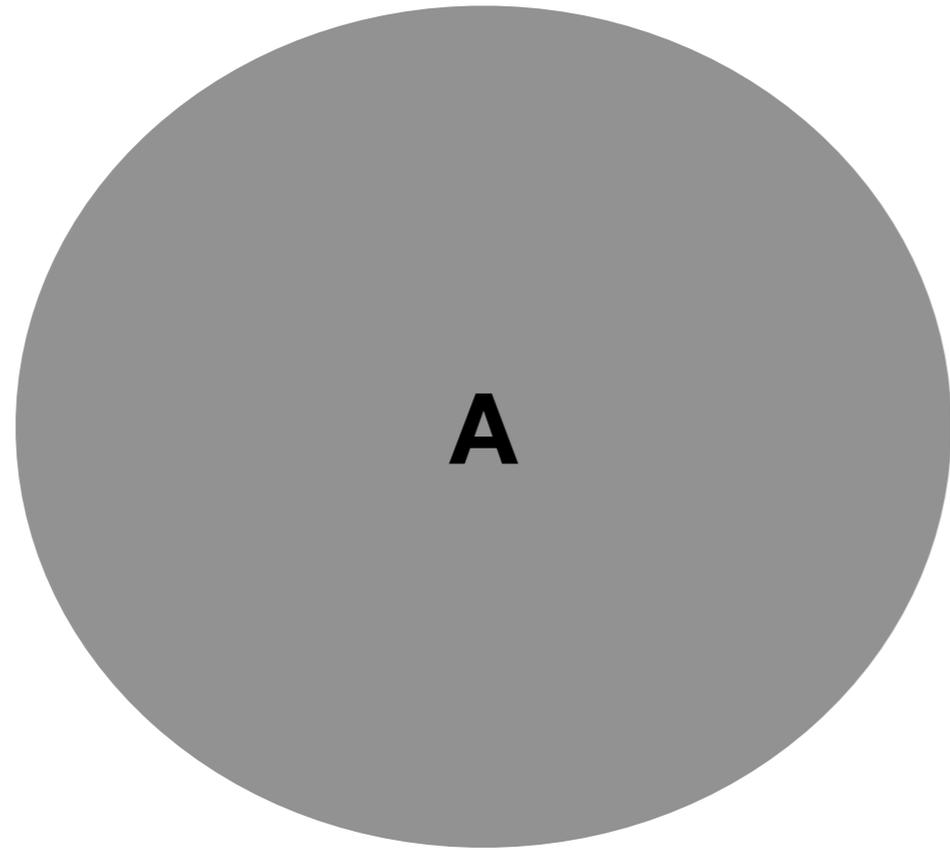
**Possible
Interpretations
of a
Model**

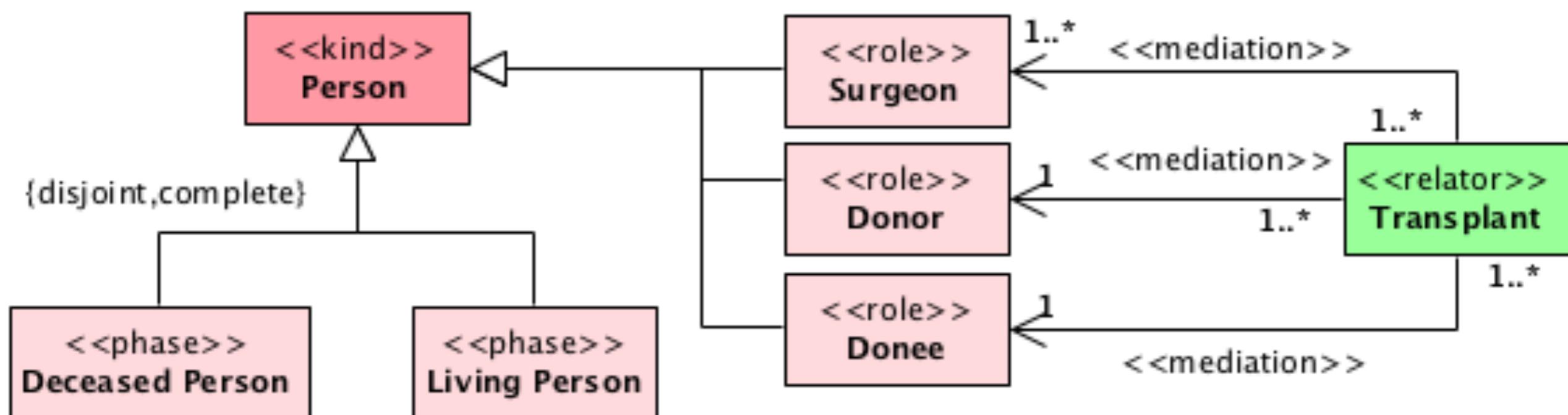


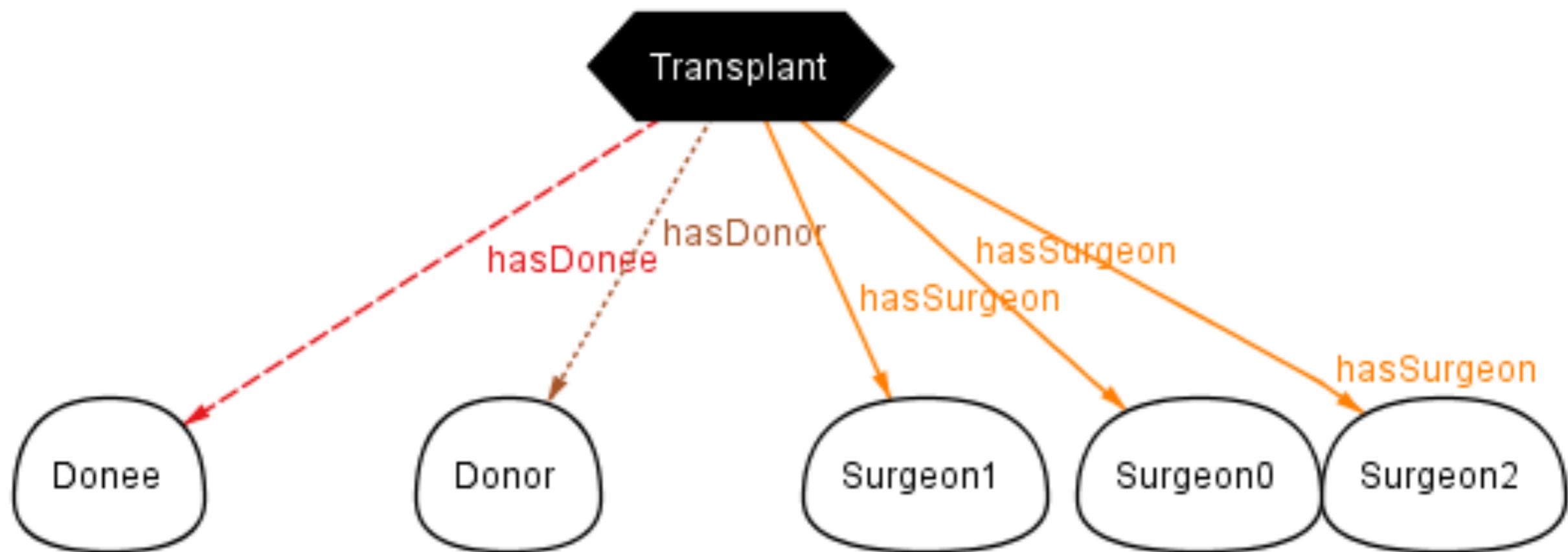
**Intended
Interpretations
of that
Model**

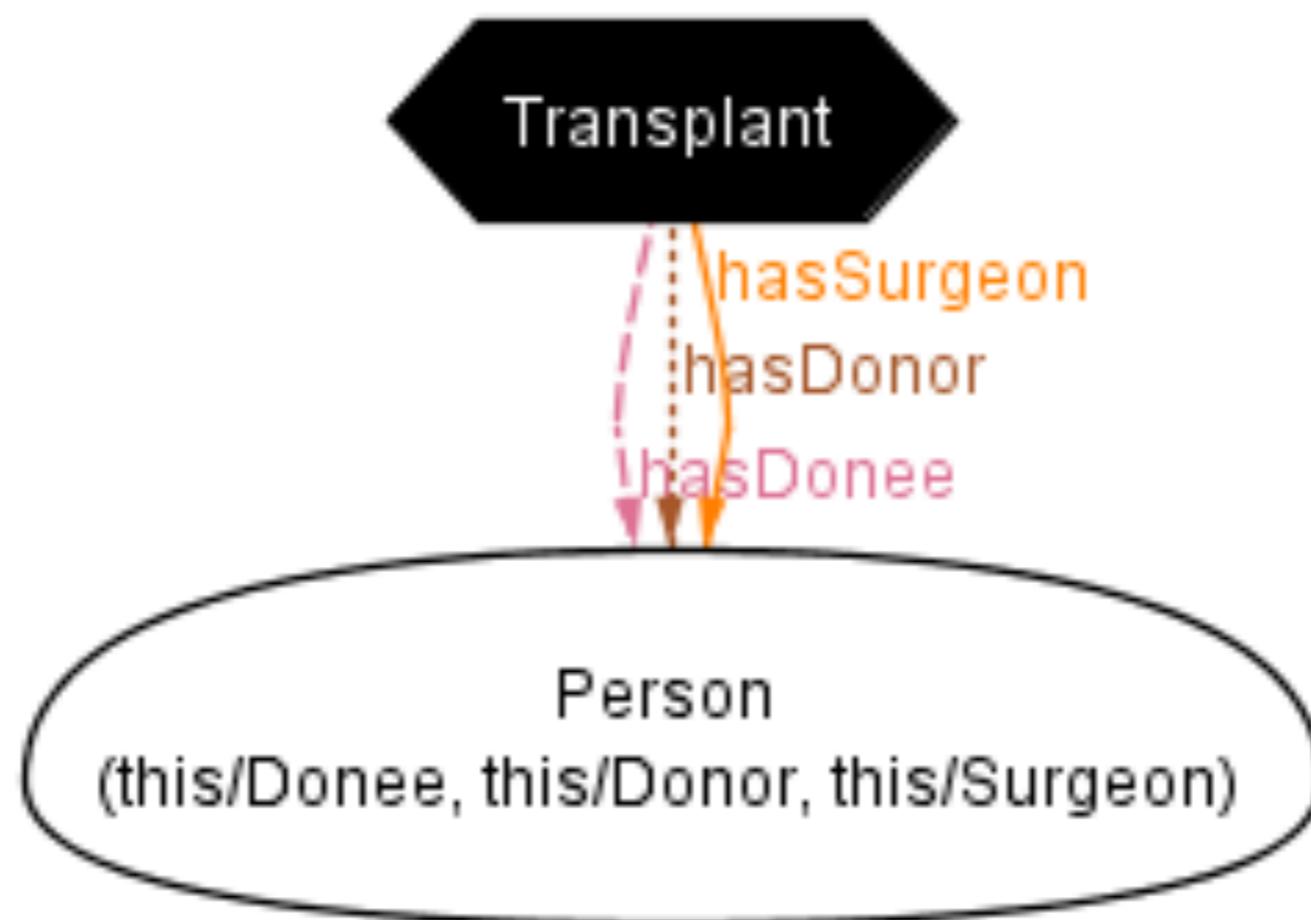


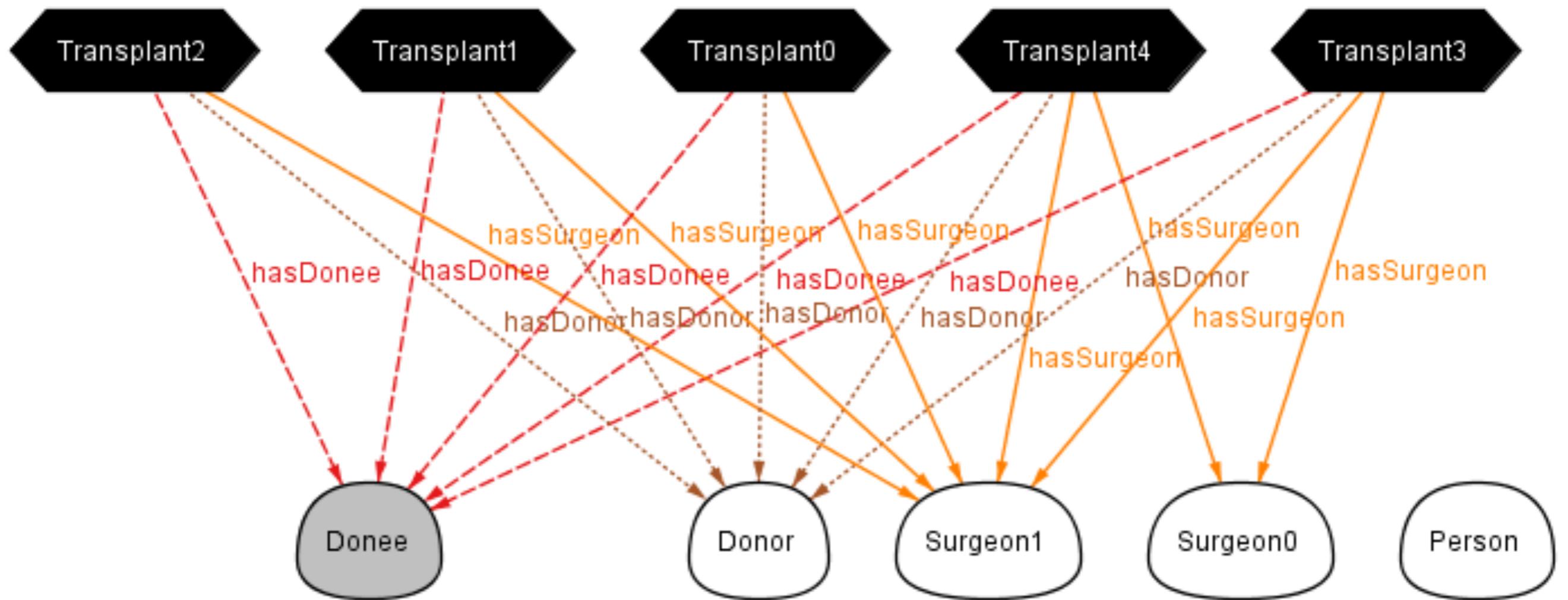
Constraints



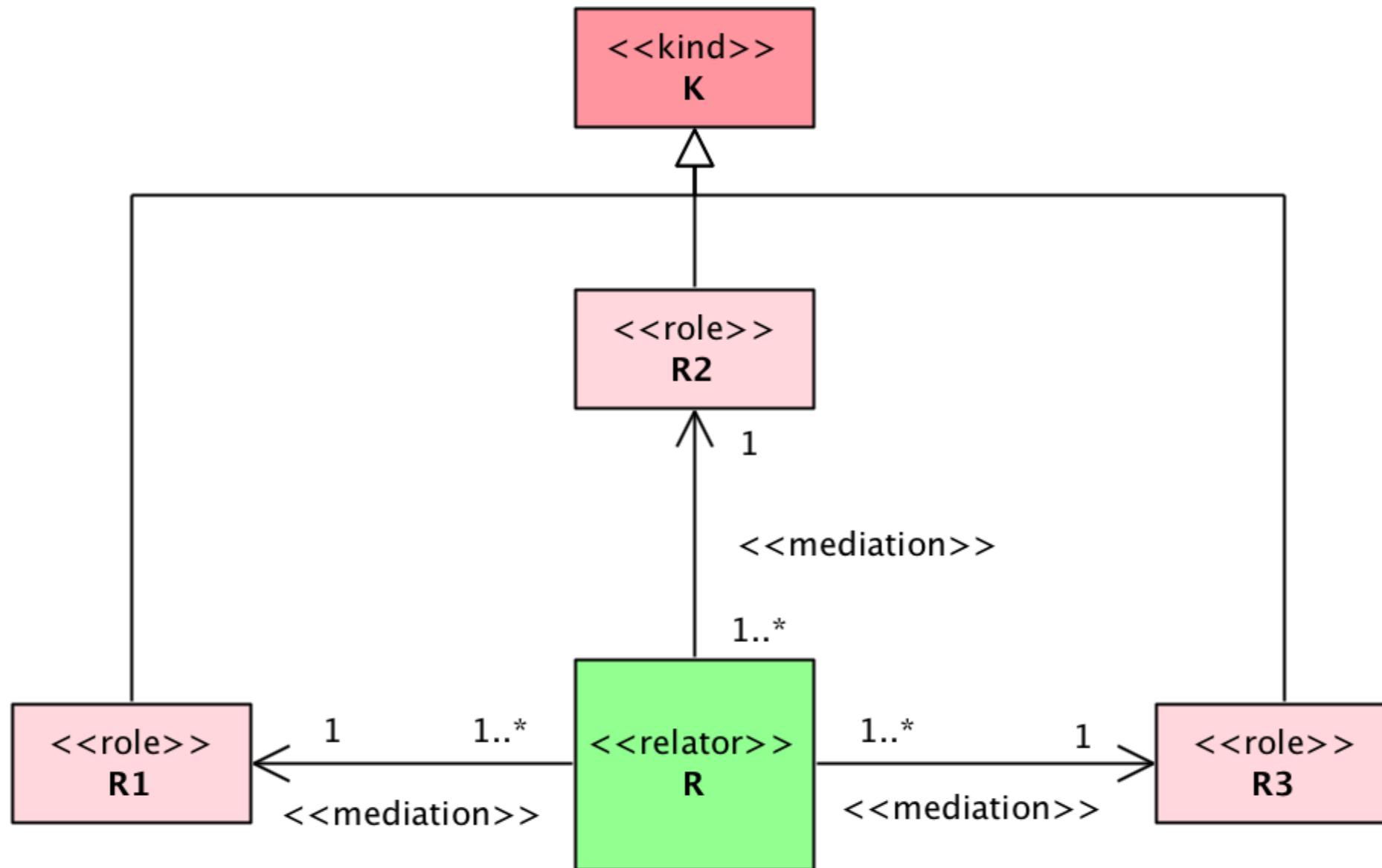








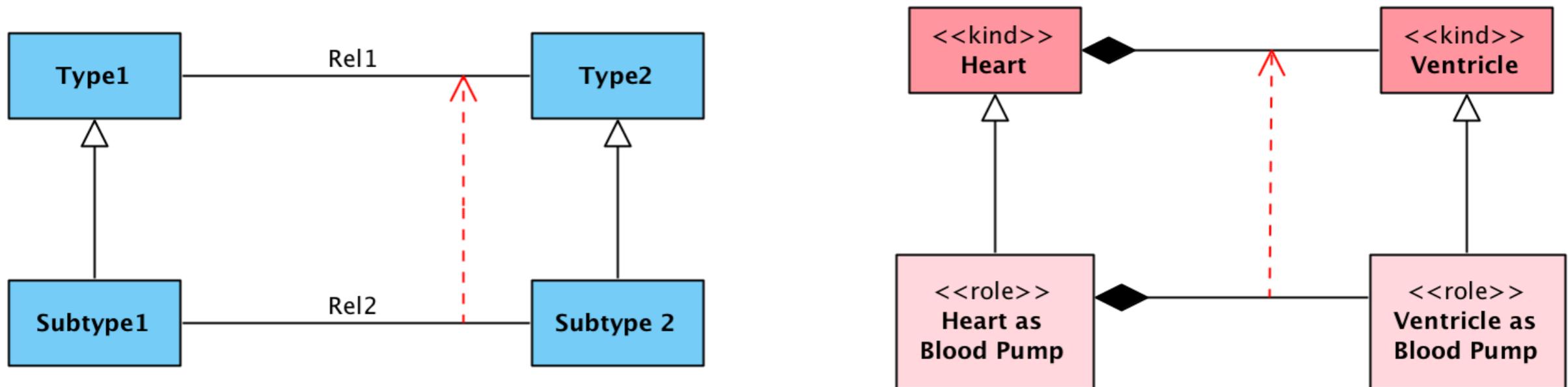
The Emerging **Anti-Pattern**

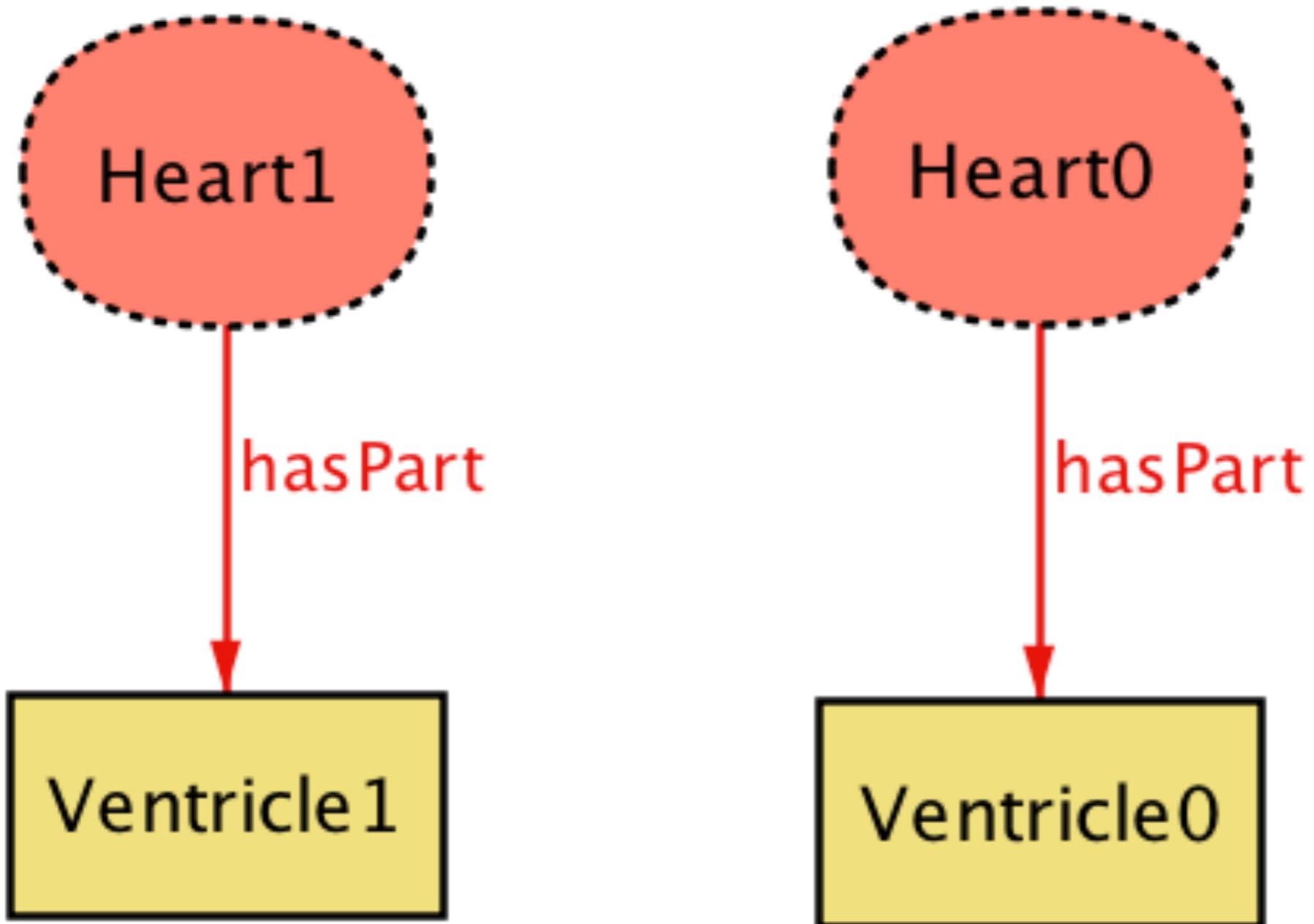


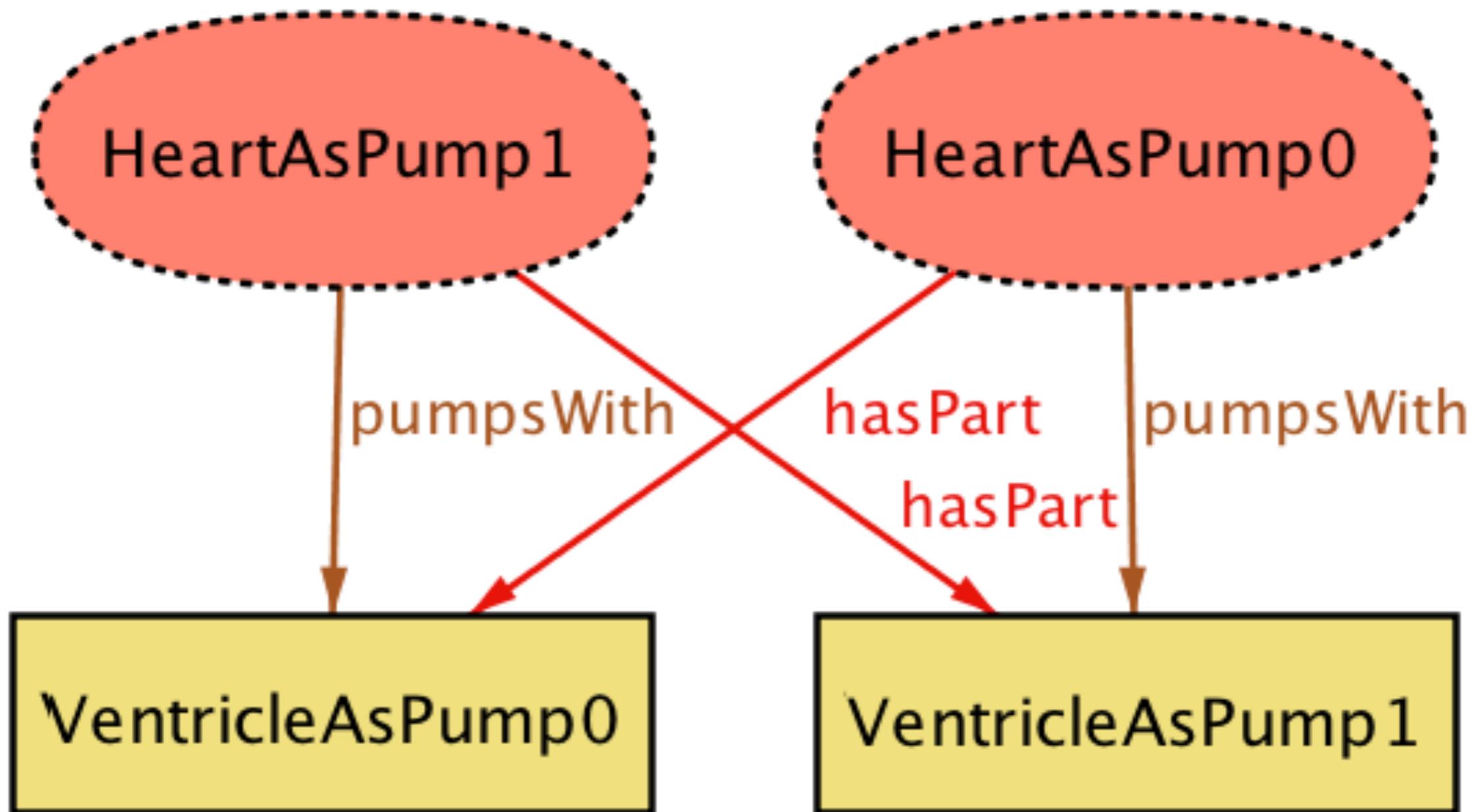
Anti-Pattern Catalogue

- Association Cycle
- Binary Relation Between Over. Types
- Deceiving Intersection
- Free Role Specialization
- Imprecise Abstraction
- Multiple Relational Dependency
- Part Composing Over. Roles
- Whole Composed by Over. Parts
- **Relator Mediating Over. Types (RelOver)**
- Relation Composition
- Relator Mediating Rigid Types
- Relation Specialization
- Repeatable Relator Instances
- Relationally Dependent Phase
- Generalization Set With Mixed Rigidity
- Heterogeneous Collective
- Homogeneous Functional Complex
- Mixin With Same Identity
- Mixin With Same Rigidity
- Undefined Formal Association
- Undefined Phase Partition

Relation Specialization (RelSpec)

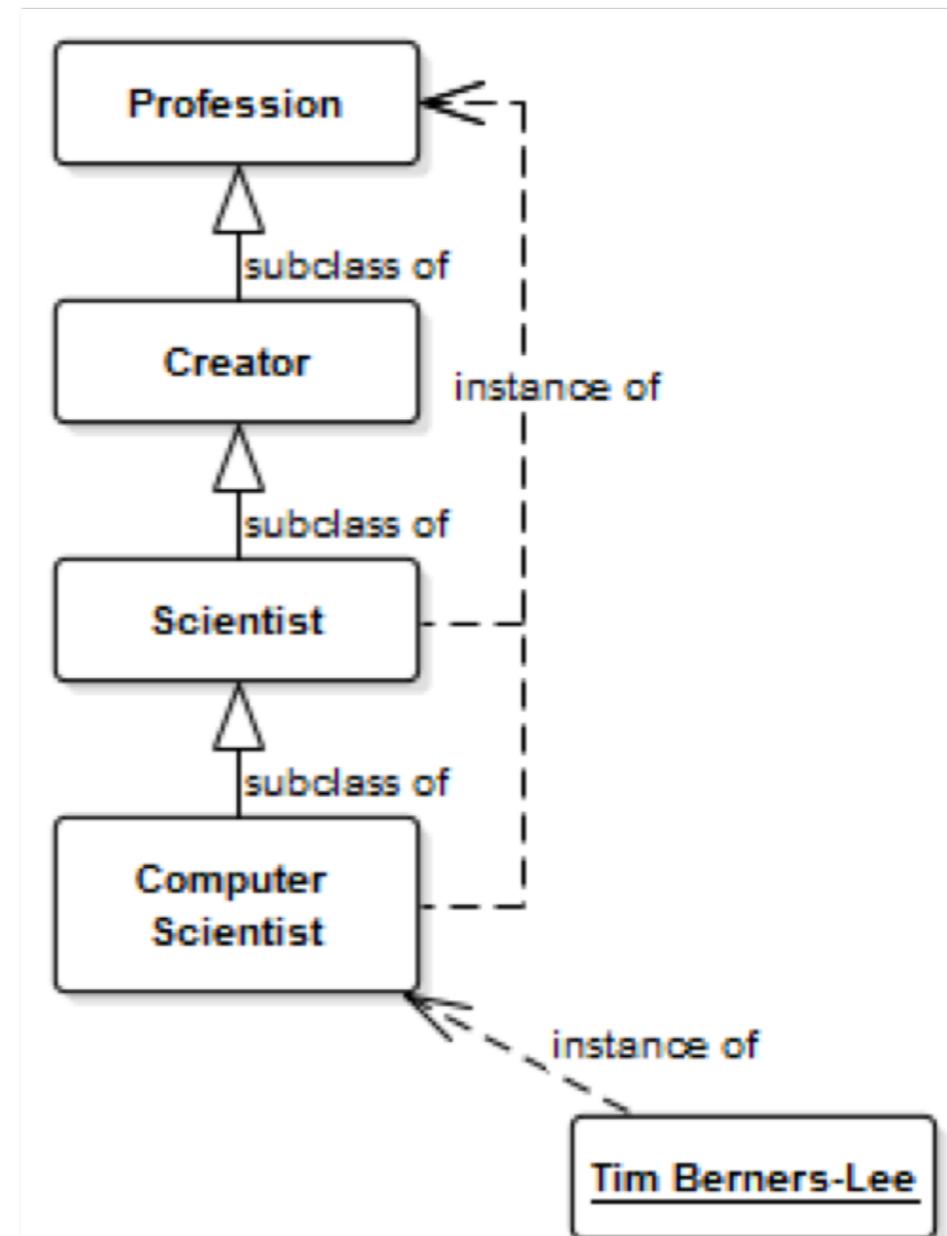
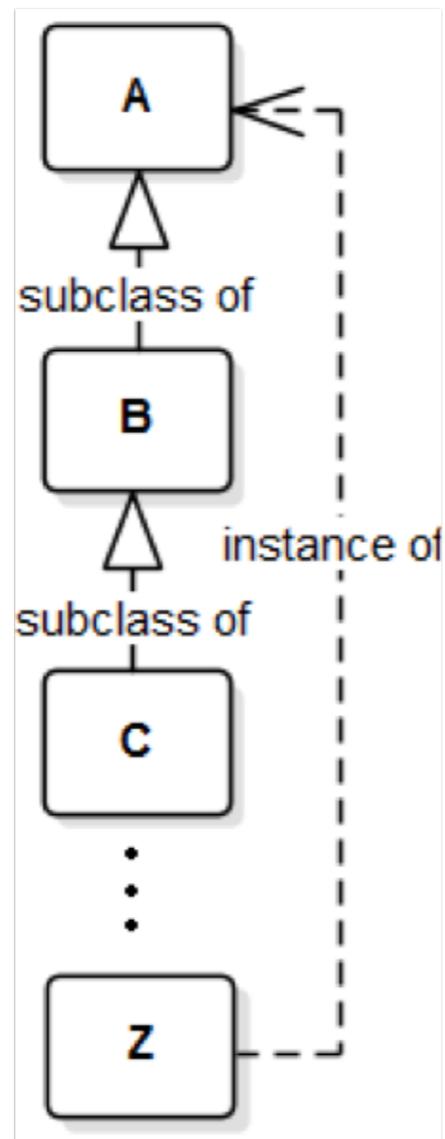






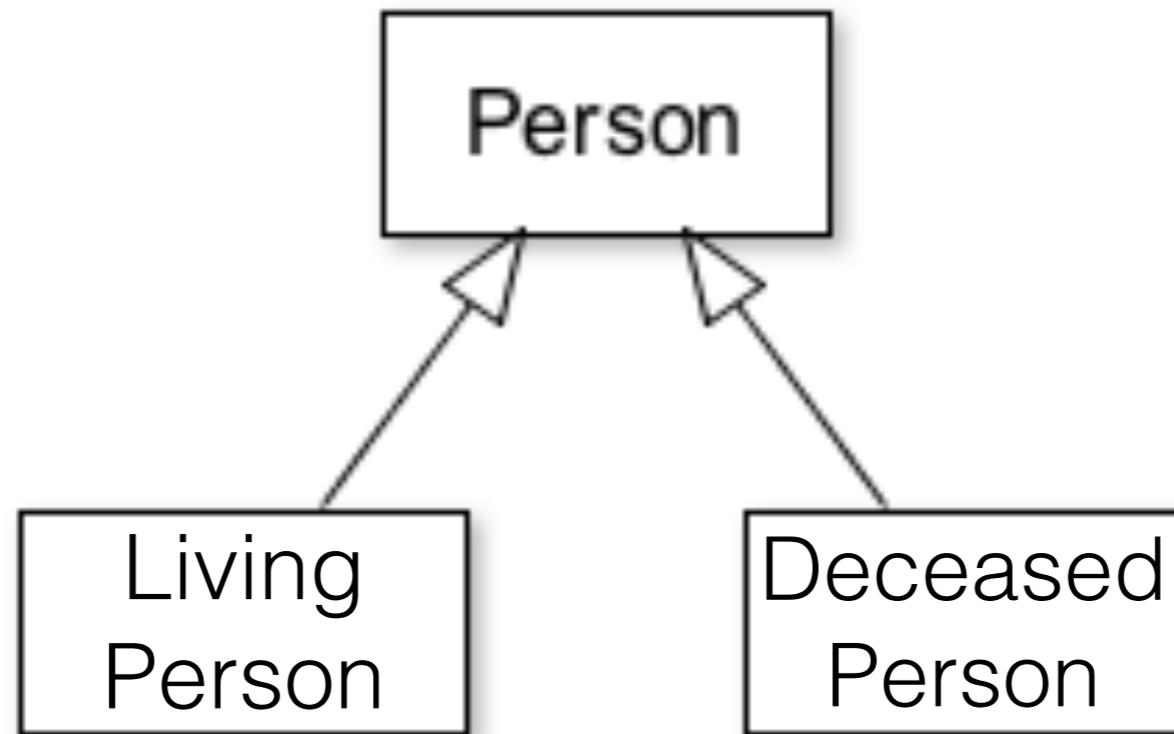
What if we went big...
(searching for Anti-
Patterns on WikiData)

Multi-Level Modeling



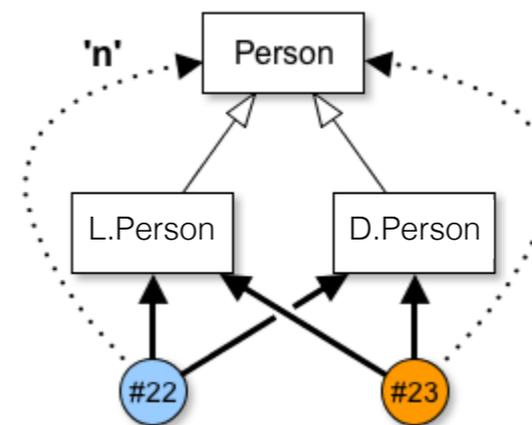
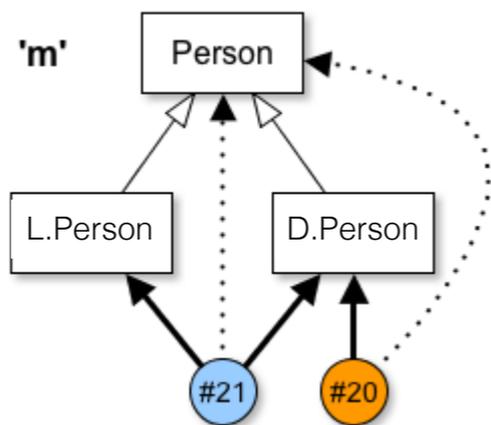
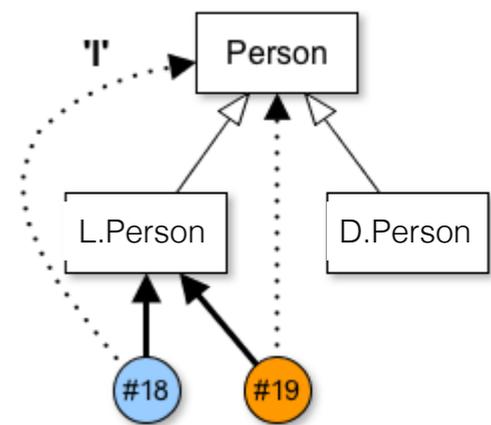
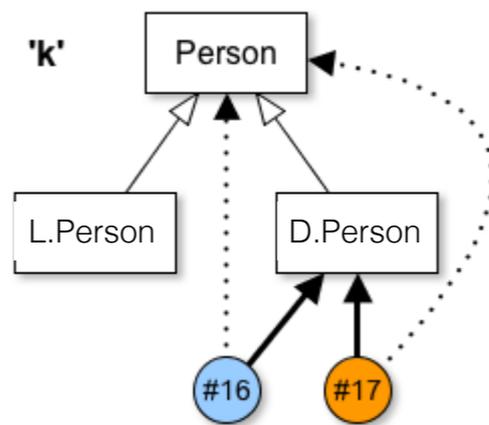
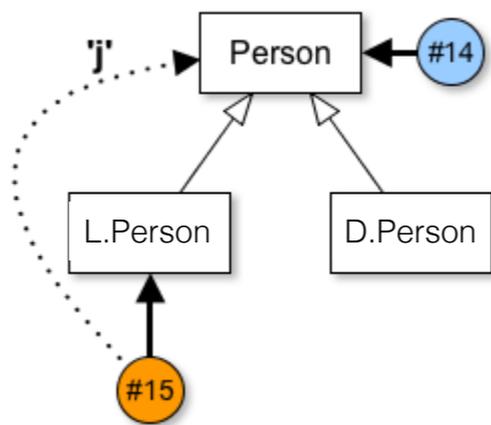
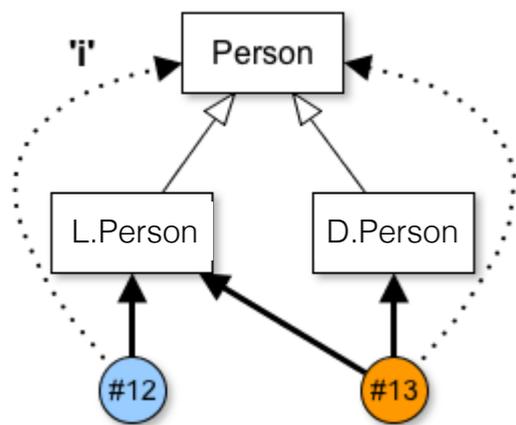
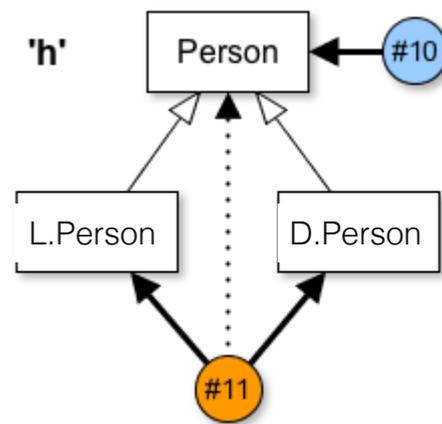
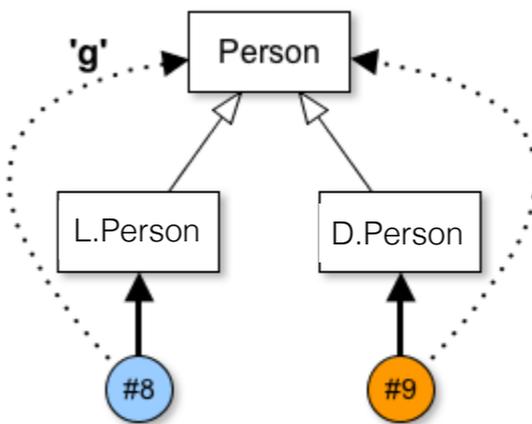
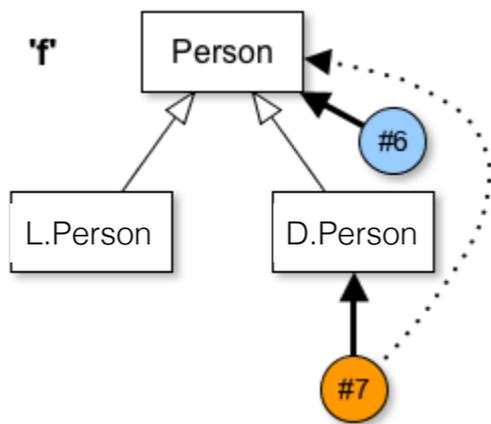
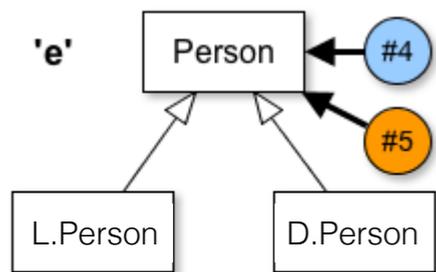
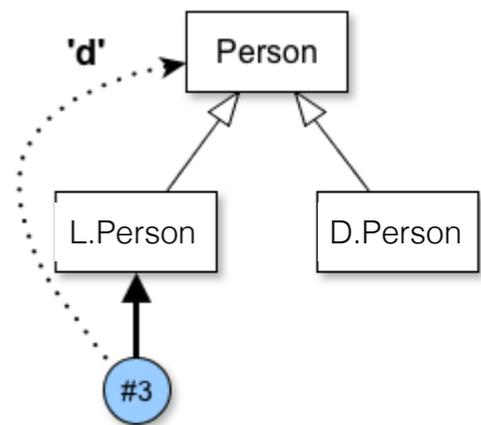
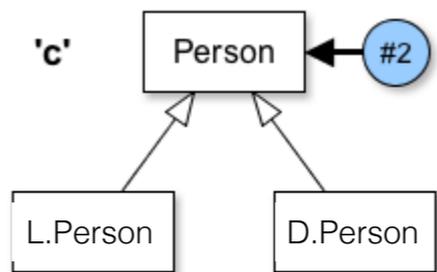
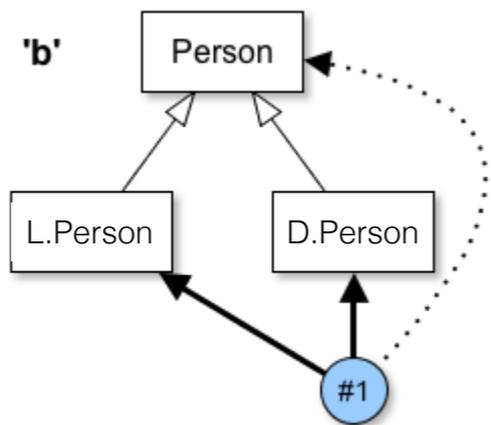
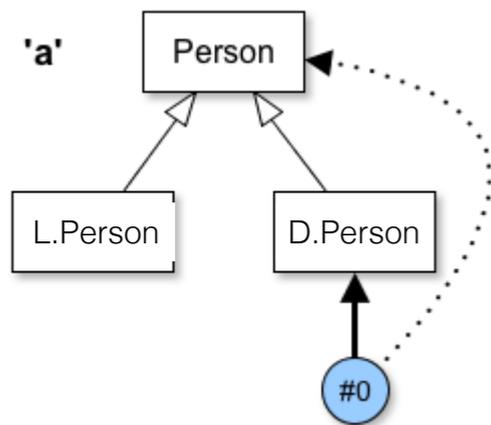
What if we went big...

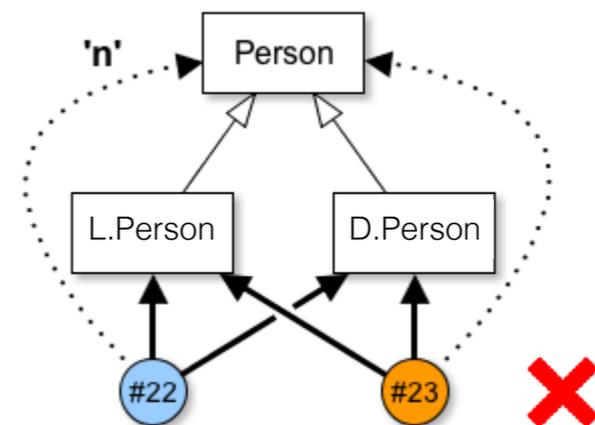
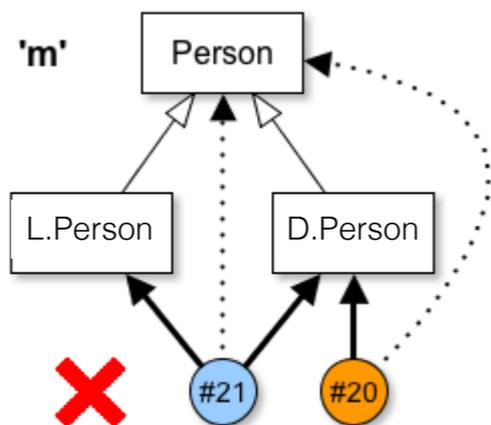
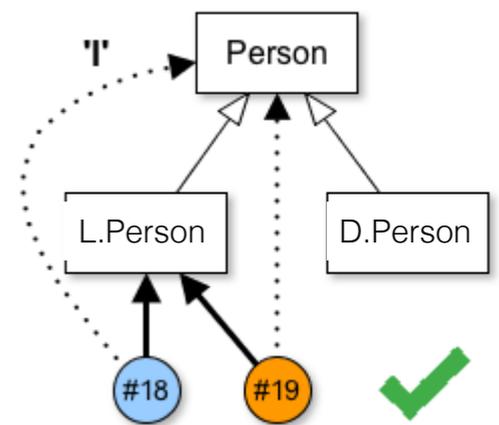
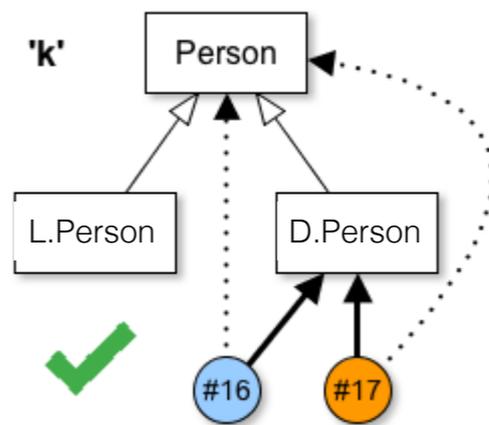
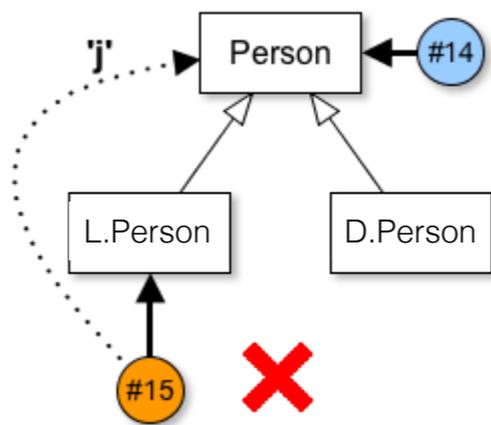
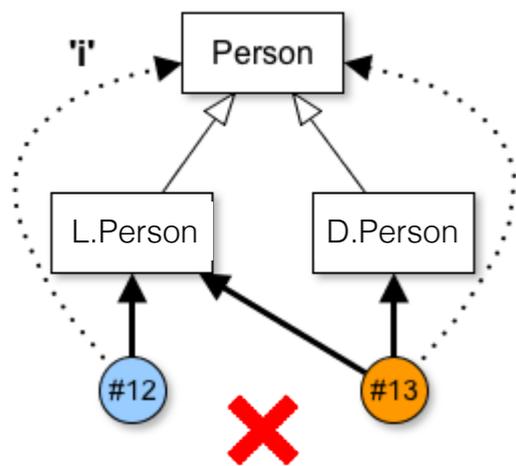
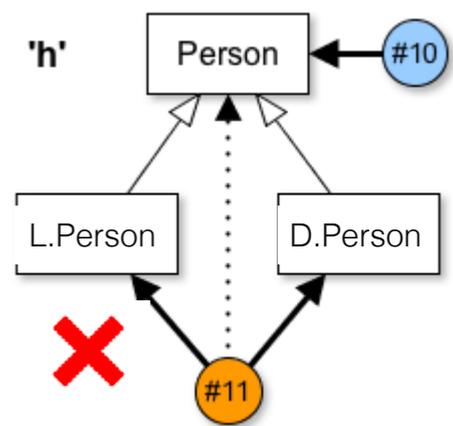
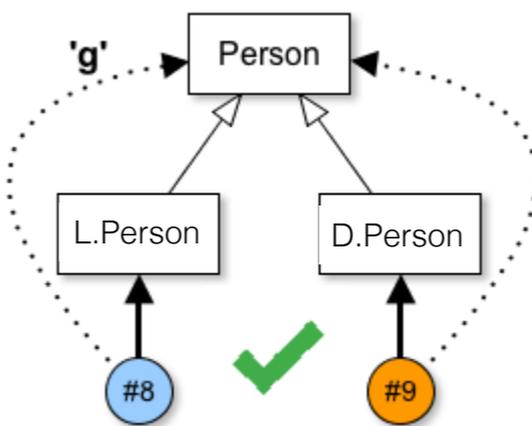
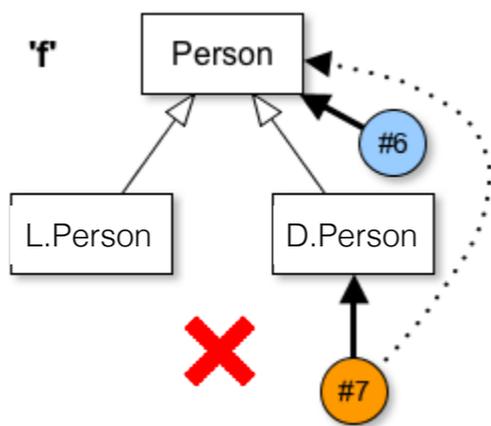
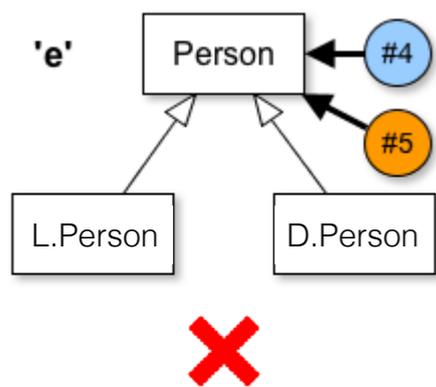
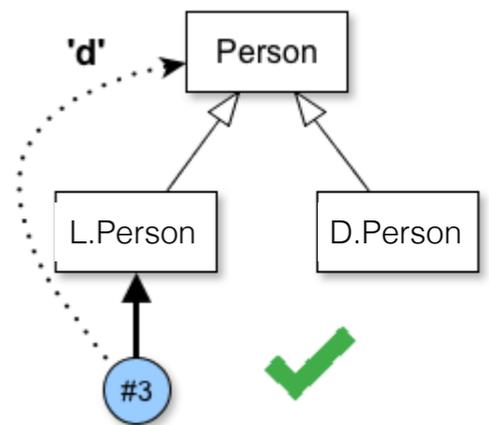
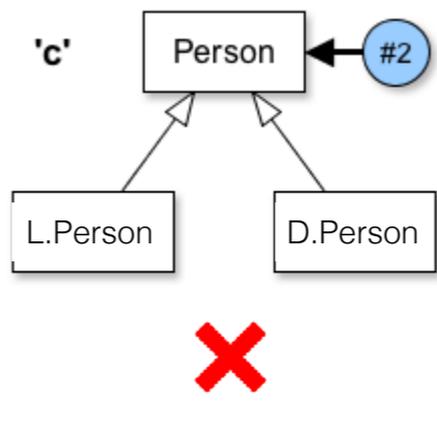
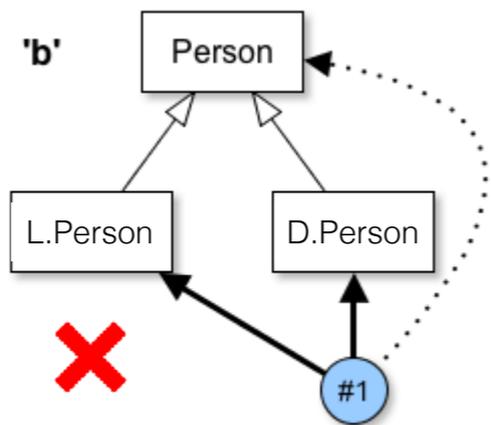
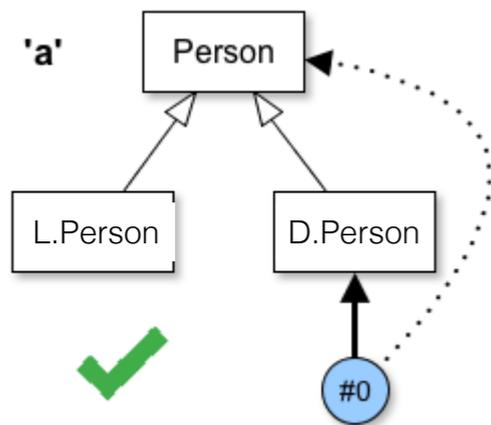
Number of classes in any taxonomic hierarchy	337,102
Number of classes in taxonomic hierarchies spanning more than one level	17,819
Number of classes involved in AP1	15,177

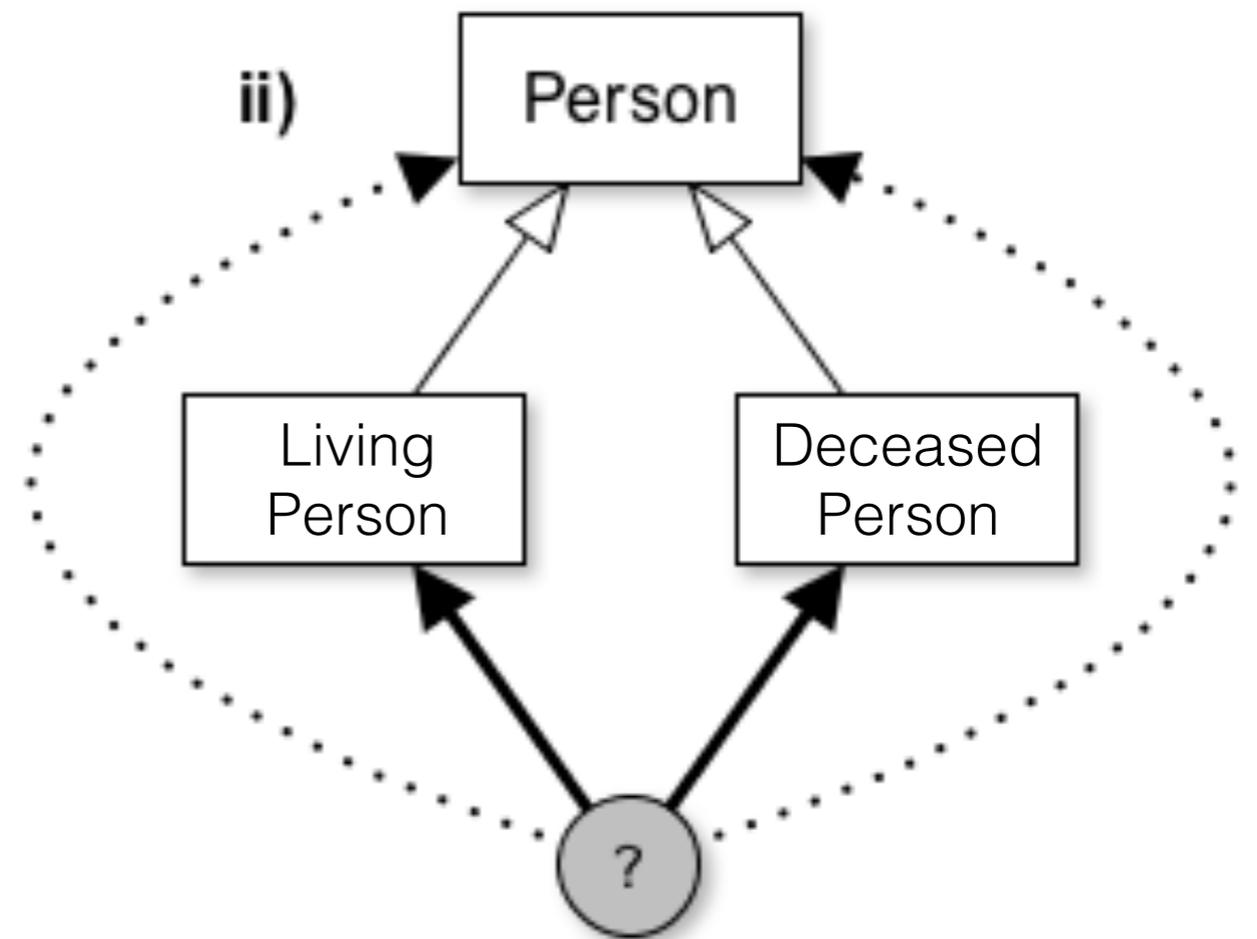
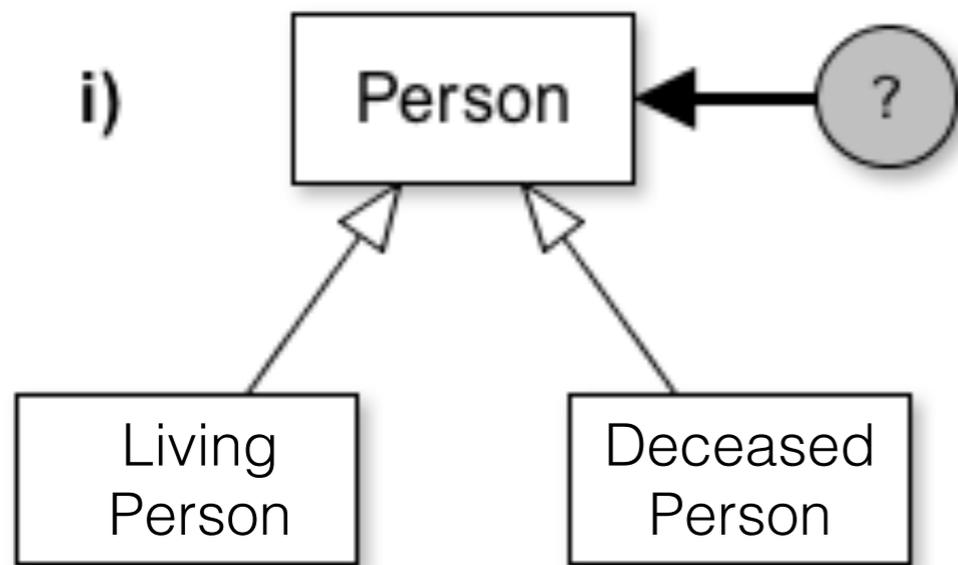


$\forall x \text{LivingPerson}(x) \rightarrow \text{Person}(x)$

$\forall x \text{DeceasedPerson}(x) \rightarrow \text{Person}(x)$







$$\forall x \text{LivingPerson}(x) \rightarrow \text{Person}(x)$$

$$\forall x \text{DeceasedPerson}(x) \rightarrow \text{Person}(x)$$

$$\forall x \text{Person}(x) \rightarrow \text{LivingPerson}(x) \vee \text{DeceasedPerson}(x)$$

$$\neg \exists x \text{LivingPerson}(x) \wedge \text{DeceasedPerson}(x)$$

4

Validation



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