Applied **Ontology** & Conceptual **Modeling**

Giancarlo Guizzardi

Educational Series on
Applied Ontology (ESAO)
Lauch Event, September, 2021

unibz
Freie Universität Bozen
Libera Università di Bolzano
Università Liedia de Bulsan

UNIVERSITEIT TWENTE.

Acknowledgements

- Nicola Guarino
- João Paulo Almeida
- Ricardo Falbo (in memoriam)
- Tiago Sales
- Claudenir Fonseca
- John Mylopoulos
- Daniele Porello
- Alessander Botti
- Mattia Fumagalli

“Conceptual Modeling is the activity of **representing the** physical or social **world for** the purposes of communication, problem-solving and meaning negotiation among **humans**”

(Guarino, Mylopoulos & Guizzardi, 2020)
Philosophical Foundations for Conceptual Modeling

Conceptual Model

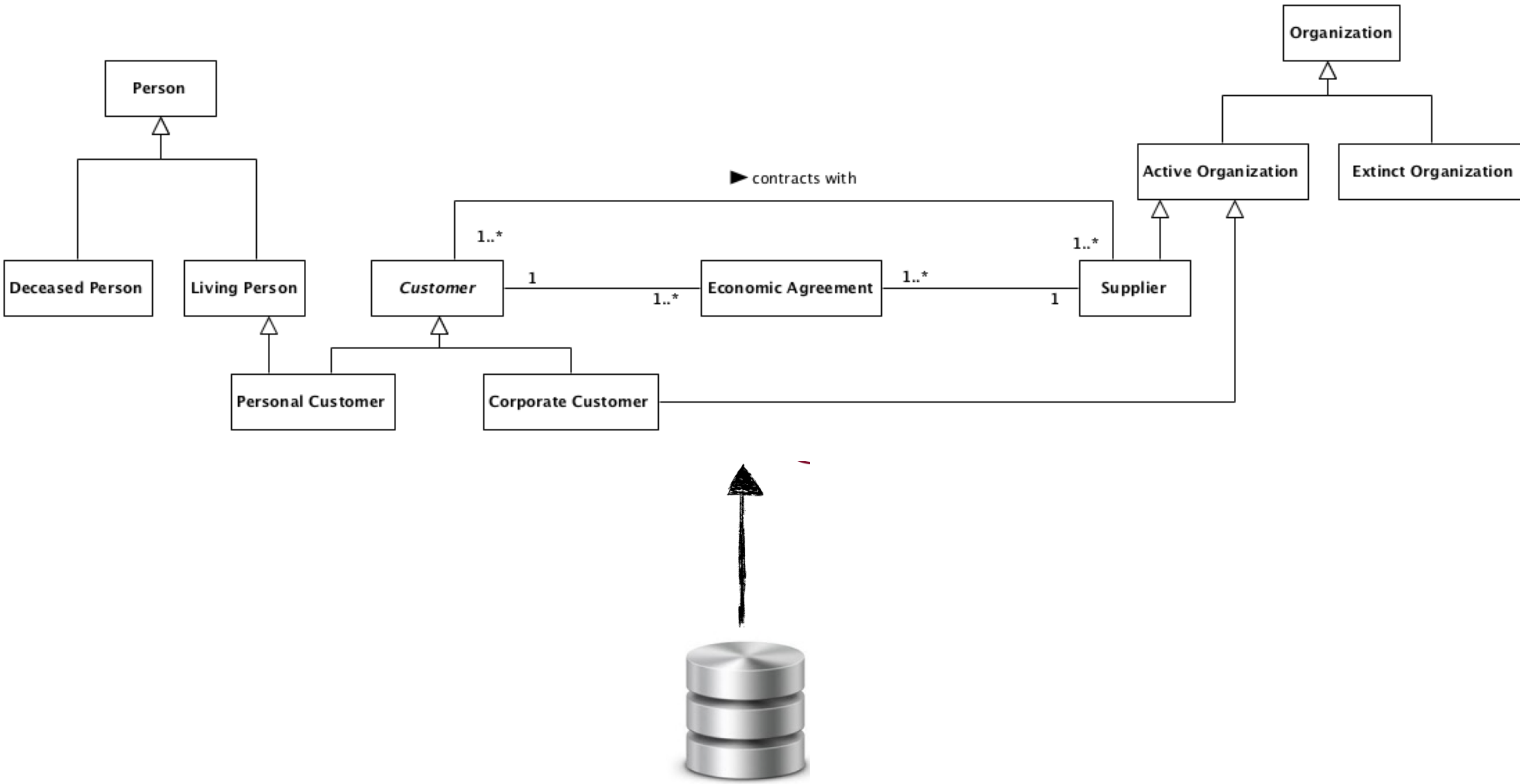
$\approx$

Interface between Reality and Cognition

Conceptual Modeling

$\neq$

Commitment to **Conceptualism** or Representation of **Epistemic** Issues


Person
Deceased Person
Living Person
Customer
Personal Customer
Corporate Customer
contracts with
1..*
1
1..*
Economic Agreement
1..*
1
1..*
Supplier
Organization
Active Organization
Extinct Organization

Another look at data

by GEORGE H. MEALY
Computer Consultant
Scituate, Massachusetts

> “*data are fragments of a* ***theory of the real world****, and data processing juggles* ***representations*** *of these fragments of theory...*”

INTRODUCTION

them in a somewhat new form may prove to be at least suggestive.

To begin on a philosophical plane, let us note that we usually behave as if there were three realms of interest in data processing: the real world itself, ideas about it existing in the minds of men, and symbols on paper or some other storage medium. The lat-

particular ontology, we can avoid a quarrel by adopt-

Toward a theory of data

Relations

To fix our ideas, consider the following example of genealogical data, taken from Reference 2:

Another look at data

by GEORGE H. MEALY
Computer Consultant
Scituate, Massachusetts

> *"data are fragments of a theory of the real world, and data processing juggles representations of these fragments of theory...* ***The issue is ontology, or the question of what exists.****"*

INTRODUCTION

them in a somewhat new form may prove to be at least suggestive.

To begin on a philosophical plane, let us note that we usually behave as if there were three realms of interest in data processing: the real world itself, ideas about it existing in the minds of men, and symbols on paper or some other storage medium. The lat-

particular ontology, we can avoid a quarrel by adopt-

Toward a theory of data

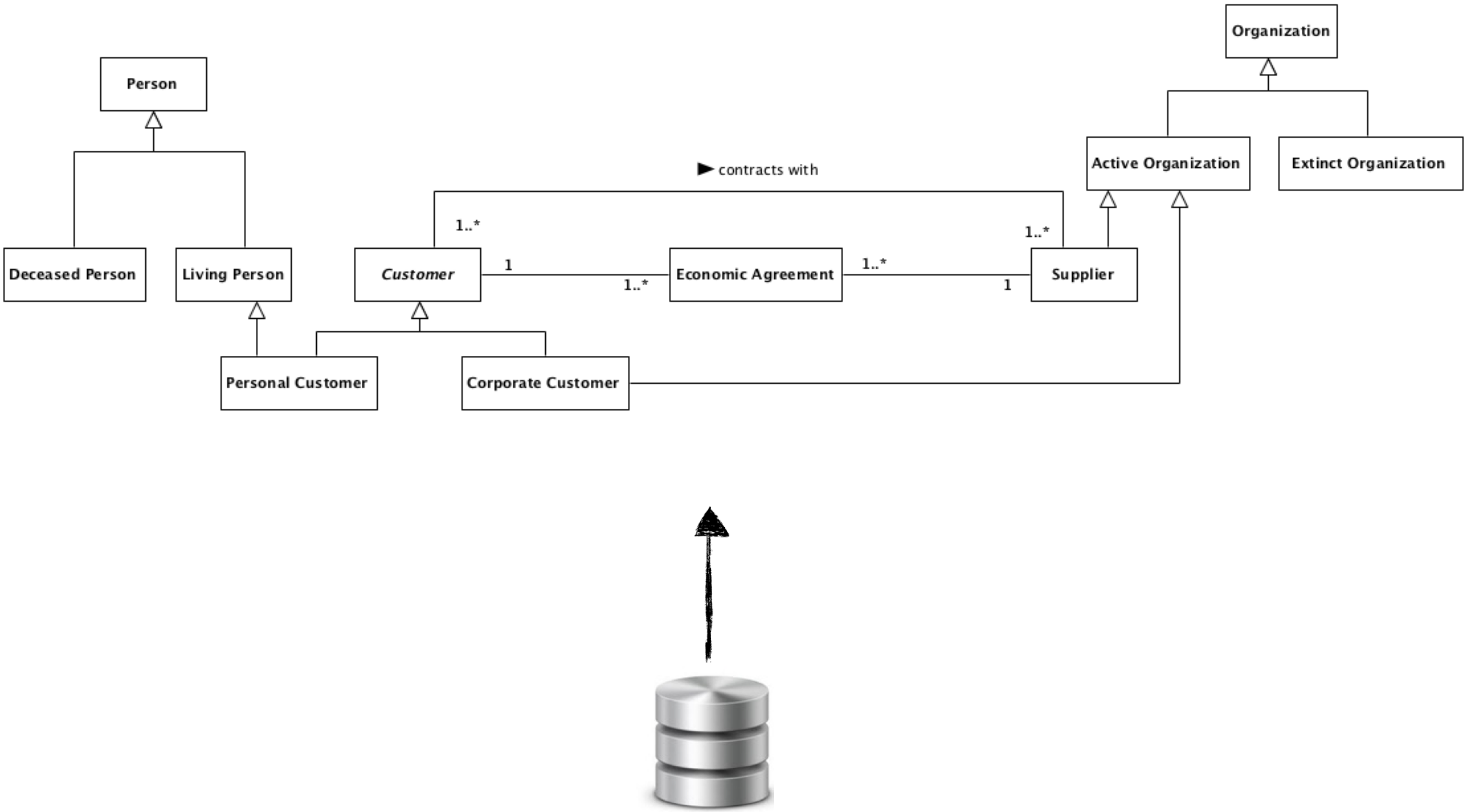
Relations

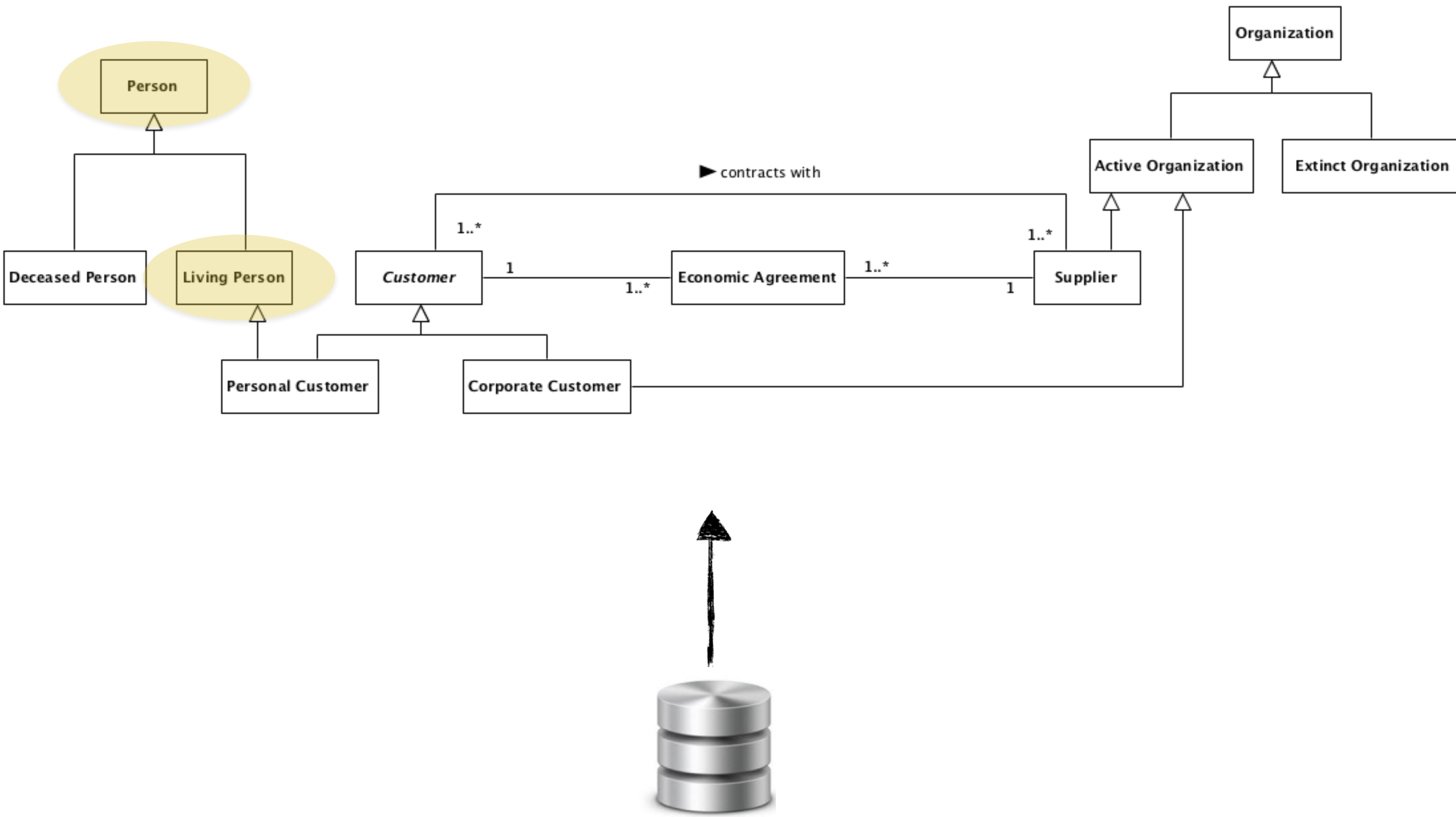
To fix our ideas, consider the following example of genealogical data, taken from Reference 2:

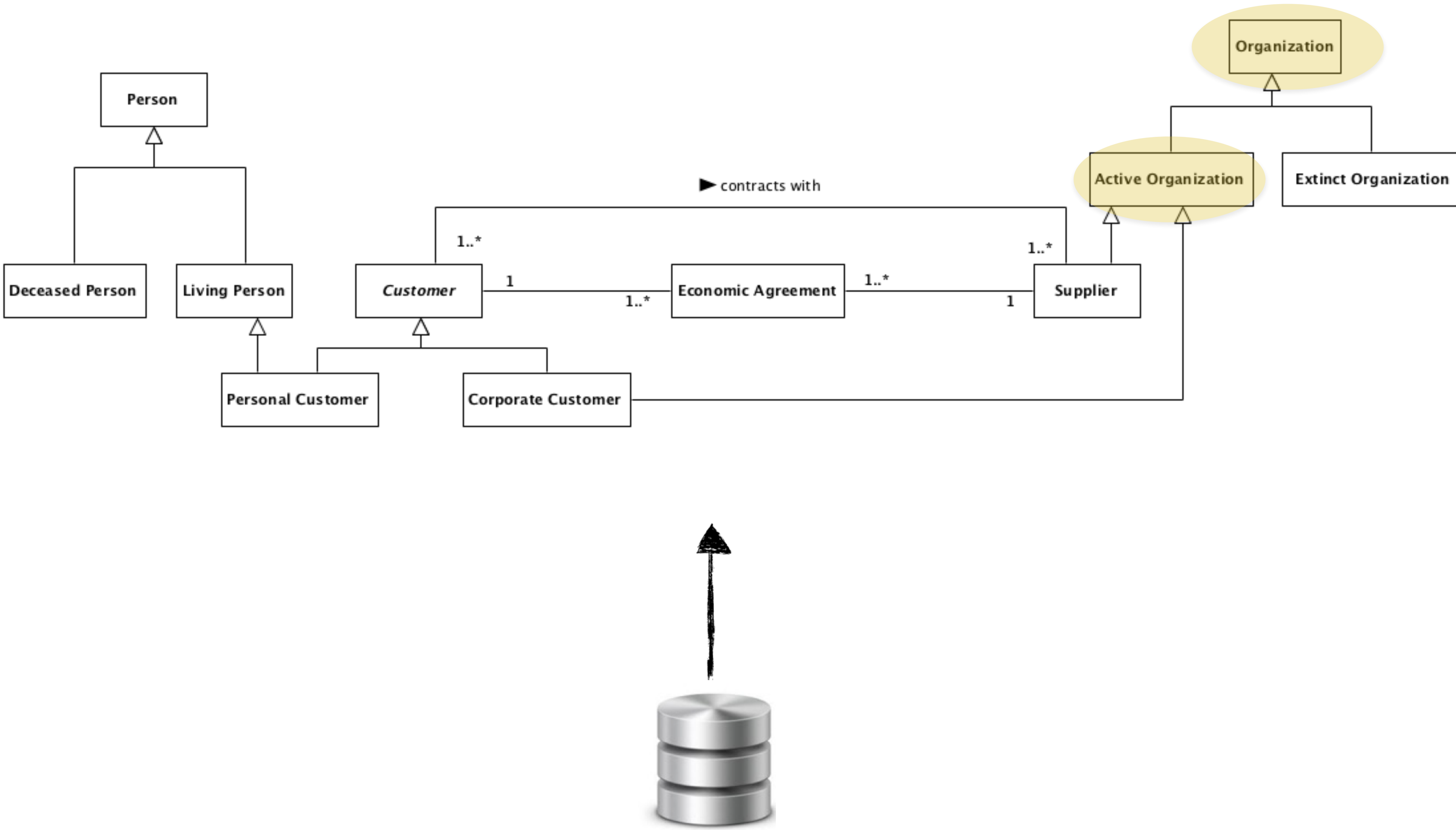
The opposite of Ontology is not Non-Ontology is Bad Ontology!

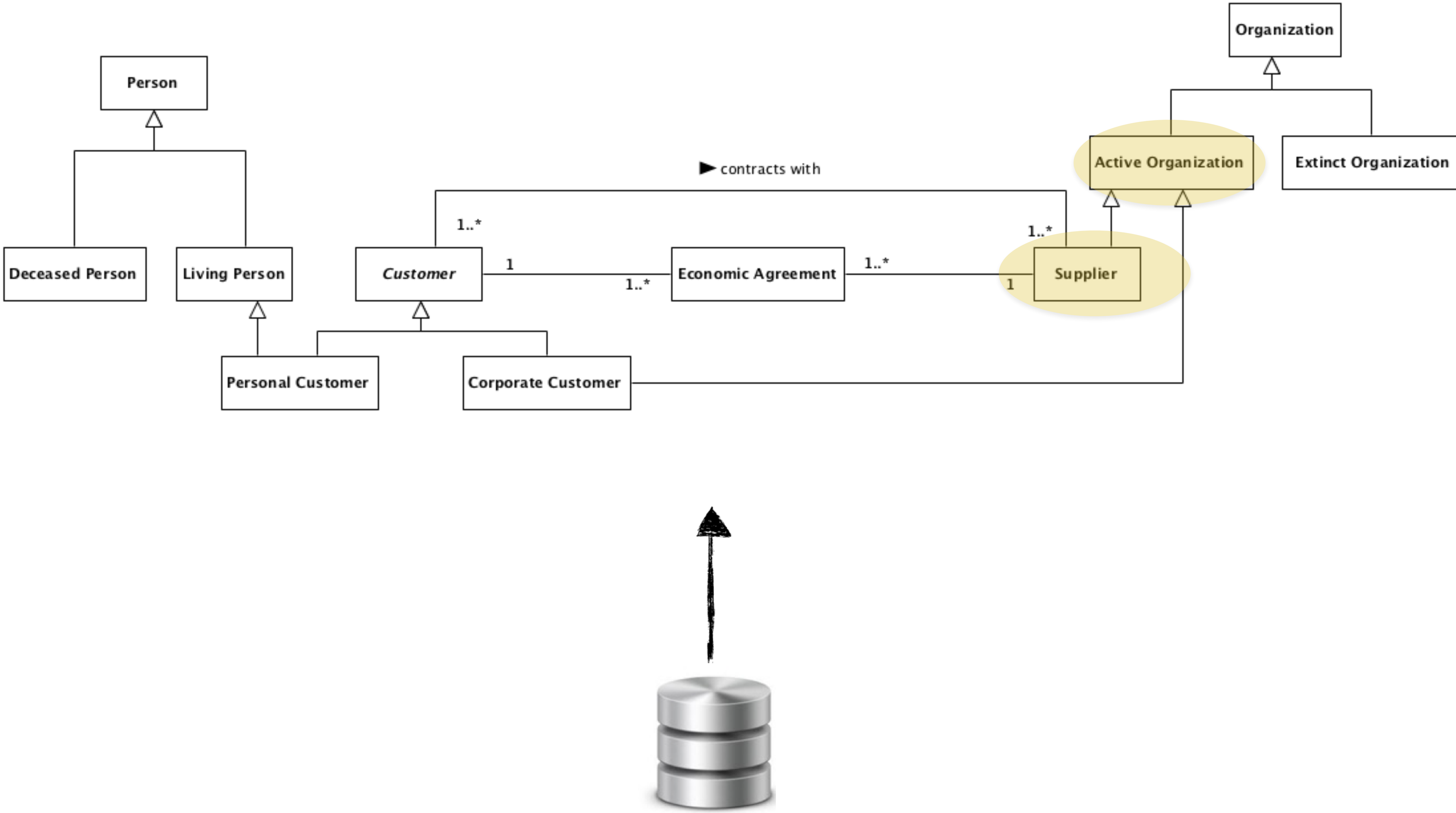
ontology ≈

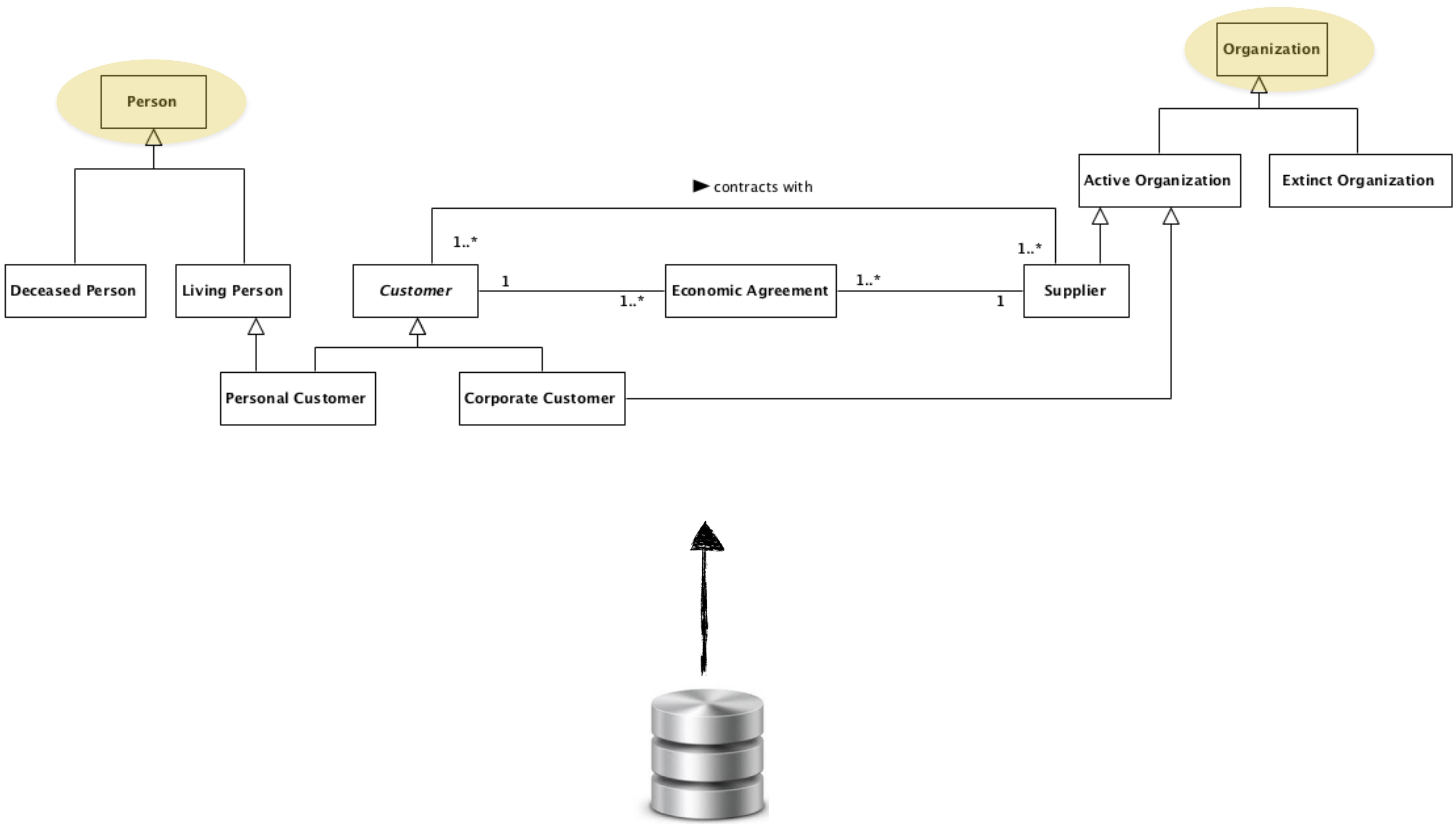
A theory about the kinds of entities and their ties that are assumed to exist by an given description of reality


Organization
Person
Active Organization
Extinct Organization
contracts with
1..*
1..*
Deceased Person
Living Person
Customer
1
1..*
Economic Agreement
1..*
1
Supplier
Personal Customer
Corporate Customer

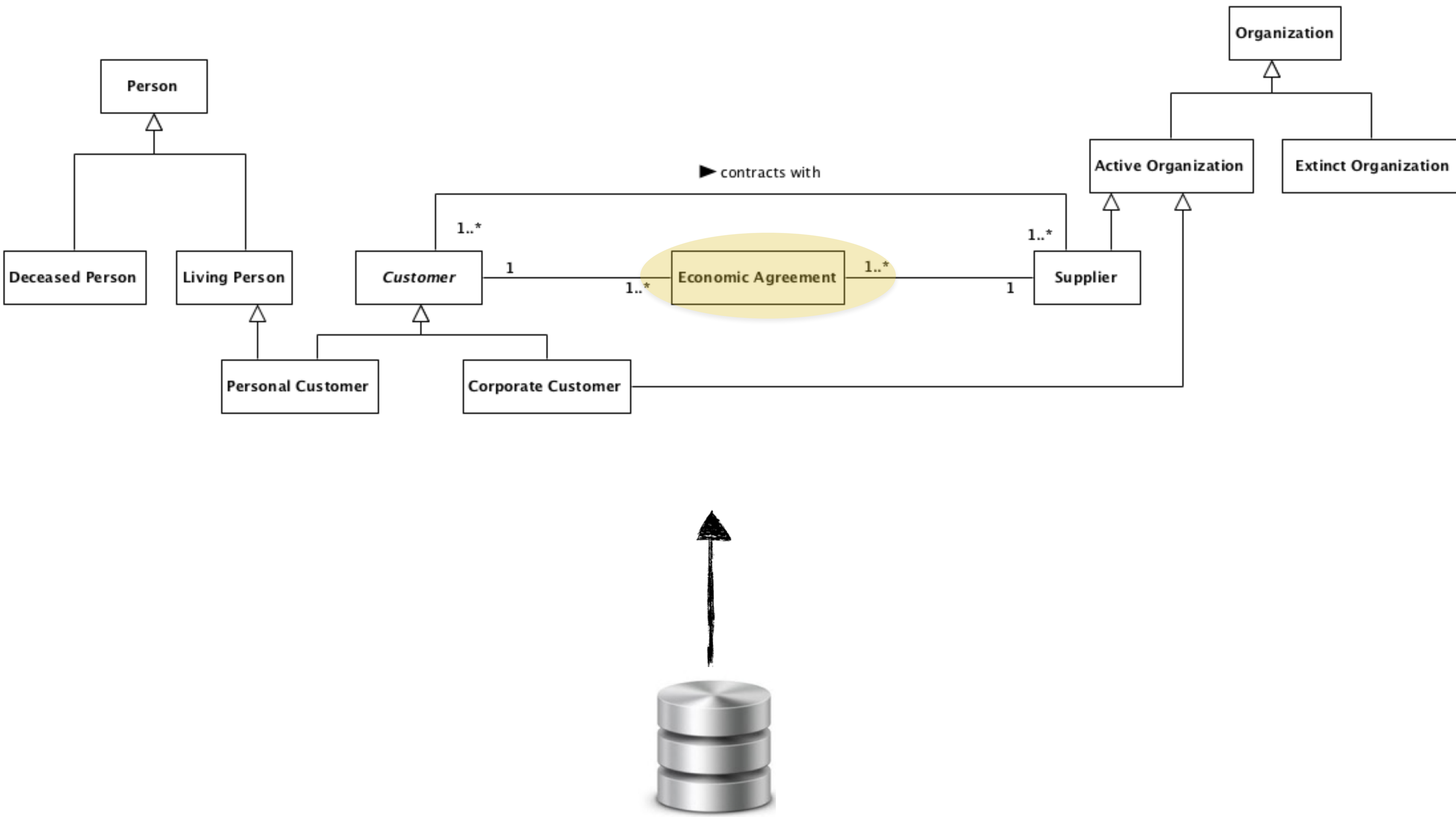

Organization
Person
Active Organization
Extinct Organization
contracts with
1..*
1..*
Deceased Person
Living Person
Customer
1
1..*
Economic Agreement
1..*
1
Supplier
Personal Customer
Corporate Customer

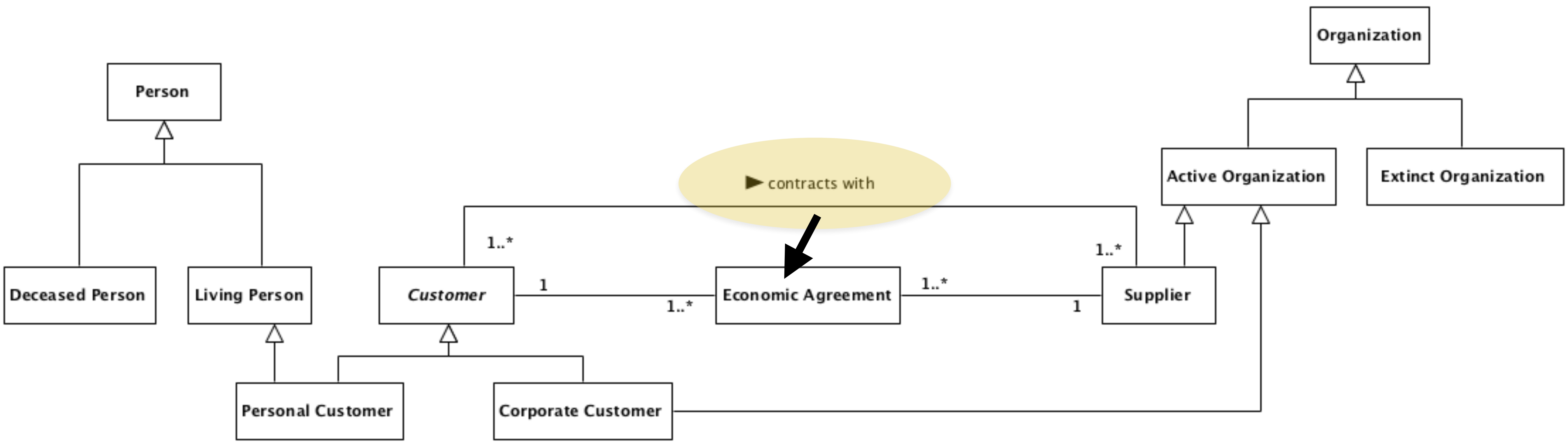

Organization
Person
Active Organization
Extinct Organization
▶ contracts with
1..*
1..*
Deceased Person
Living Person
Customer
1
1..*
Economic Agreement
1..*
1
Supplier
Personal Customer
Corporate Customer


Person
Deceased Person
Living Person
Customer
Personal Customer
Corporate Customer
contracts with
1..*
1
1..*
Economic Agreement
1..*
1..*
1
Supplier
Organization
Active Organization
Extinct Organization



Person
Organization
Deceased Person
Living Person
Customer
Economic Agreement
Supplier
Active Organization
Extinct Organization
Personal Customer
Corporate Customer
contracts with
1..*
1..*
1
1..*
1..*
1


Person
Deceased Person
Living Person
Customer
Personal Customer
Corporate Customer
contracts with
1..*
1
1..*
Economic Agreement
1..*
1
1..*
Supplier
Organization
Active Organization
Extinct Organization



Person
Organization
Deceased Person
Living Person
Customer
Economic Agreement
Supplier
Active Organization
Extinct Organization
Personal Customer
Corporate Customer
contracts with
1..*
1..*
1
1..*
1..*
1

Why is this **important**?

Conceptual Model

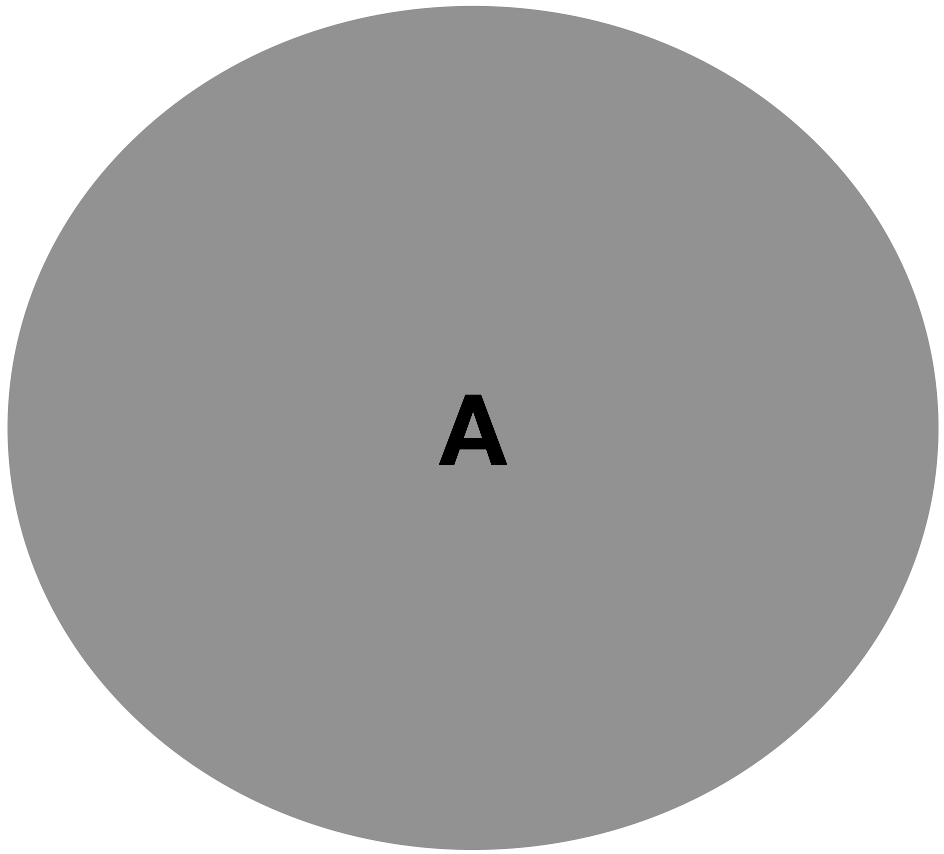
$\approx$

Meaning Contract

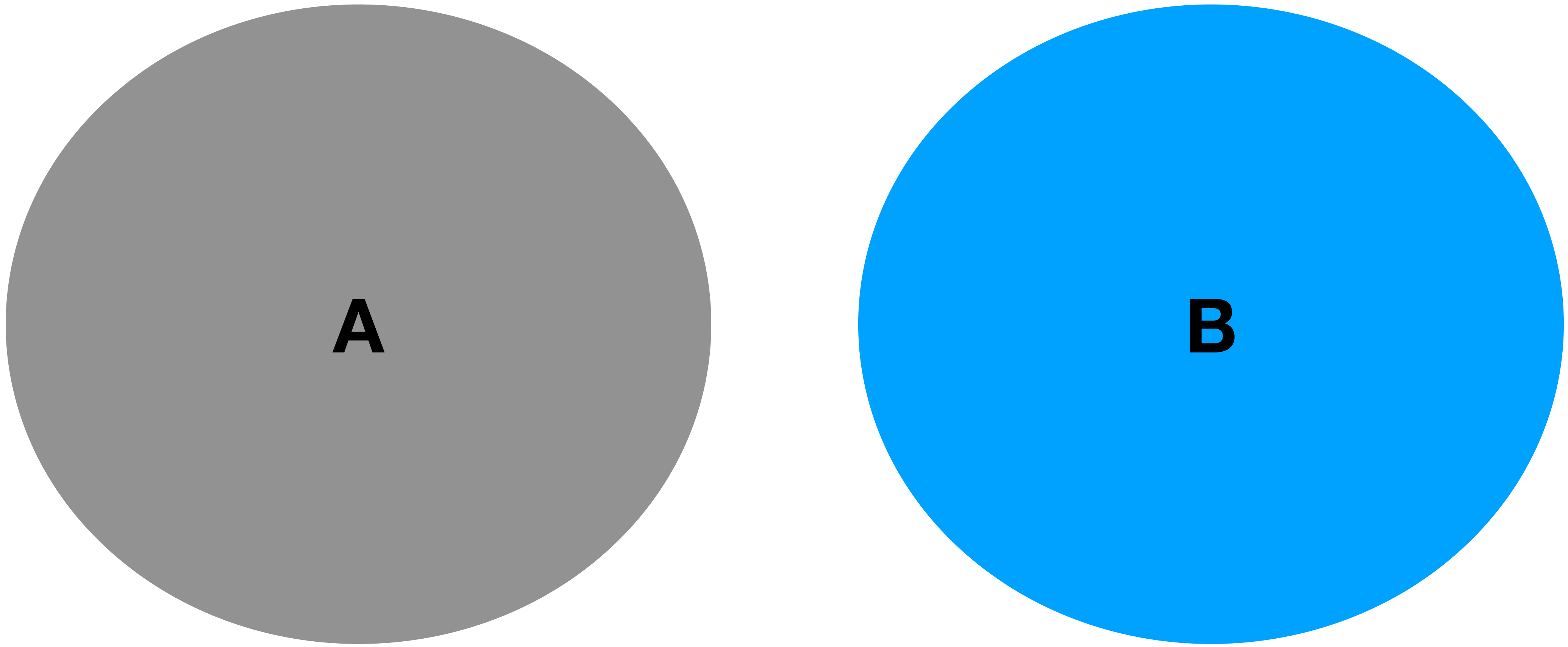
representing a worldview

Verification = “Did we build the model right?”

Validation = “Did we build the right model?”

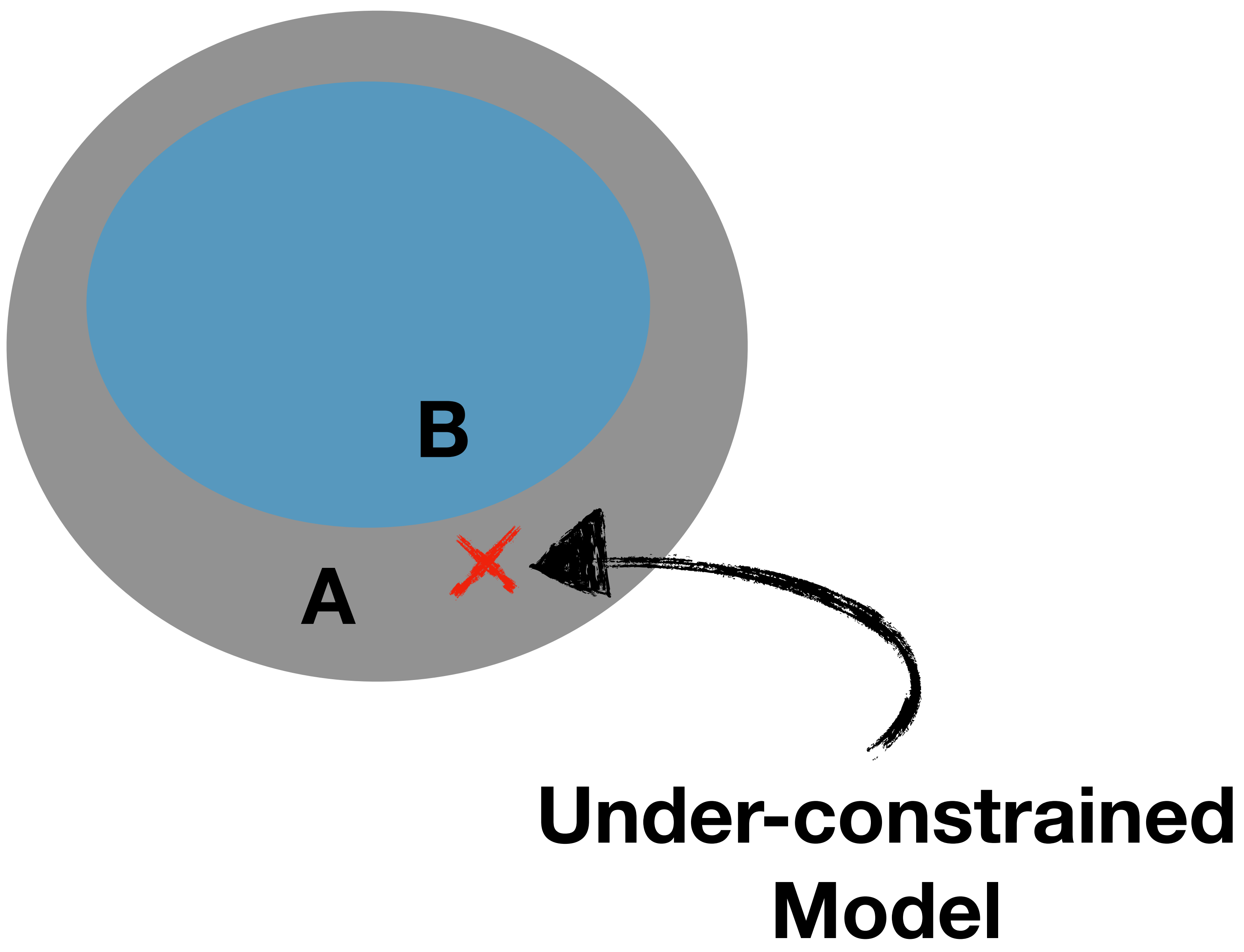


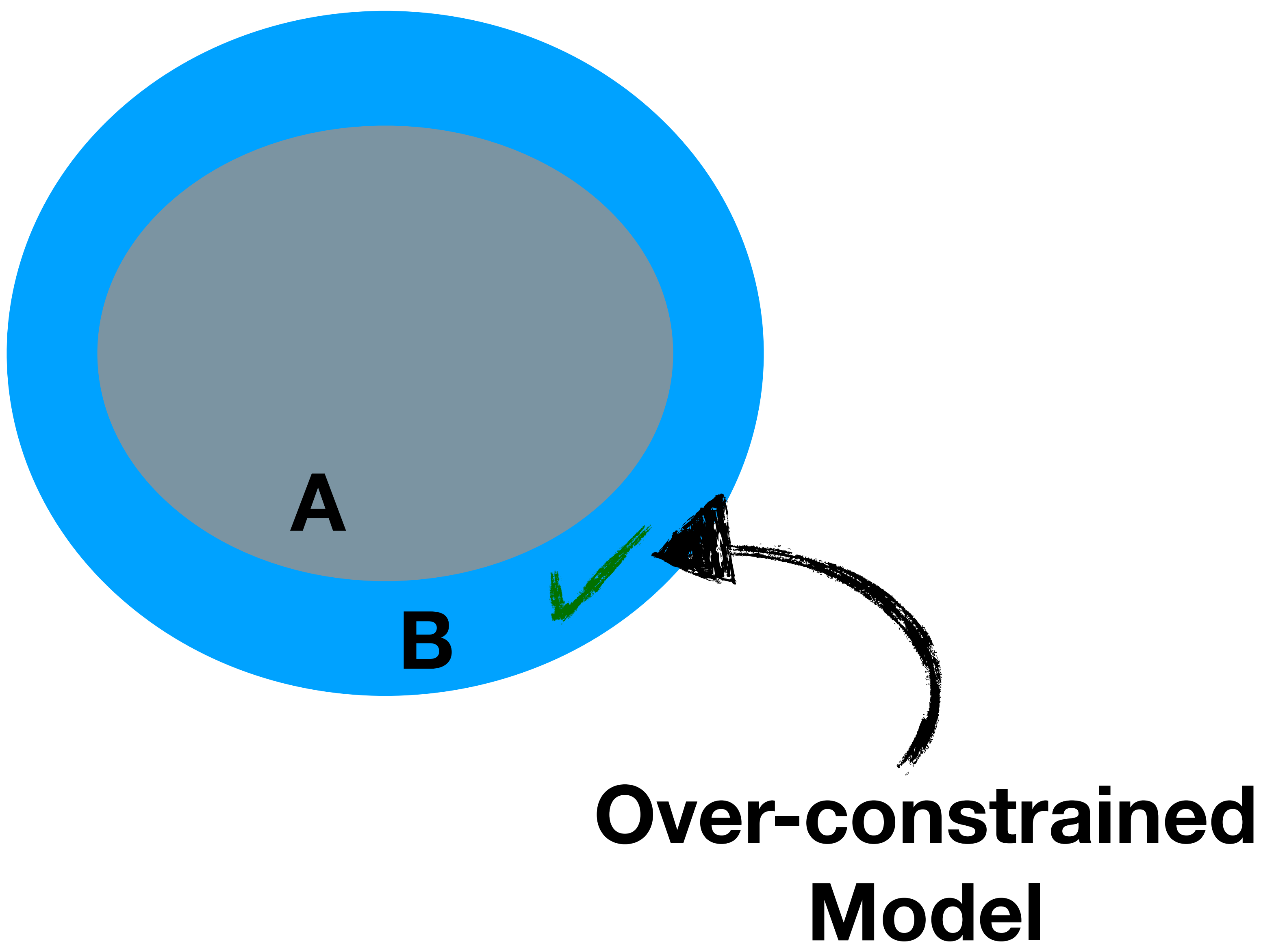
Possible Interpretations of a Model

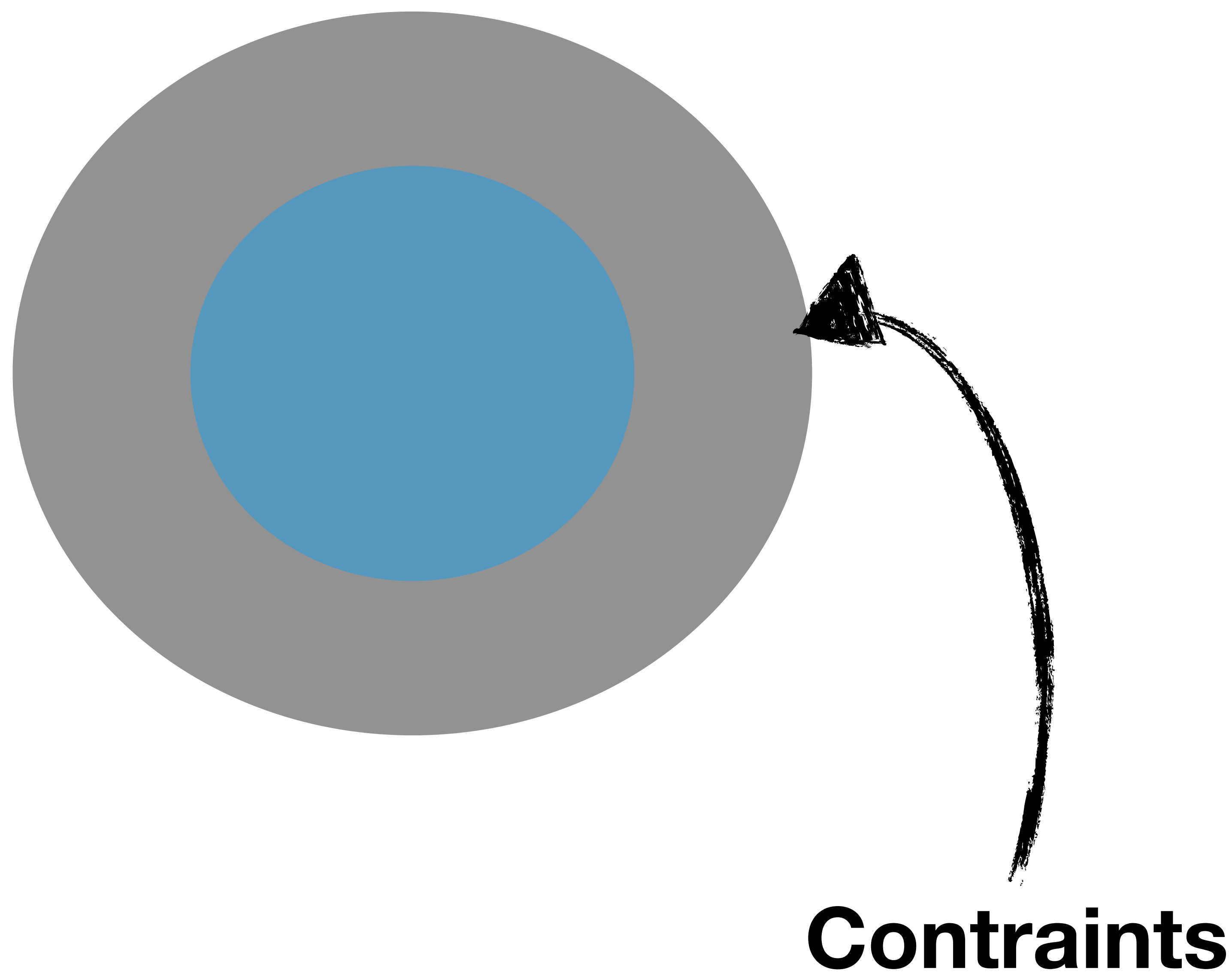


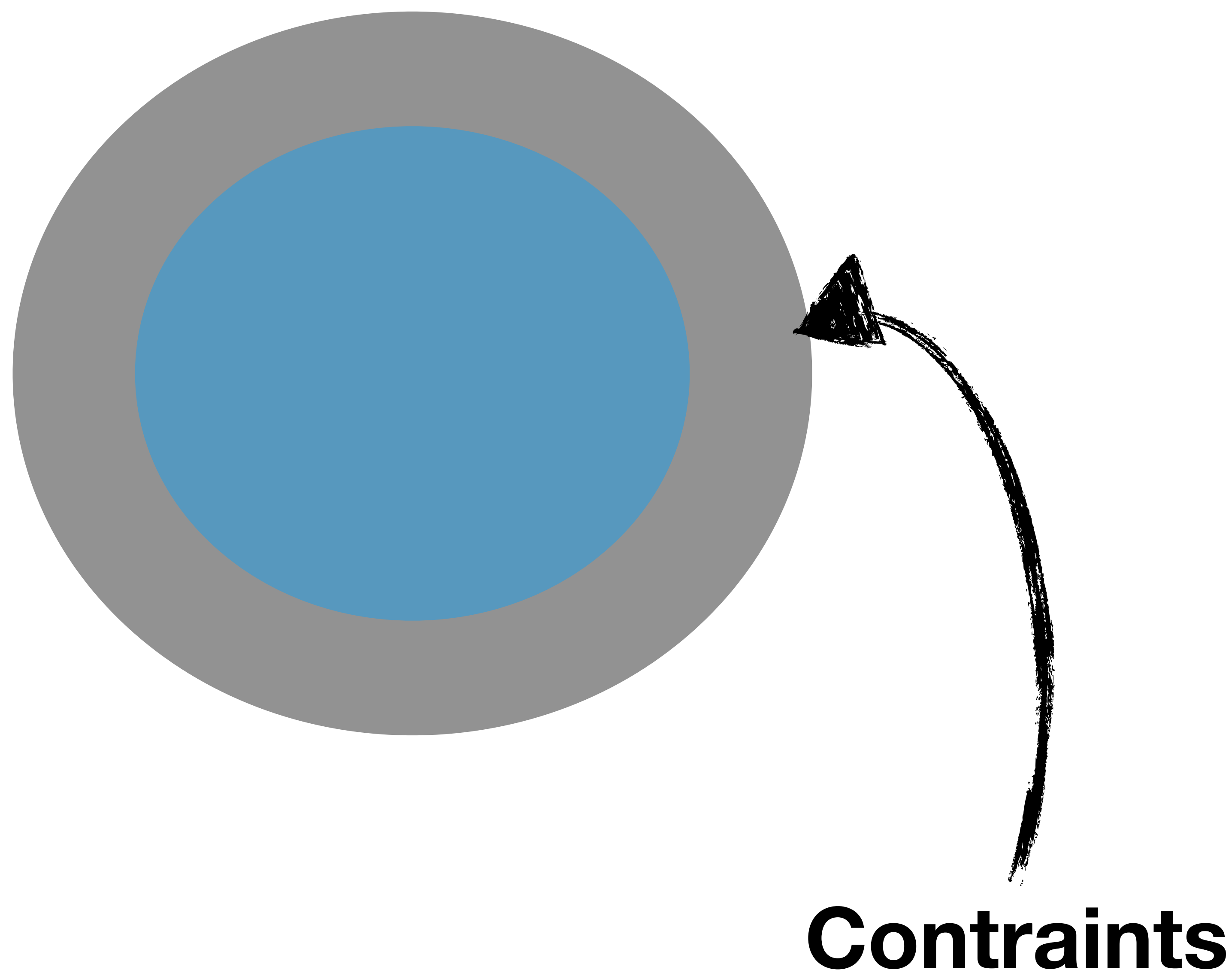
Possible Interpretations of a Model

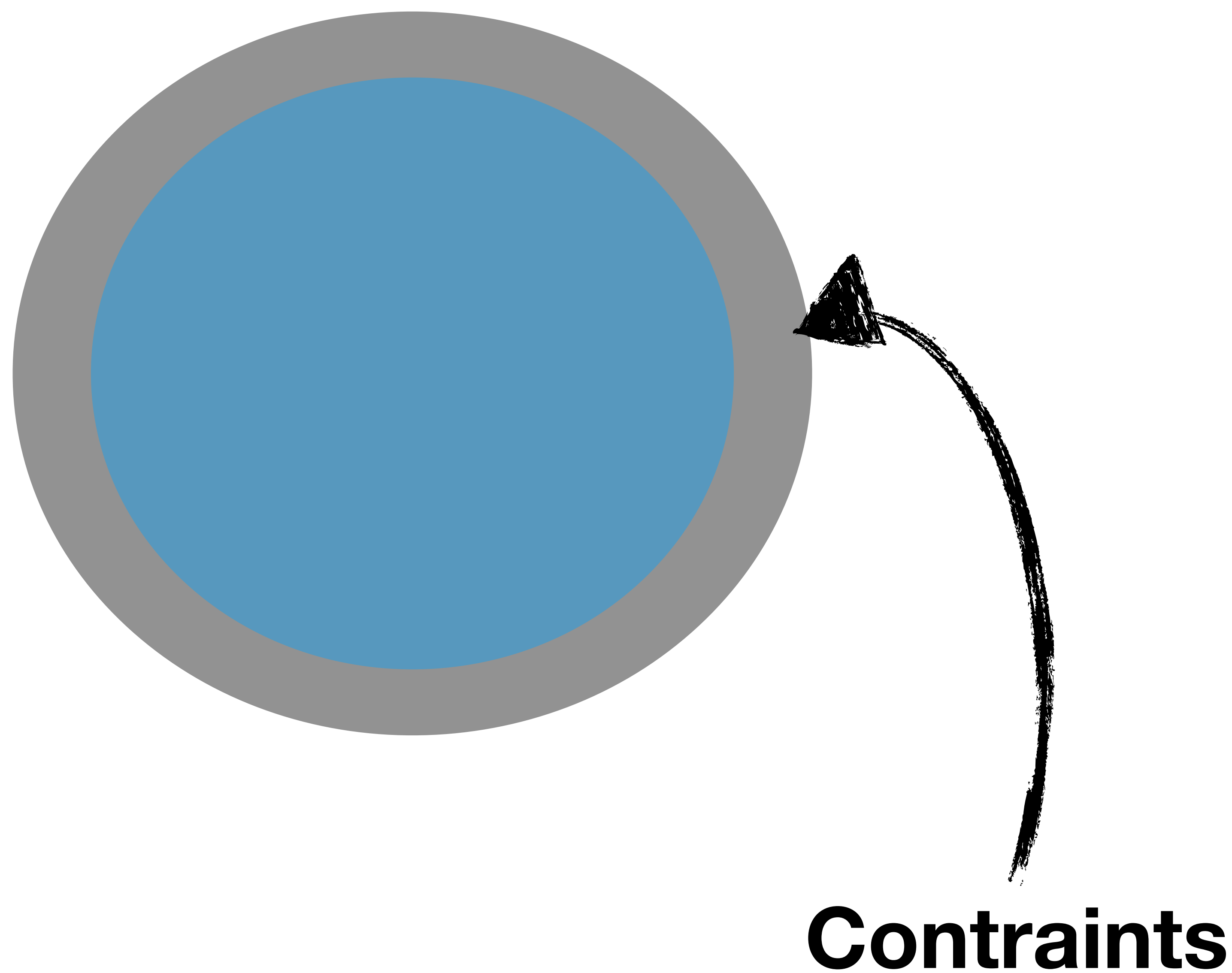
Intended Interpretations of that Model

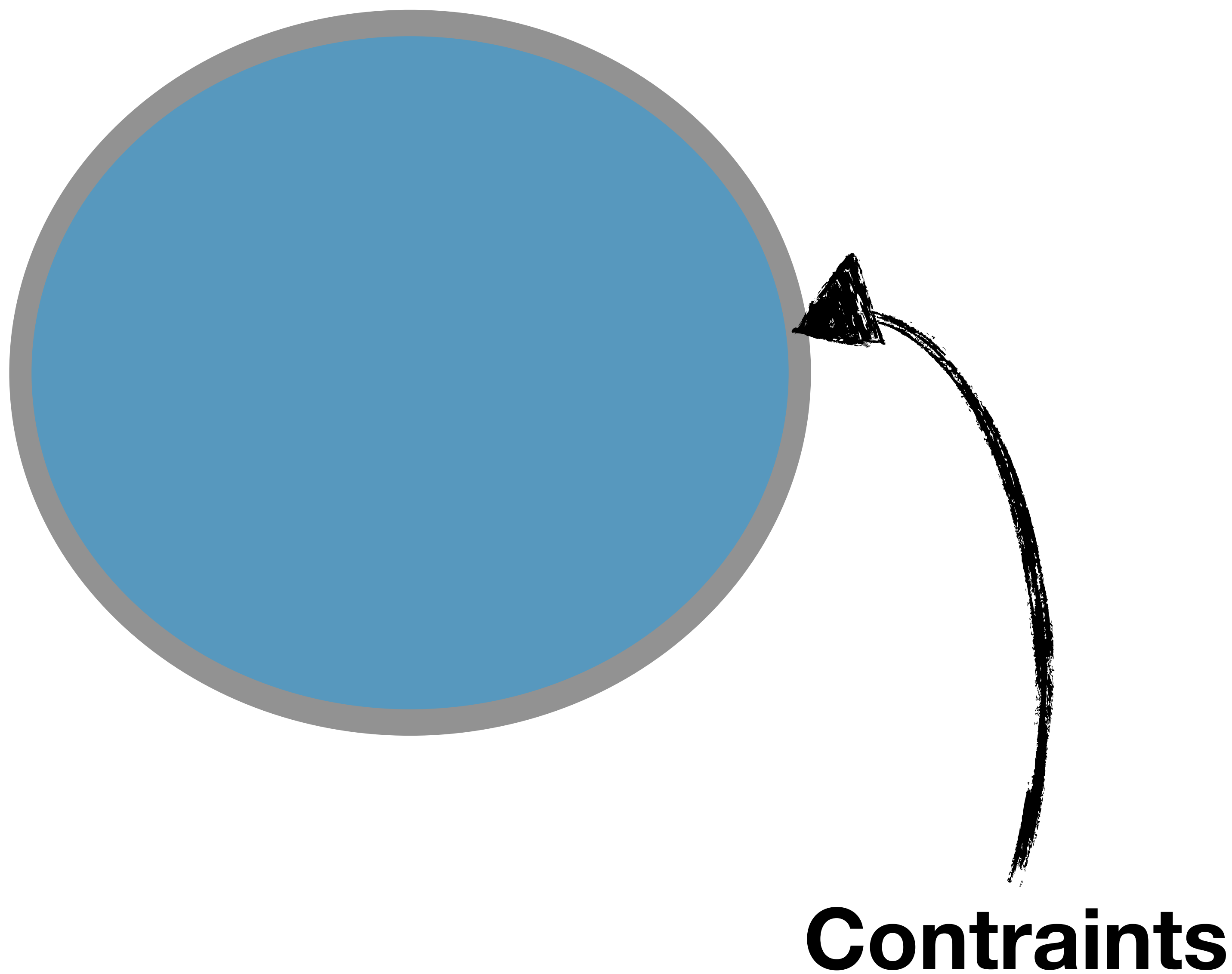

B
A
Under-constrained
Model

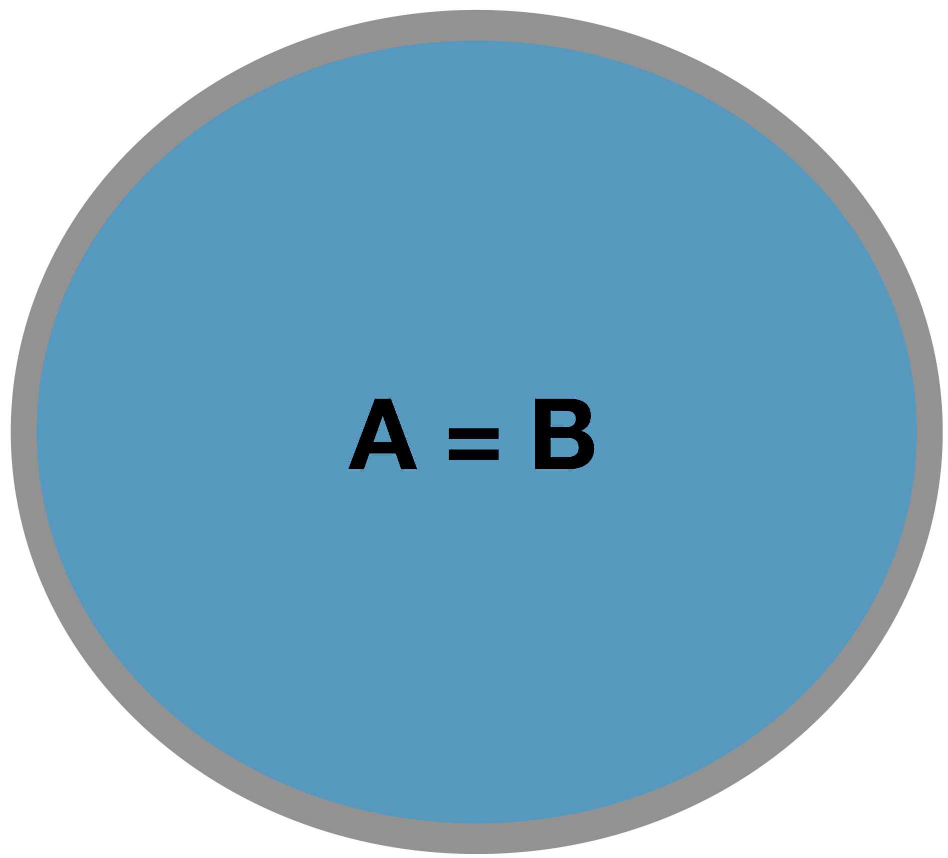

A
B
Over-constrained
Model

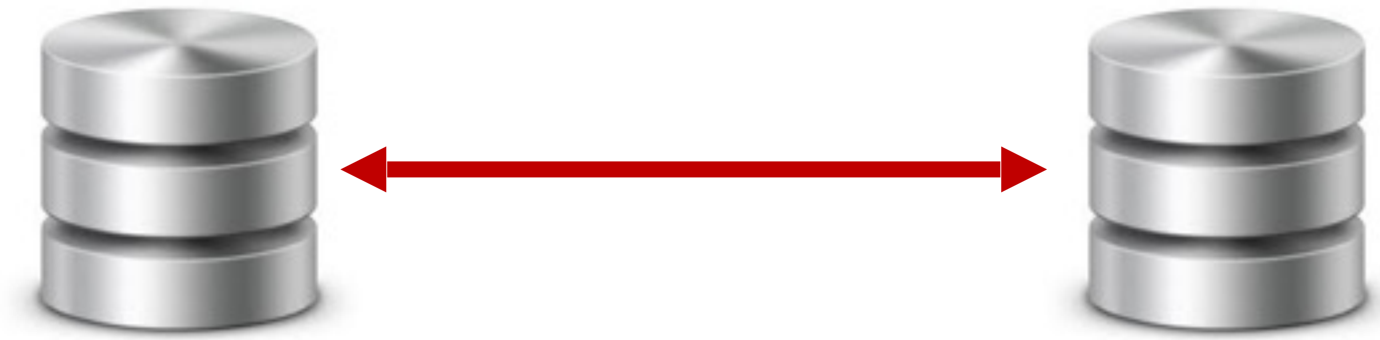

Contraints

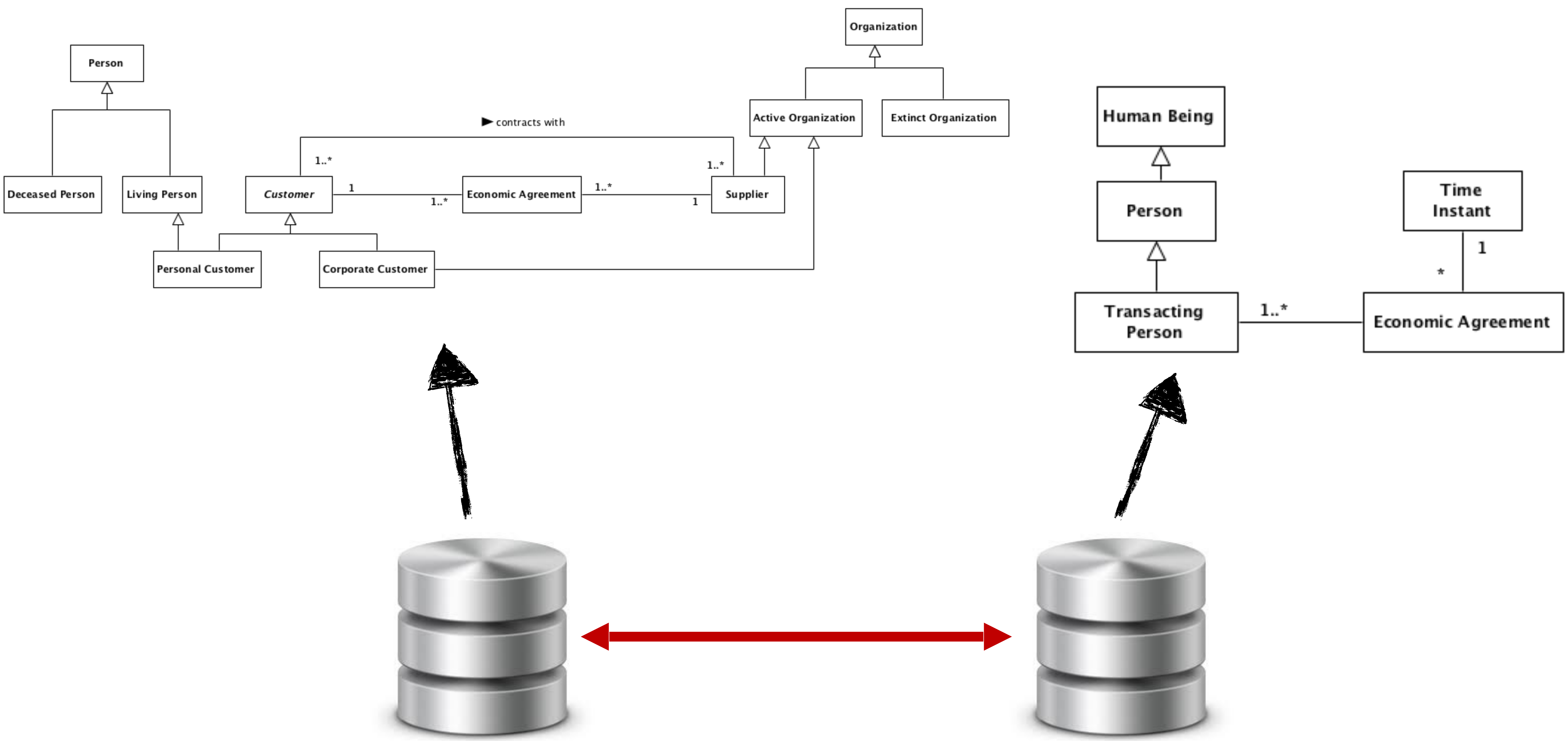

Contraints

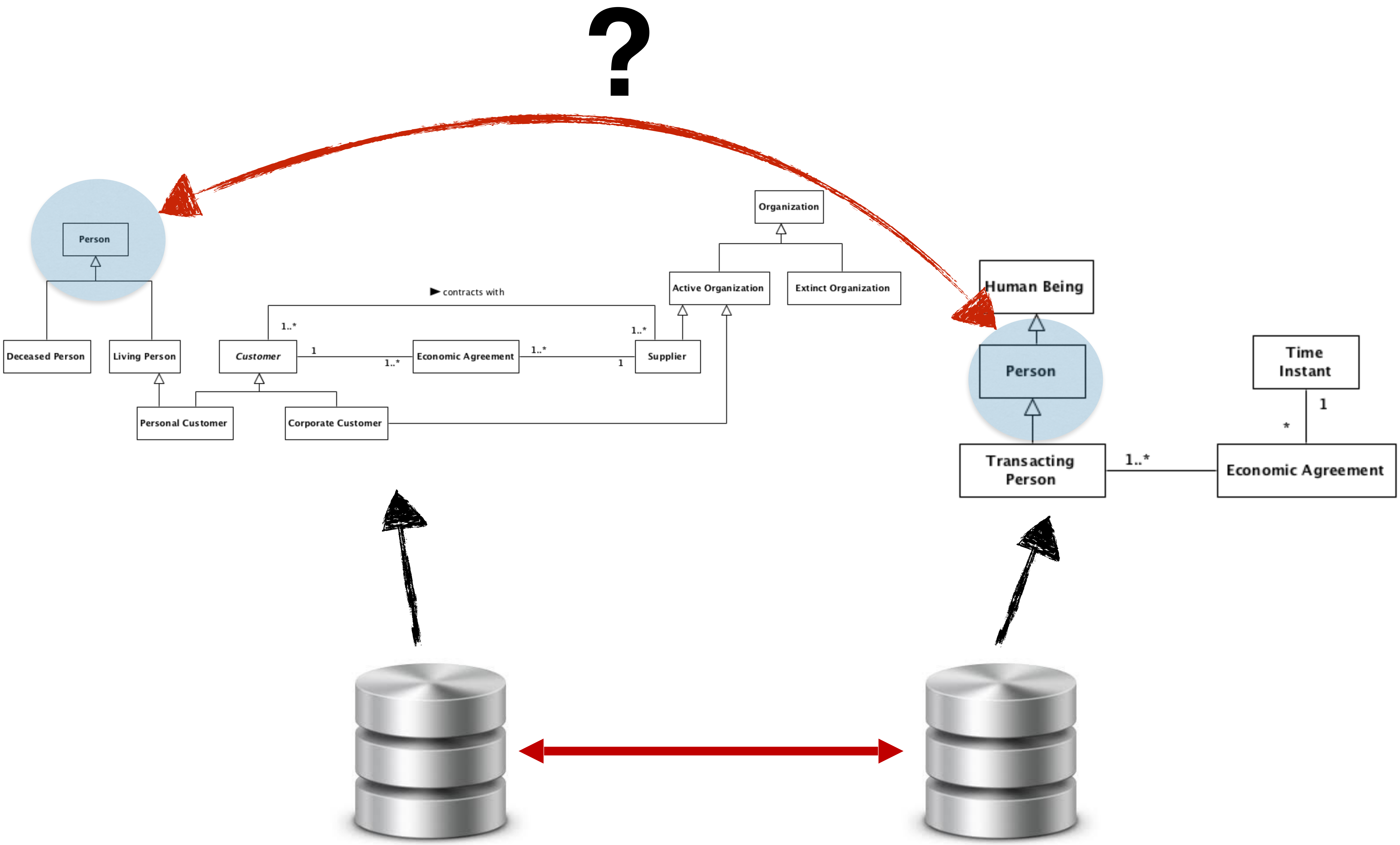

Contraints

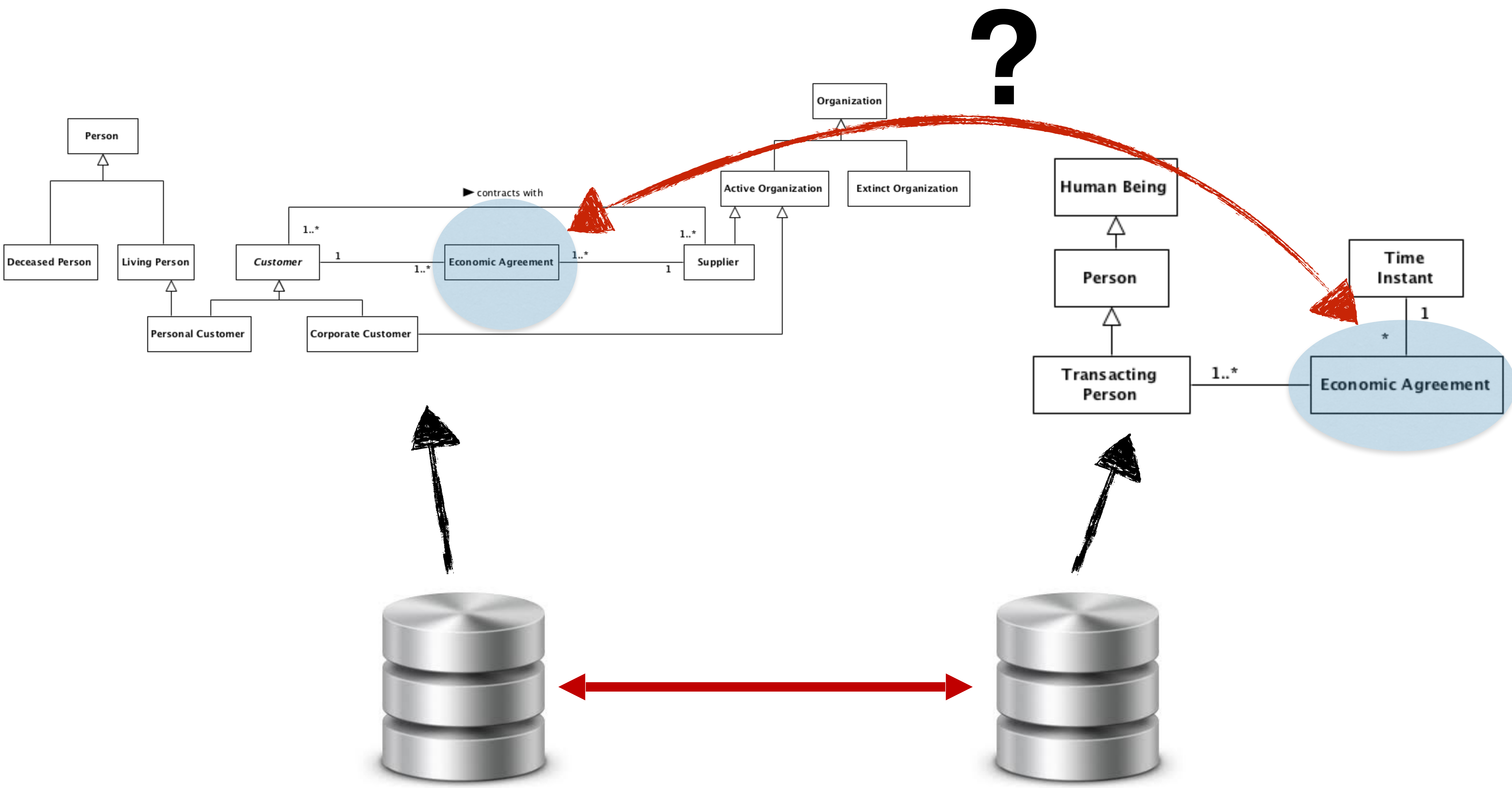

Contraints


A = B




Person
Deceased Person
Living Person
Personal Customer
Customer
Corporate Customer
contracts with
1..*
1
1..*
Economic Agreement
1..*
1
1..*
Supplier
Organization
Active Organization
Extinct Organization
Human Being
Person
Transacting Person
1..*
Economic Agreement
Time Instant
1
*


?
Person
Deceased Person
Living Person
Personal Customer
Corporate Customer
Customer
contracts with
Economic Agreement
Supplier
1..*
1
Organization
Active Organization
Extinct Organization
Human Being
Person
Transacting Person
Time Instant
Economic Agreement
1
*


?
Person
Deceased Person
Living Person
Customer
Personal Customer
Corporate Customer
contracts with
Economic Agreement
Organization
Active Organization
Extinct Organization
Supplier
1..*
1
1..*
1..*
1
1..*
Human Being
Person
Transacting Person
Time Instant
Economic Agreement
1..*
1
*

Ontology ≈

An area devoted to developing these domain-independent “toolboxes” with “tools”for supporting ontological analysis

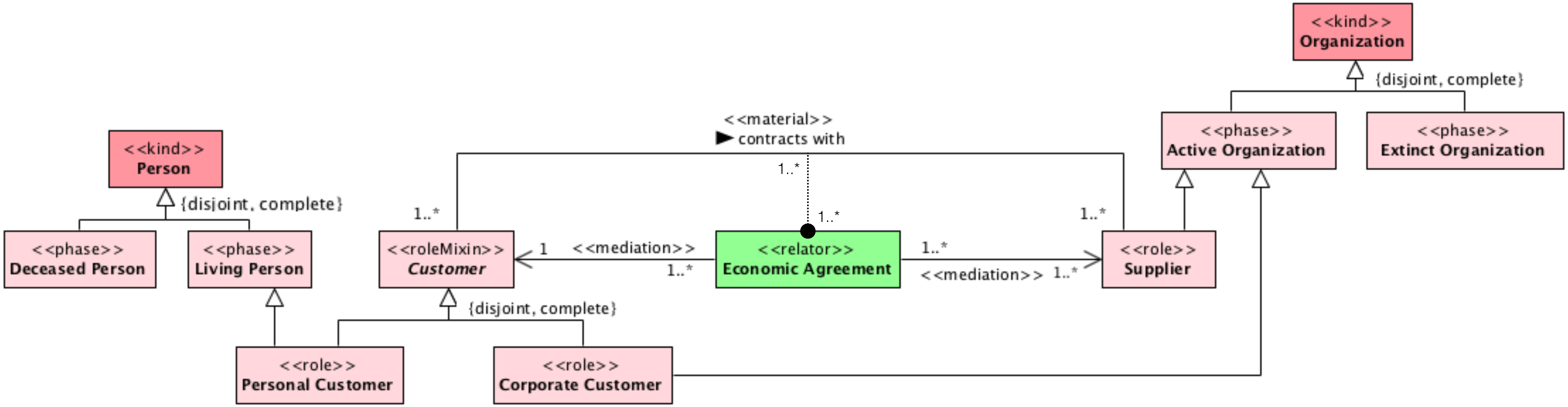
Ontology-Driven Conceptual Model

$\approx$

A model representing the result of an ontological analysis over a given domain

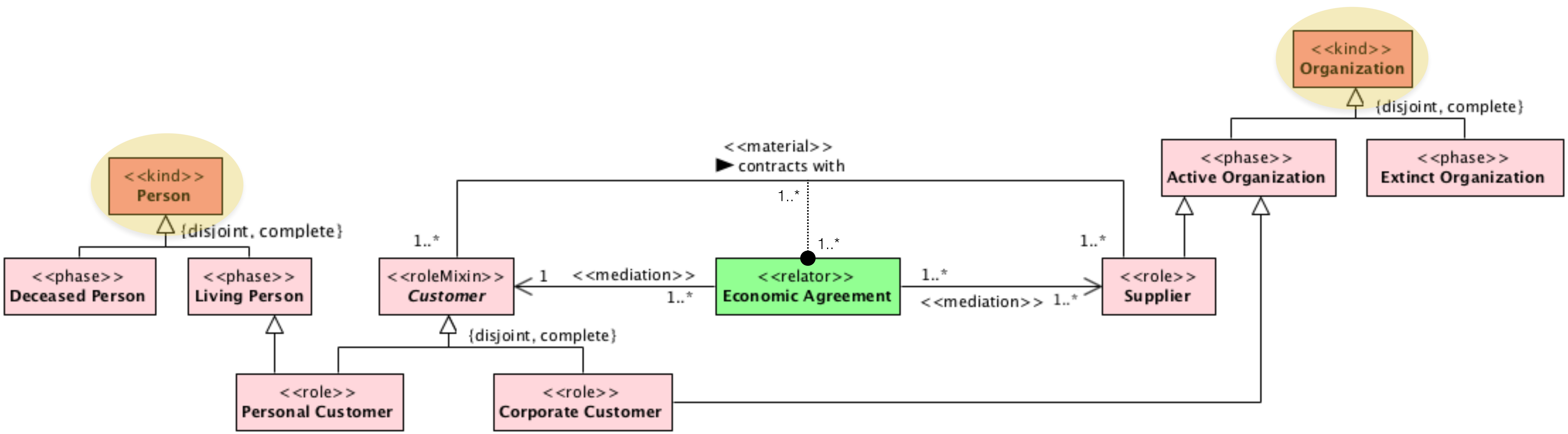
Unified Foundational Ontology

Object Types, Identity and Taxonomic Structures, Part-Whole Relations, Intrinsic and Relational Properties, Weak Entities, Attributes and Datatypes, Events, Multi-Level Modeling,…

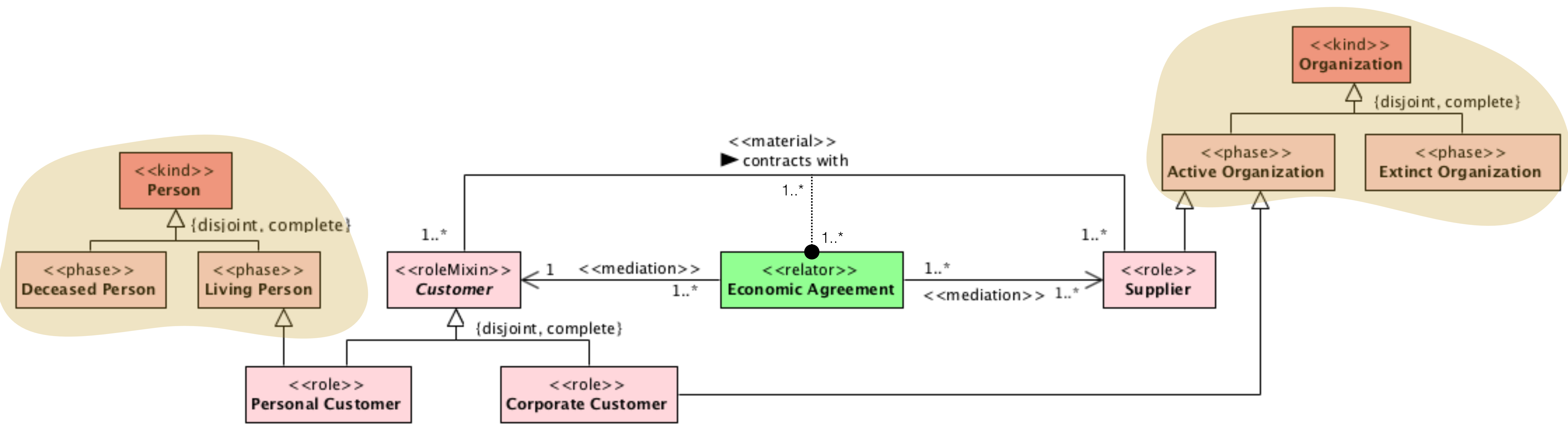


<<kind>>
Person
{disjoint, complete}
<<phase>>
Deceased Person
<<phase>>
Living Person
<<role>>
Personal Customer
<<roleMixin>>
Customer
{disjoint, complete}
<<role>>
Corporate Customer
<<material>>
contracts with
1..*
1..*
1..*
1..*
1
<<mediation>>
1..*
<<relator>>
Economic Agreement
1..*
<<mediation>>
1..*
<<role>>
Supplier
<<kind>>
Organization
{disjoint, complete}
<<phase>>
Active Organization
<<phase>>
Extinct Organization

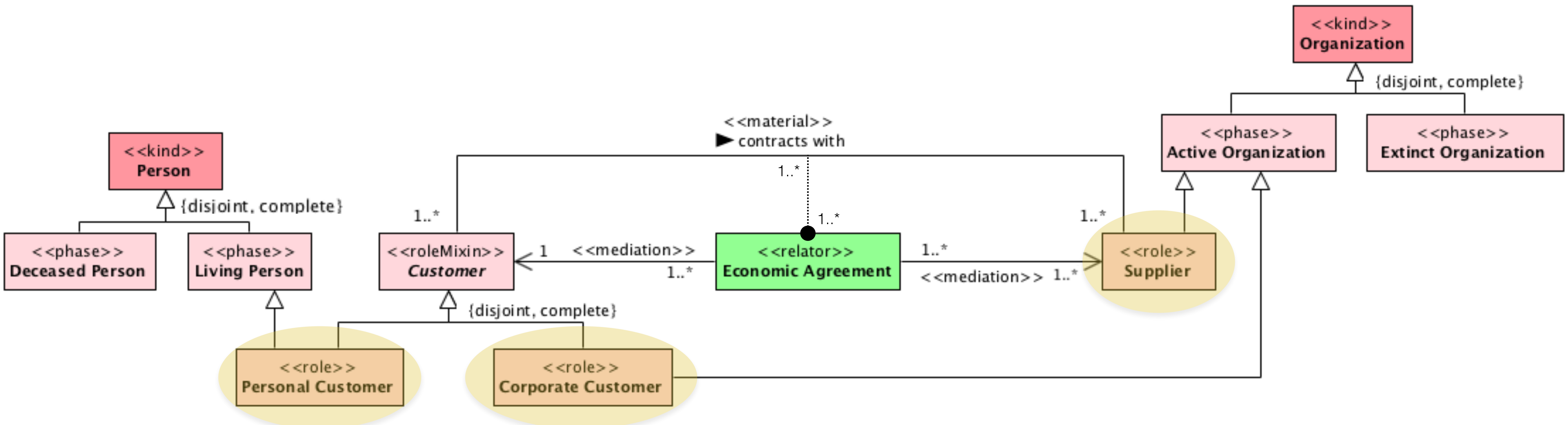
ONTOUML

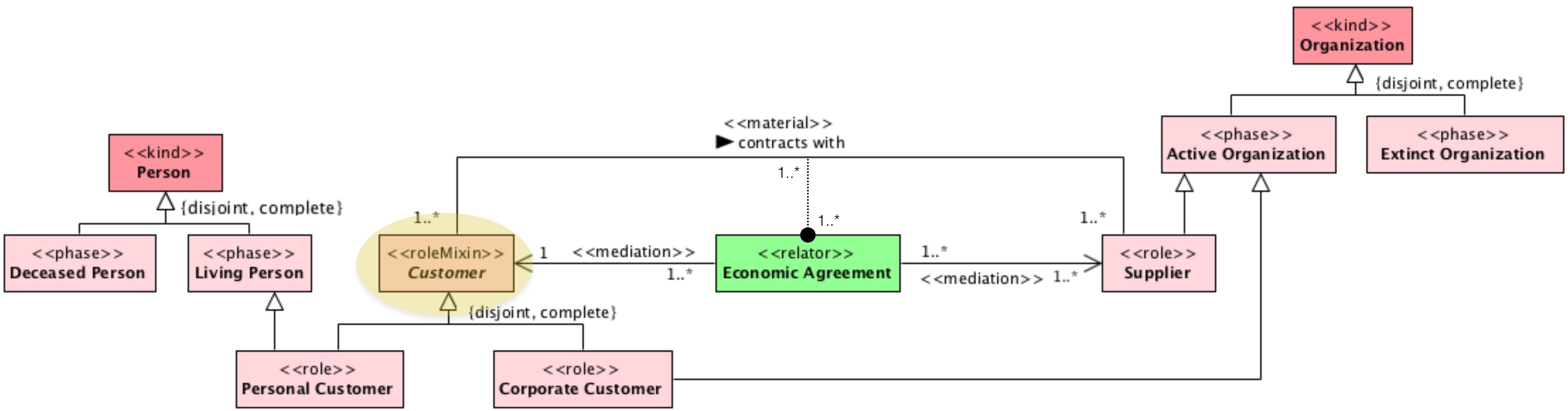


<<kind>>
Person
{disjoint, complete}
<<phase>>
Deceased Person
<<phase>>
Living Person
<<role>>
Personal Customer
<<roleMixin>>
Customer
{disjoint, complete}
<<role>>
Corporate Customer
<<material>>
contracts with
1..*
1..*
1..*
1..*
1
<<mediation>>
1..*
<<relator>>
Economic Agreement
1..*
<<mediation>>
1..*
<<role>>
Supplier
<<kind>>
Organization
{disjoint, complete}
<<phase>>
Active Organization
<<phase>>
Extinct Organization



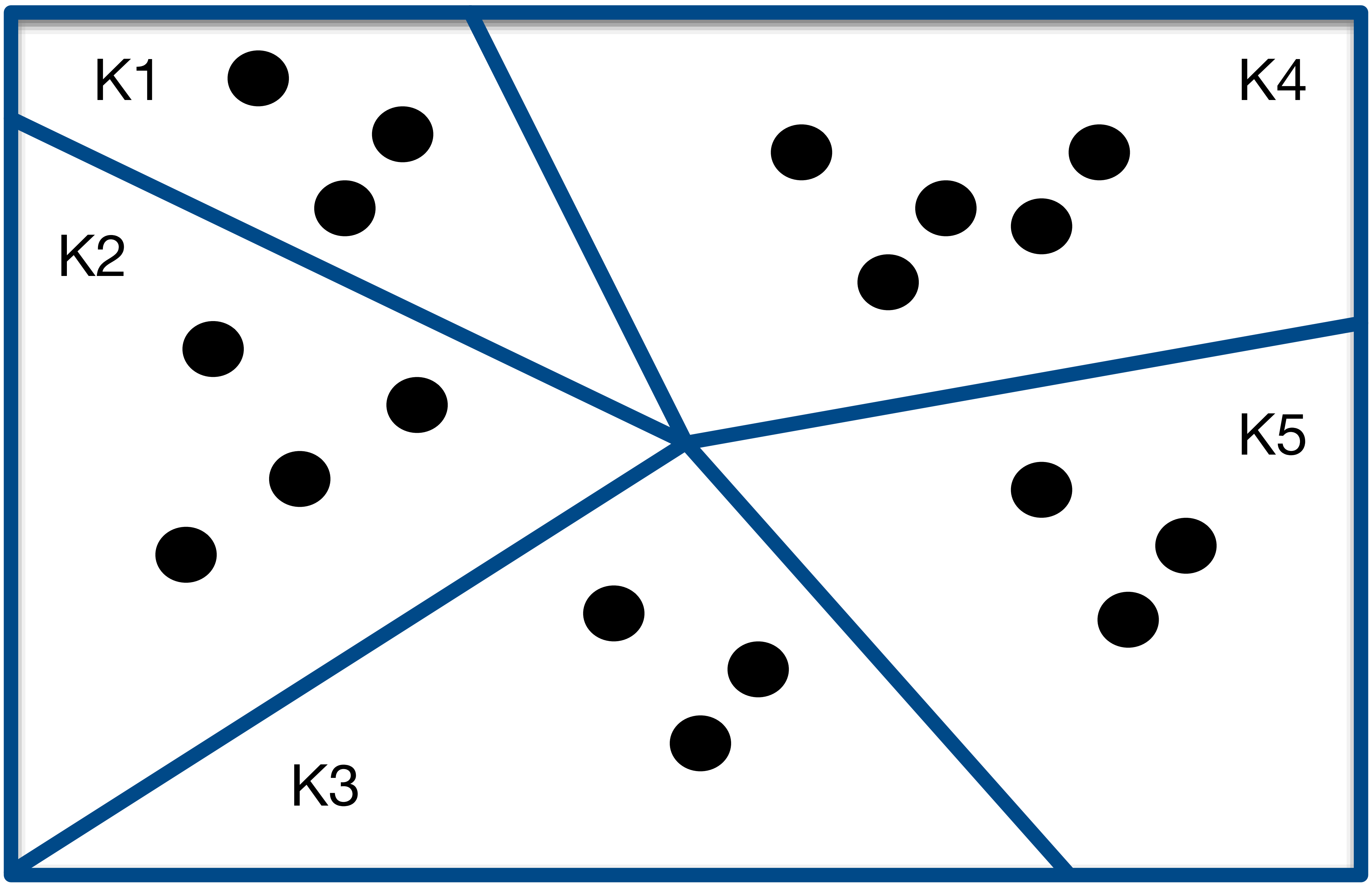
<<kind>>
Person
{disjoint, complete}
<<phase>>
Deceased Person
<<phase>>
Living Person
<<role>>
Personal Customer
<<roleMixin>>
Customer
{disjoint, complete}
<<role>>
Corporate Customer
<<material>>
contracts with
1..*
1..*
1..*
1..*
1
<<mediation>>
1..*
<<relator>>
Economic Agreement
1..*
<<mediation>>
1..*
<<role>>
Supplier
<<kind>>
Organization
{disjoint, complete}
<<phase>>
Active Organization
<<phase>>
Extinct Organization


<<kind>>
Organization
{disjoint, complete}
<<phase>>
Active Organization
<<phase>>
Extinct Organization
<<kind>>
Person
{disjoint, complete}
<<phase>>
Deceased Person
<<phase>>
Living Person
<<material>>
contracts with
1..*
1..*
1..*
1..*
<<roleMixin>>
Customer
1
<<mediation>>
1..*
<<relator>>
Economic Agreement
1..*
<<mediation>>
1..*
<<role>>
Supplier
{disjoint, complete}
<<role>>
Personal Customer
<<role>>
Corporate Customer

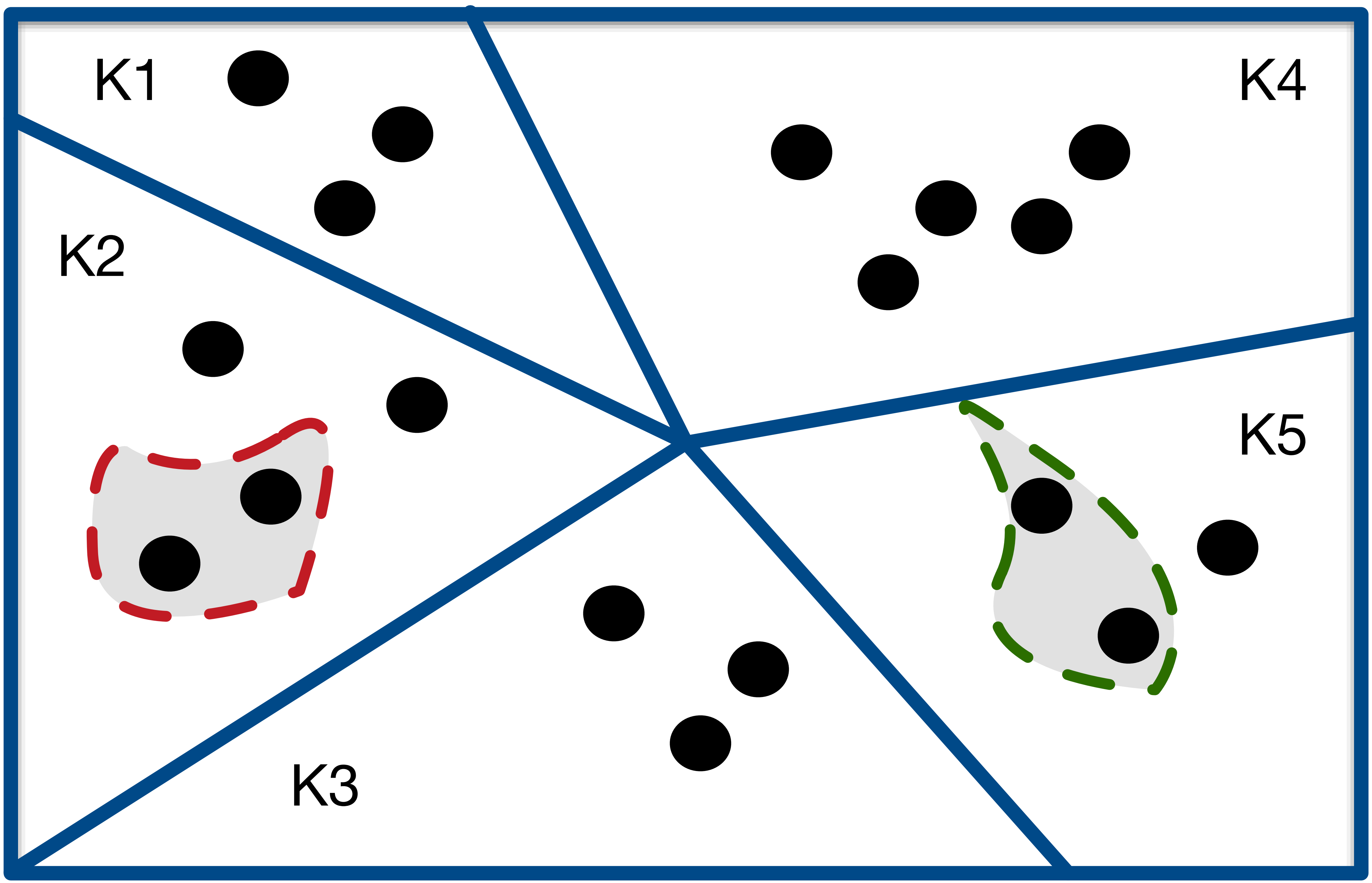


<<kind>>
Person
{disjoint, complete}
<<phase>>
Deceased Person
<<phase>>
Living Person
<<roleMixin>>
Customer
{disjoint, complete}
<<role>>
Personal Customer
<<role>>
Corporate Customer
<<material>>
contracts with
1..*
1..*
1..*
1..*
1
<<mediation>>
1..*
<<relator>>
Economic Agreement
1..*
<<mediation>>
1..*
<<role>>
Supplier
<<kind>>
Organization
{disjoint, complete}
<<phase>>
Active Organization
<<phase>>
Extinct Organization

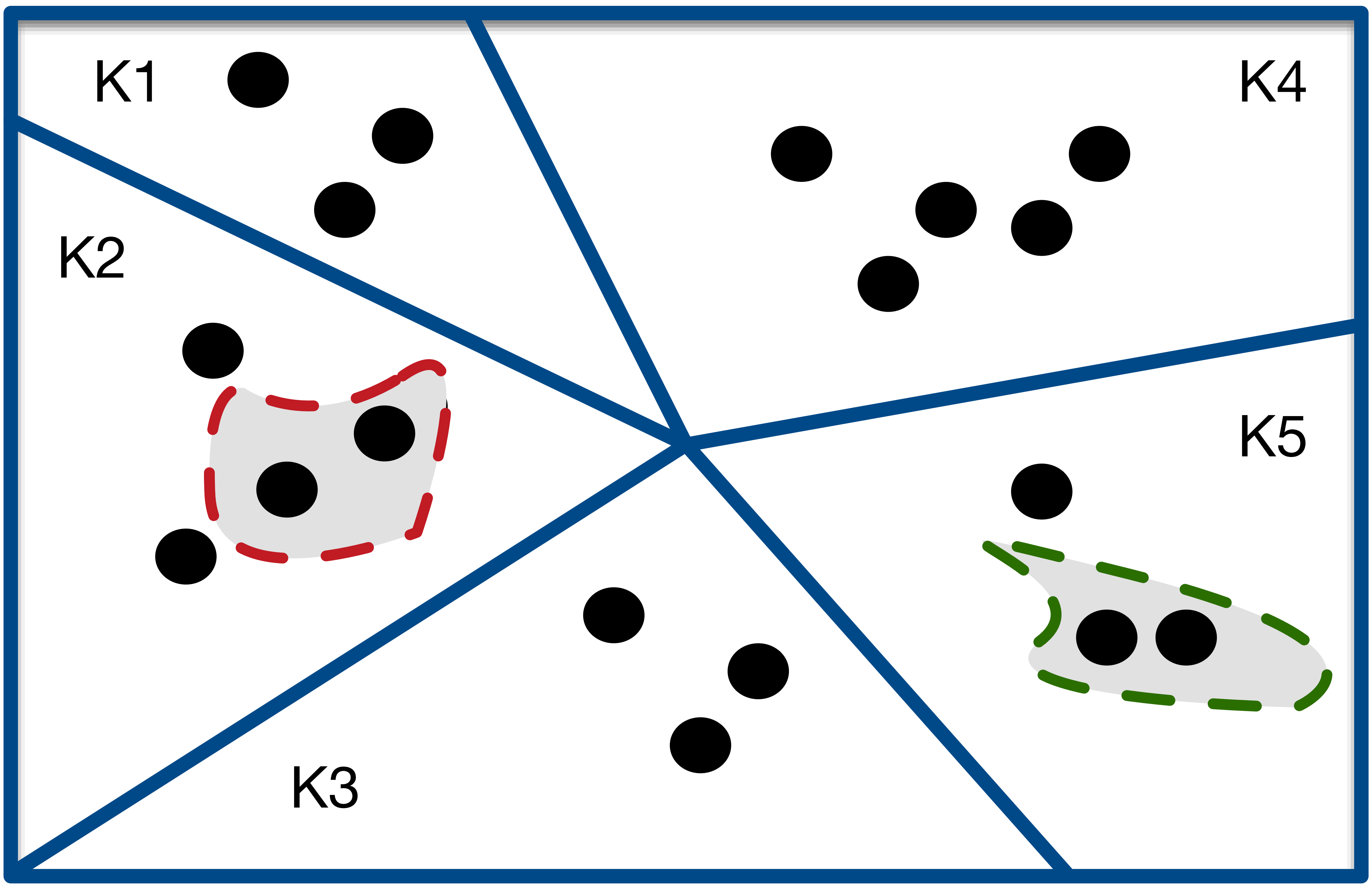
Kinds



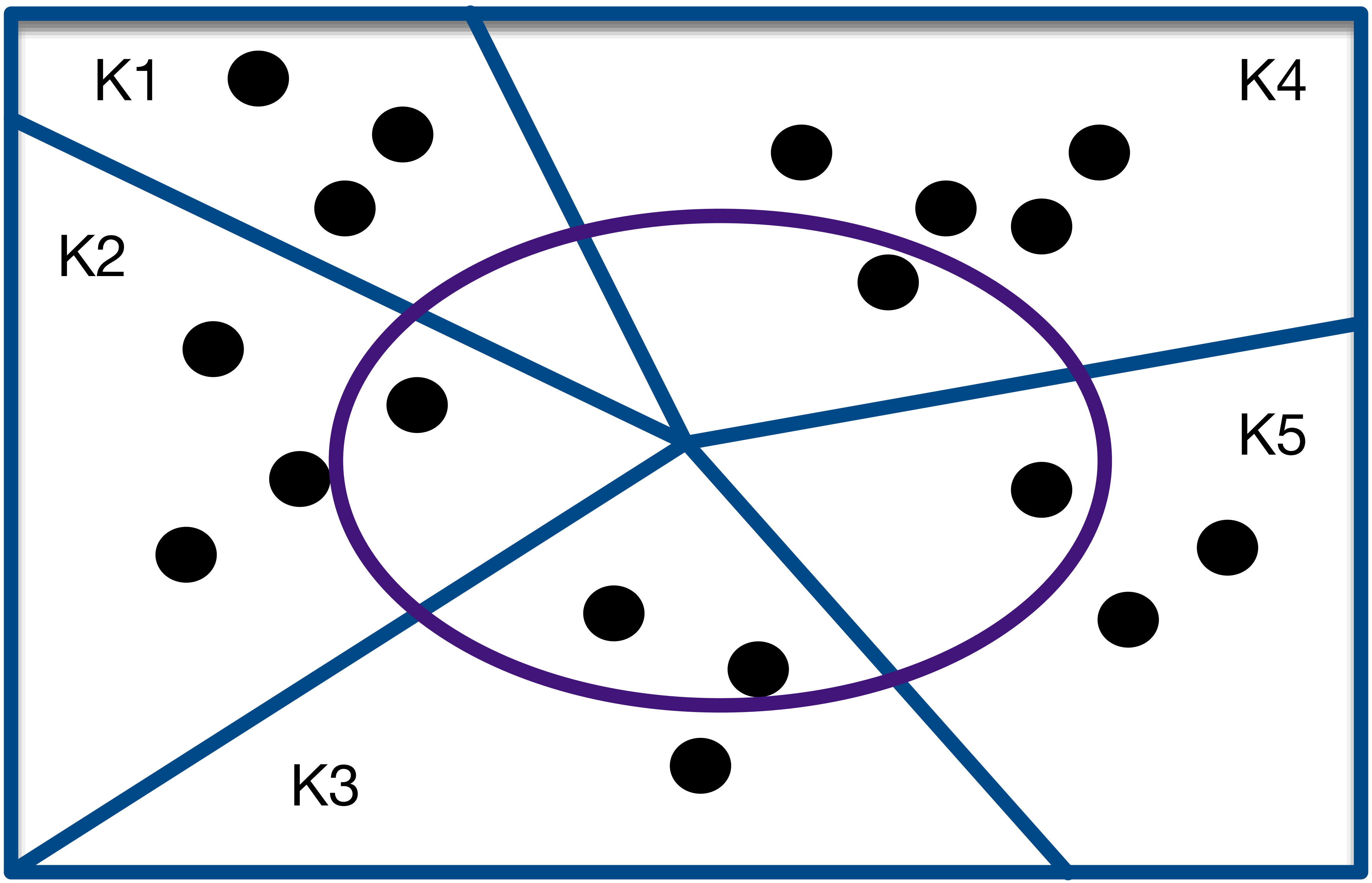
Roles and **Phases**



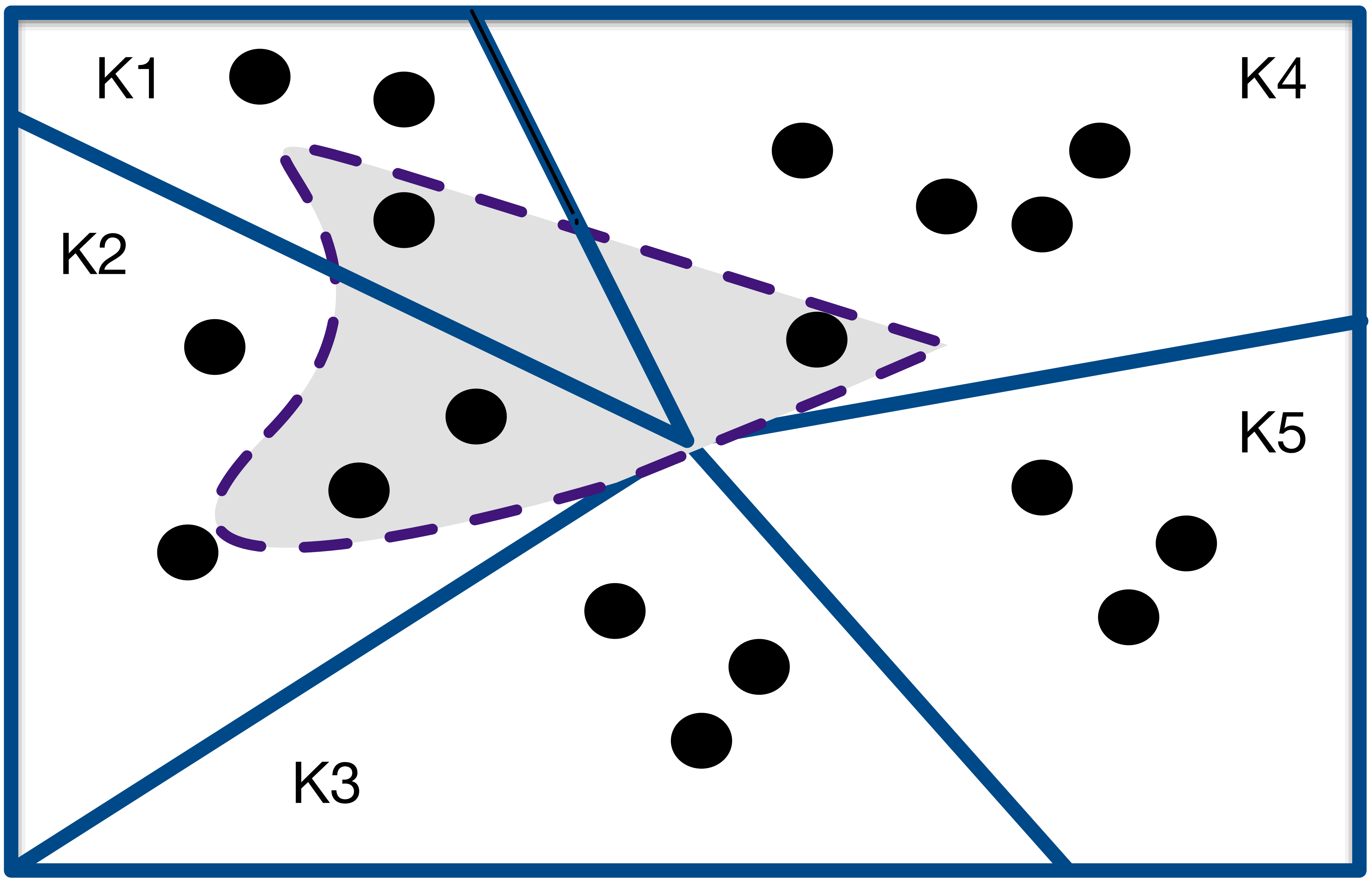
Roles and **Phases**



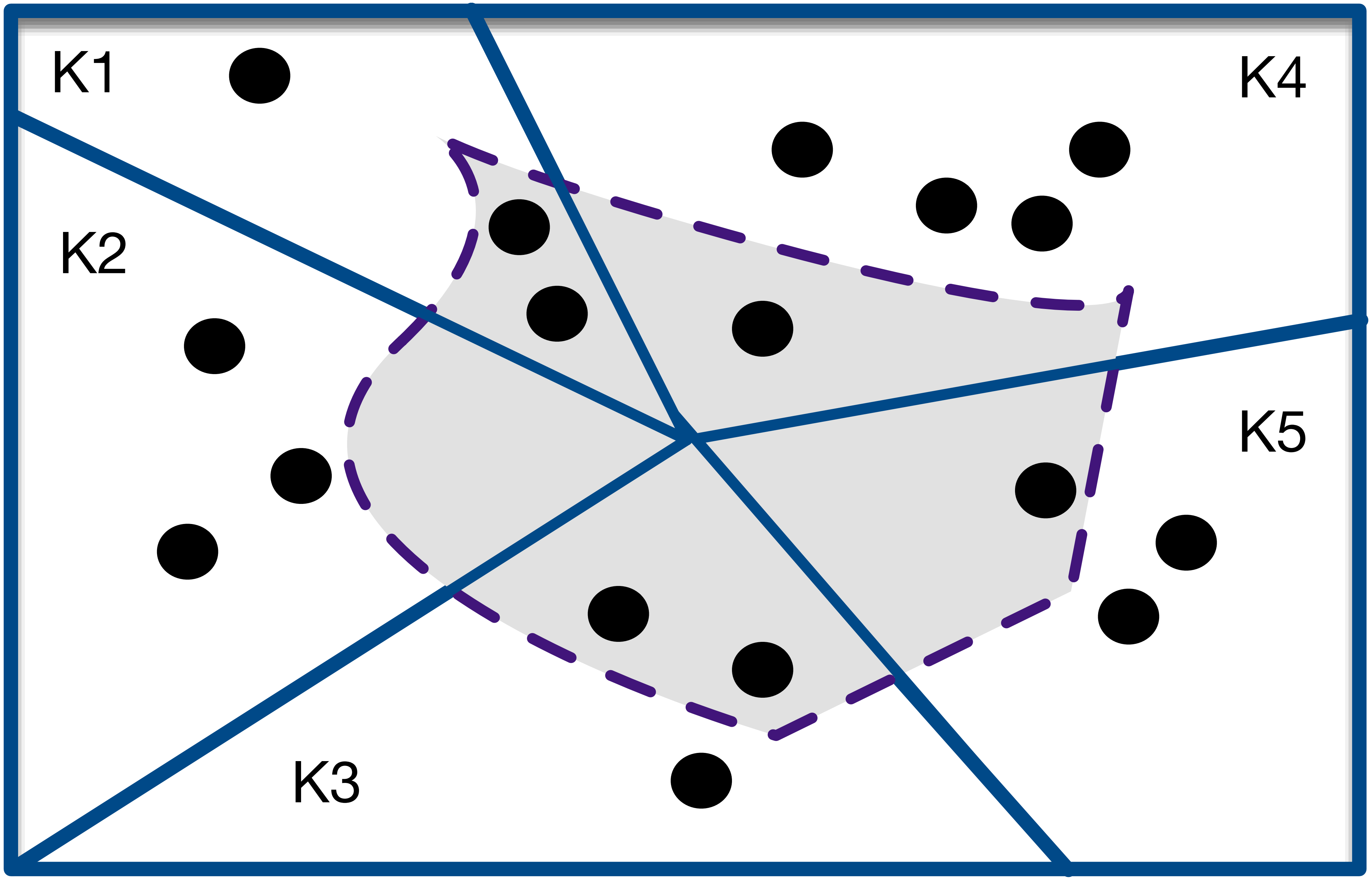
Rigid MIXINS

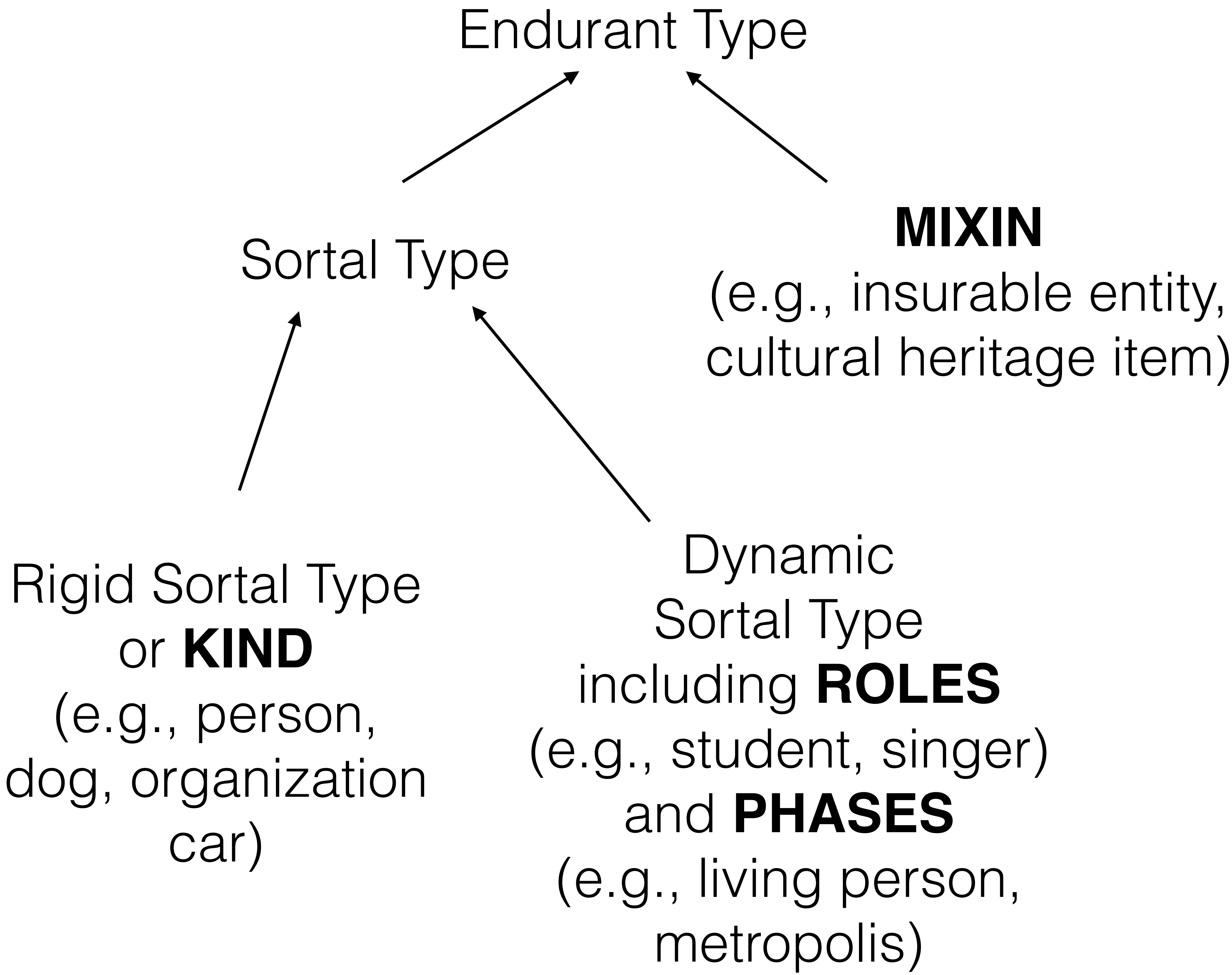


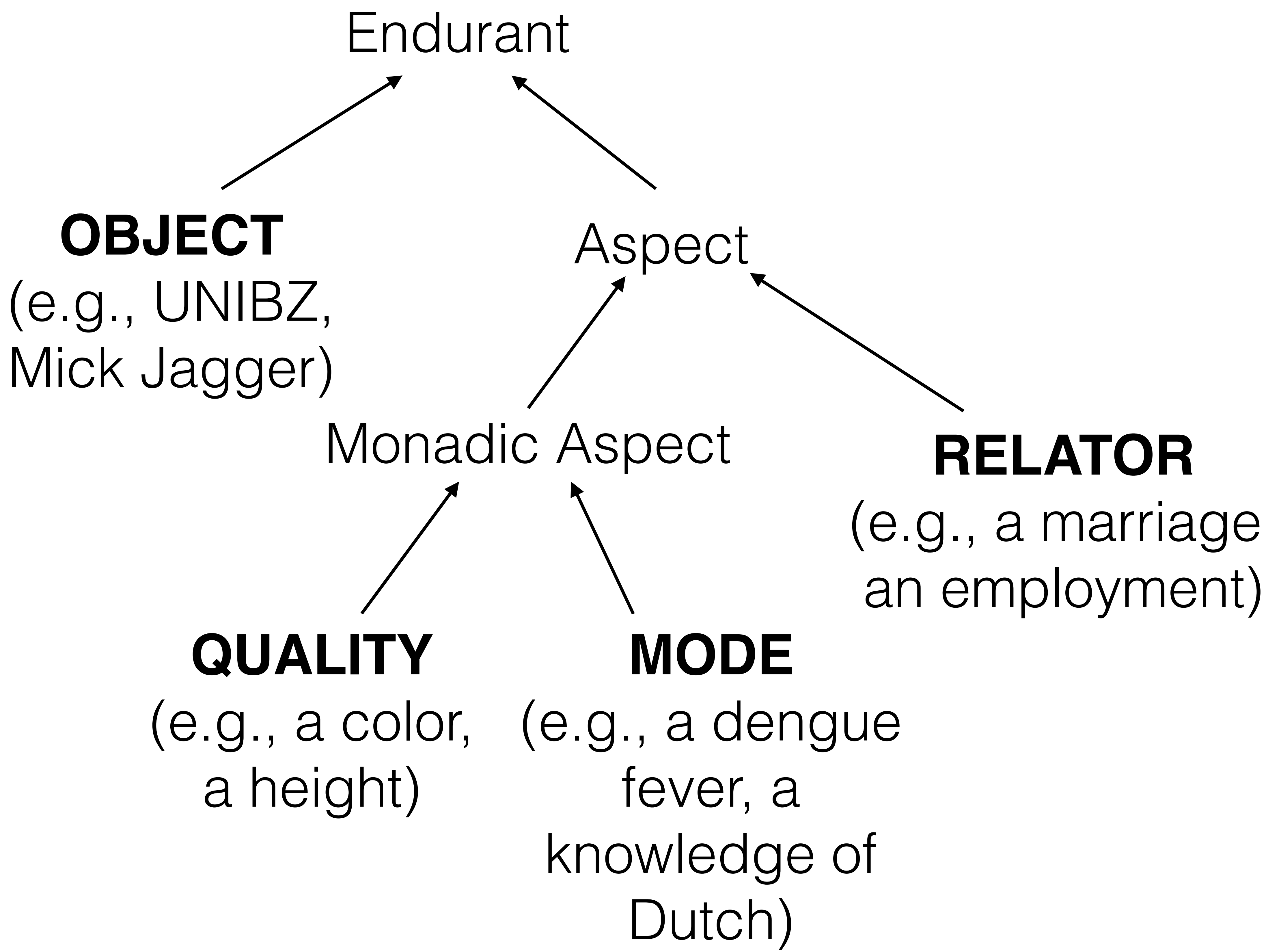
Dynamic MIXINS

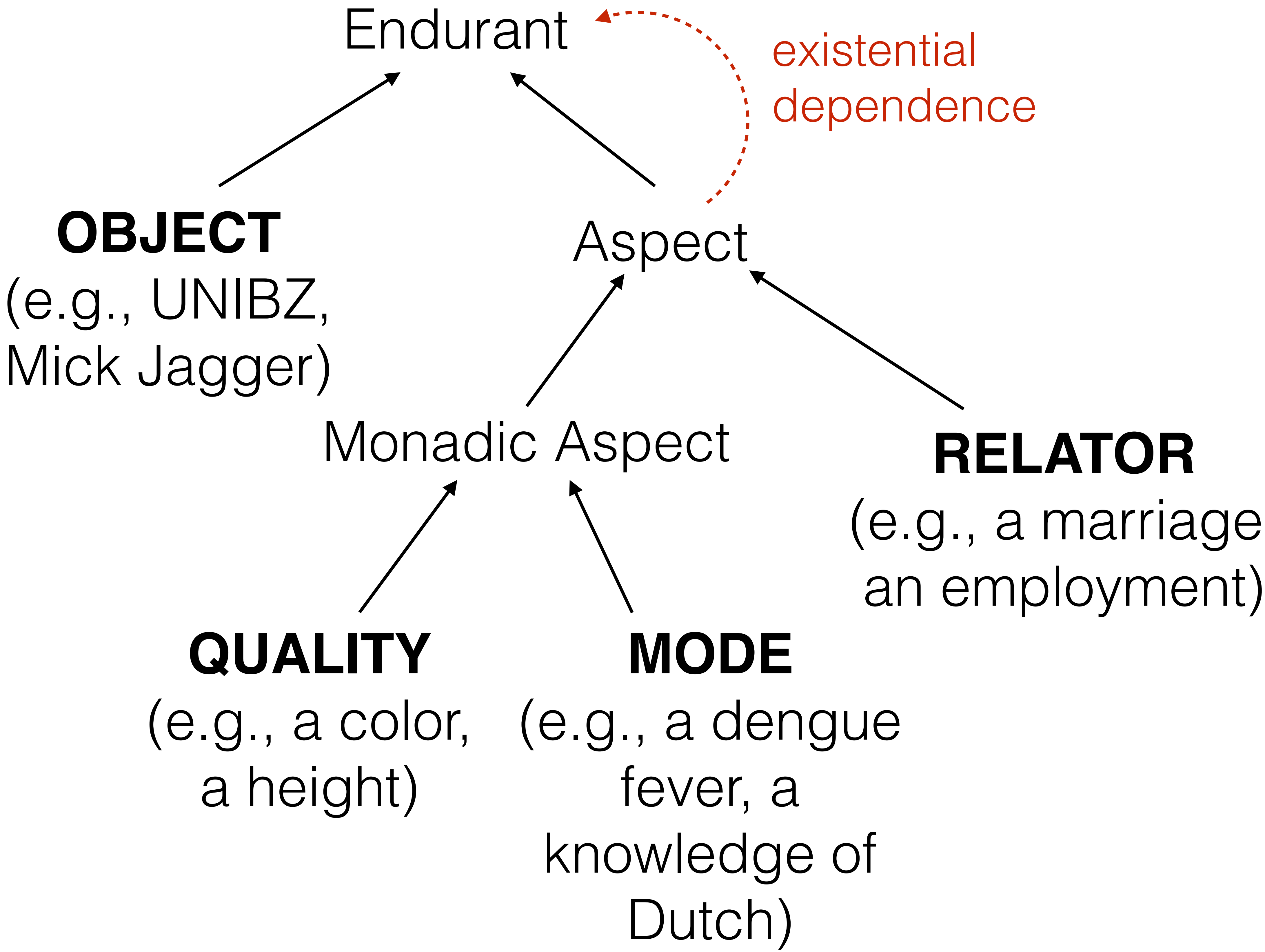


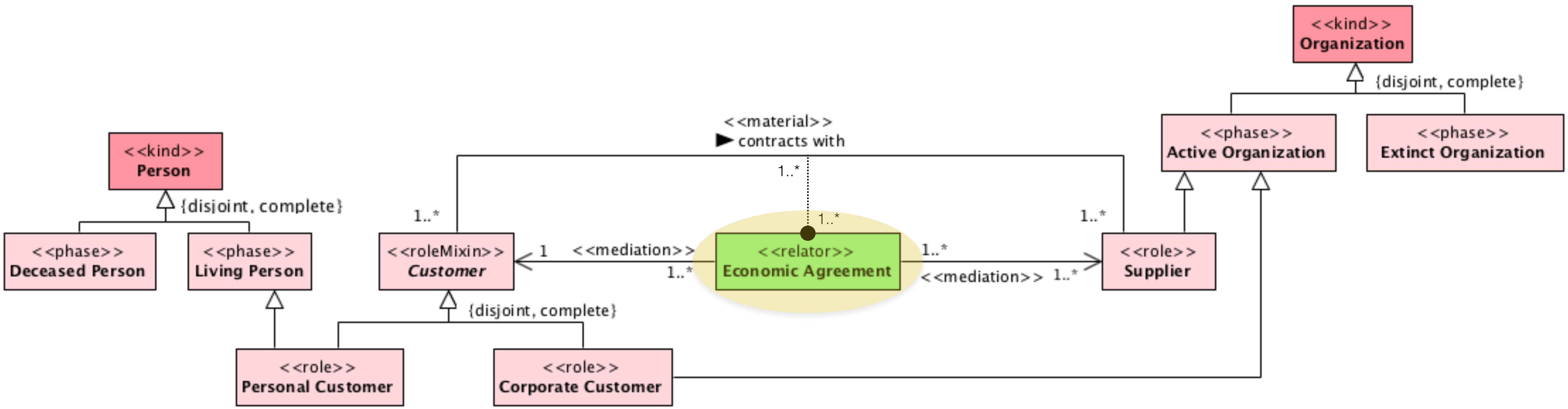
Dynamic MIXINS



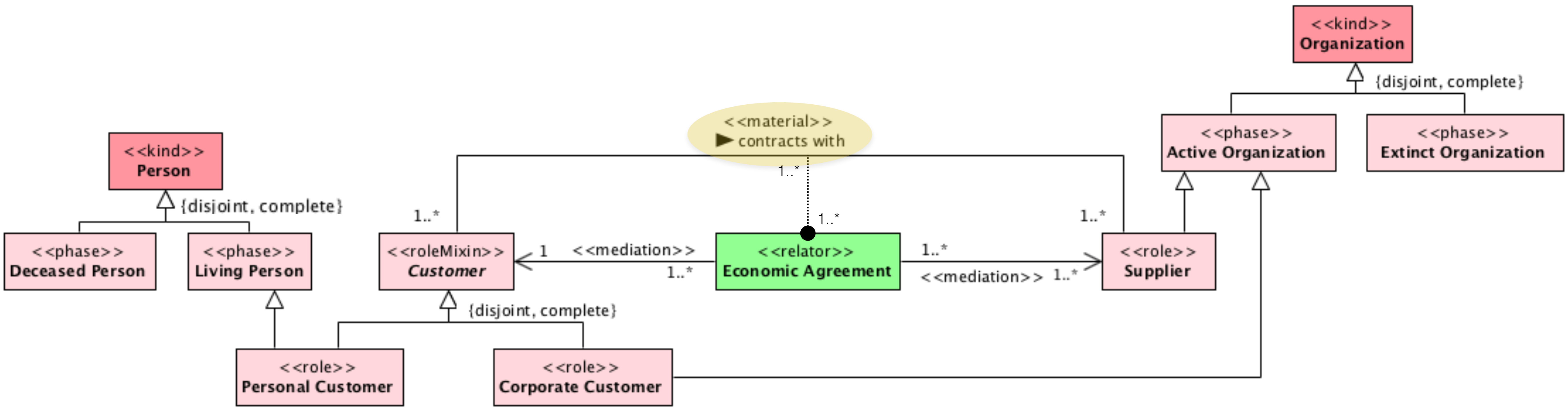

Endurant Type
Sortal Type
MIXIN
(e.g., insurable entity, cultural heritage item)
Rigid Sortal Type or **KIND** (e.g., person, dog, organization car)
Dynamic Sortal Type including **ROLES** (e.g., student, singer) and **PHASES** (e.g., living person, metropolis)


Endurant
OBJECT
(e.g., UNIBZ, Mick Jagger)
Aspect
Monadic Aspect
RELATOR
(e.g., a marriage, an employment)
QUALITY
(e.g., a color, a height)
MODE
(e.g., a dengue fever, a knowledge of Dutch)

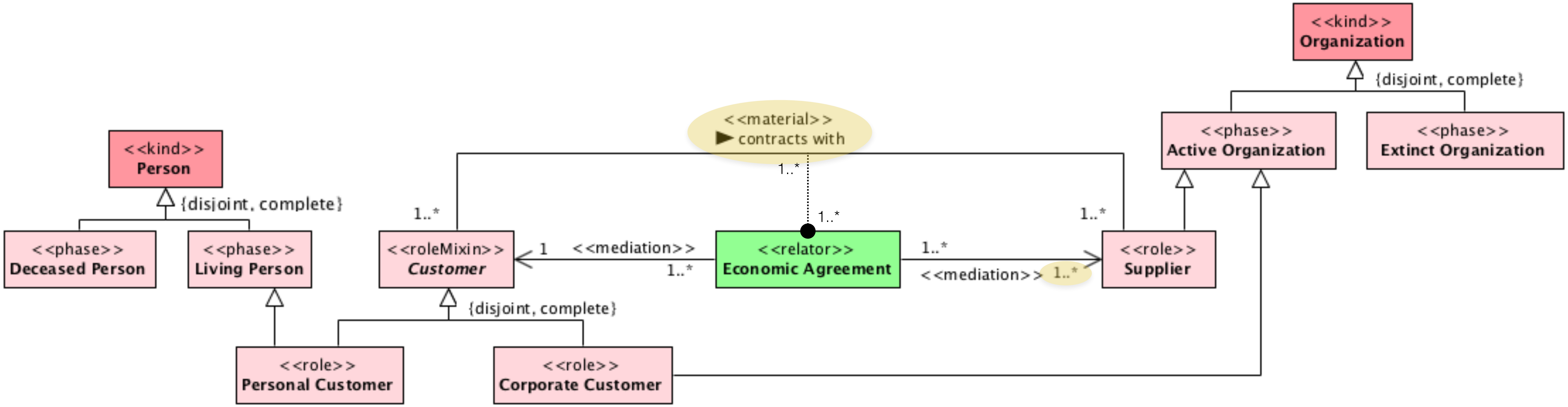

Endurant
existential
dependence
OBJECT
(e.g., UNIBZ,
Mick Jagger)
Aspect
Monadic Aspect
RELATOR
(e.g., a marriage,
an employment)
QUALITY
(e.g., a color,
a height)
MODE
(e.g., a dengue
fever, a
knowledge of
Dutch)



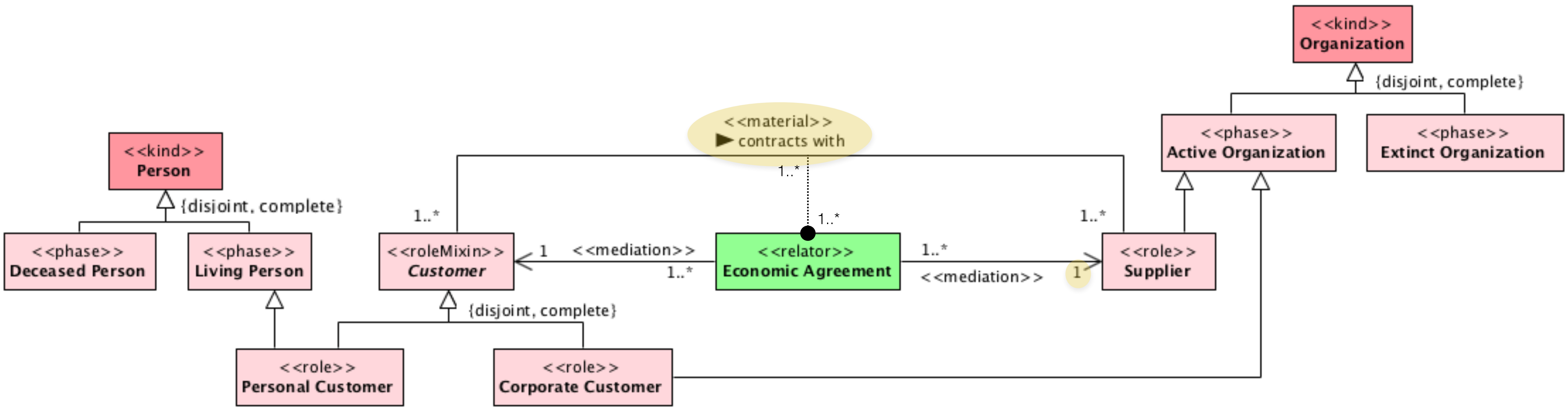
<<kind>>
Person
{disjoint, complete}
<<phase>>
Deceased Person
<<phase>>
Living Person
<<role>>
Personal Customer
<<roleMixin>>
Customer
{disjoint, complete}
<<role>>
Corporate Customer
<<material>>
contracts with
1..*
1..*
1..*
1..*
1
<<mediation>>
1..*
<<relator>>
Economic Agreement
1..*
<<mediation>>
1..*
<<role>>
Supplier
<<kind>>
Organization
{disjoint, complete}
<<phase>>
Active Organization
<<phase>>
Extinct Organization



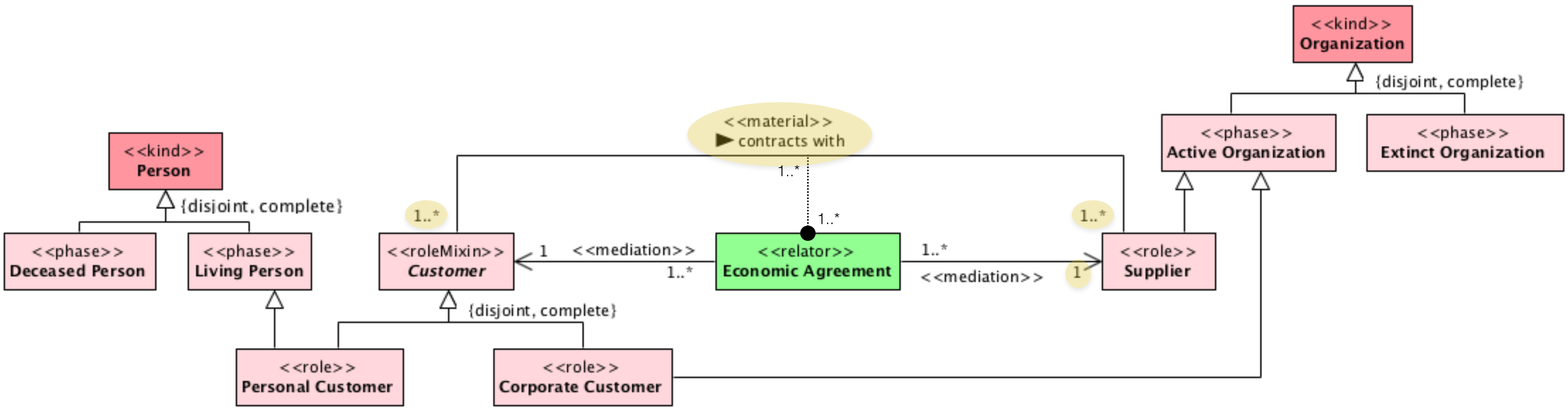
<<kind>>
Person
{disjoint, complete}
<<phase>>
Deceased Person
<<phase>>
Living Person
<<role>>
Personal Customer
<<roleMixin>>
Customer
{disjoint, complete}
<<role>>
Corporate Customer
<<material>>
contracts with
1..*
1..*
1..*
1..*
1
<<mediation>>
1..*
<<relator>>
Economic Agreement
1..*
<<mediation>>
1..*
<<role>>
Supplier
<<kind>>
Organization
{disjoint, complete}
<<phase>>
Active Organization
<<phase>>
Extinct Organization



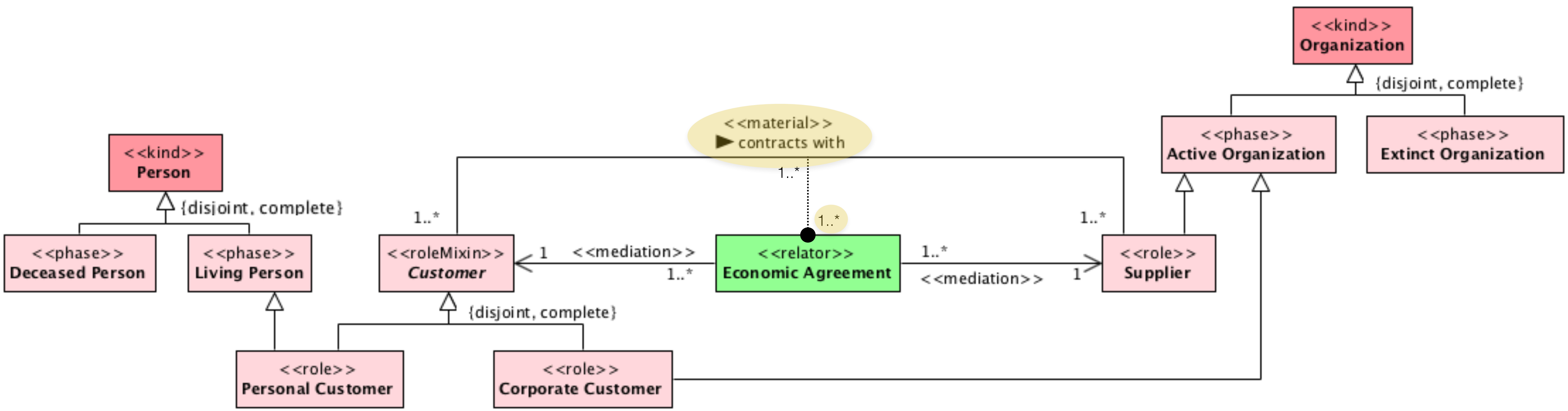
<<kind>>
Person
{disjoint, complete}
<<phase>>
Deceased Person
<<phase>>
Living Person
<<roleMixin>>
Customer
{disjoint, complete}
<<role>>
Personal Customer
<<role>>
Corporate Customer
<<material>>
contracts with
1..*
1..*
1..*
1..*
<<mediation>>
1
1..*
<<relator>>
Economic Agreement
1..*
<<mediation>>
1..*
<<role>>
Supplier
<<kind>>
Organization
{disjoint, complete}
<<phase>>
Active Organization
<<phase>>
Extinct Organization



<<kind>>
Person
{disjoint, complete}
<<phase>>
Deceased Person
<<phase>>
Living Person
<<role>>
Personal Customer
<<roleMixin>>
Customer
{disjoint, complete}
<<role>>
Corporate Customer
<<material>>
contracts with
1..*
1..*
1..*
1..*
1
<<mediation>>
1..*
<<relator>>
Economic Agreement
1..*
<<mediation>>
1
<<role>>
Supplier
<<kind>>
Organization
{disjoint, complete}
<<phase>>
Active Organization
<<phase>>
Extinct Organization



<<kind>> Organization
{disjoint, complete}
<<phase>> Active Organization
<<phase>> Extinct Organization
<<kind>> Person
{disjoint, complete}
<<phase>> Deceased Person
<<phase>> Living Person
<<material>> contracts with
1..*
1..*
1..*
1..*
<<roleMixin>> Customer
1
<<mediation>>
1..*
<<relator>> Economic Agreement
1..*
<<mediation>>
1
<<role>> Supplier
{disjoint, complete}
<<role>> Personal Customer
<<role>> Corporate Customer



<<kind>>
Organization
{disjoint, complete}
<<phase>>
Active Organization
<<phase>>
Extinct Organization
<<material>>
contracts with
1..*
<<kind>>
Person
{disjoint, complete}
1..*
1..*
1..*
<<phase>>
Deceased Person
<<phase>>
Living Person
<<roleMixin>>
Customer
1
<<mediation>>
1..*
<<relator>>
Economic Agreement
1..*
<<mediation>>
1
<<role>>
Supplier
{disjoint, complete}
<<role>>
Personal Customer
<<role>>
Corporate Customer

What does
that buy us?

ODCM Engineering

- Language which primitives reflect a rich system of **ontological distinctions** and grammar reflects ontological **rules**
- methodology reflecting ontological **meta-properties**

1

Brazilian

Person

Adult

Man

Minister of sports

Father

Actor

Football player

Husband

Philanthropist

In 1950

Brazilian

Adult

Minister of sports

Actor

Husband

Person

Man

Father

Football player

Philanthropist

In 1970

✓ Brazilian

✓ Adult

✗ Minister of sports

✗ Actor

✗ Husband

Person ✓

Man ✓

Father ✗

Football player ✓

Philanthropist ✗

In 1994

✓ Brazilian

✓ Adult

✓ Minister of sports

✓ Actor

✓ Husband

Person ✓

Man ✓

Father ✓

Football player ✗

Philanthropist ✗

In 2020

Brazilian

Adult

Minister of sports

Actor

Husband

Person

Man

Father

Football player

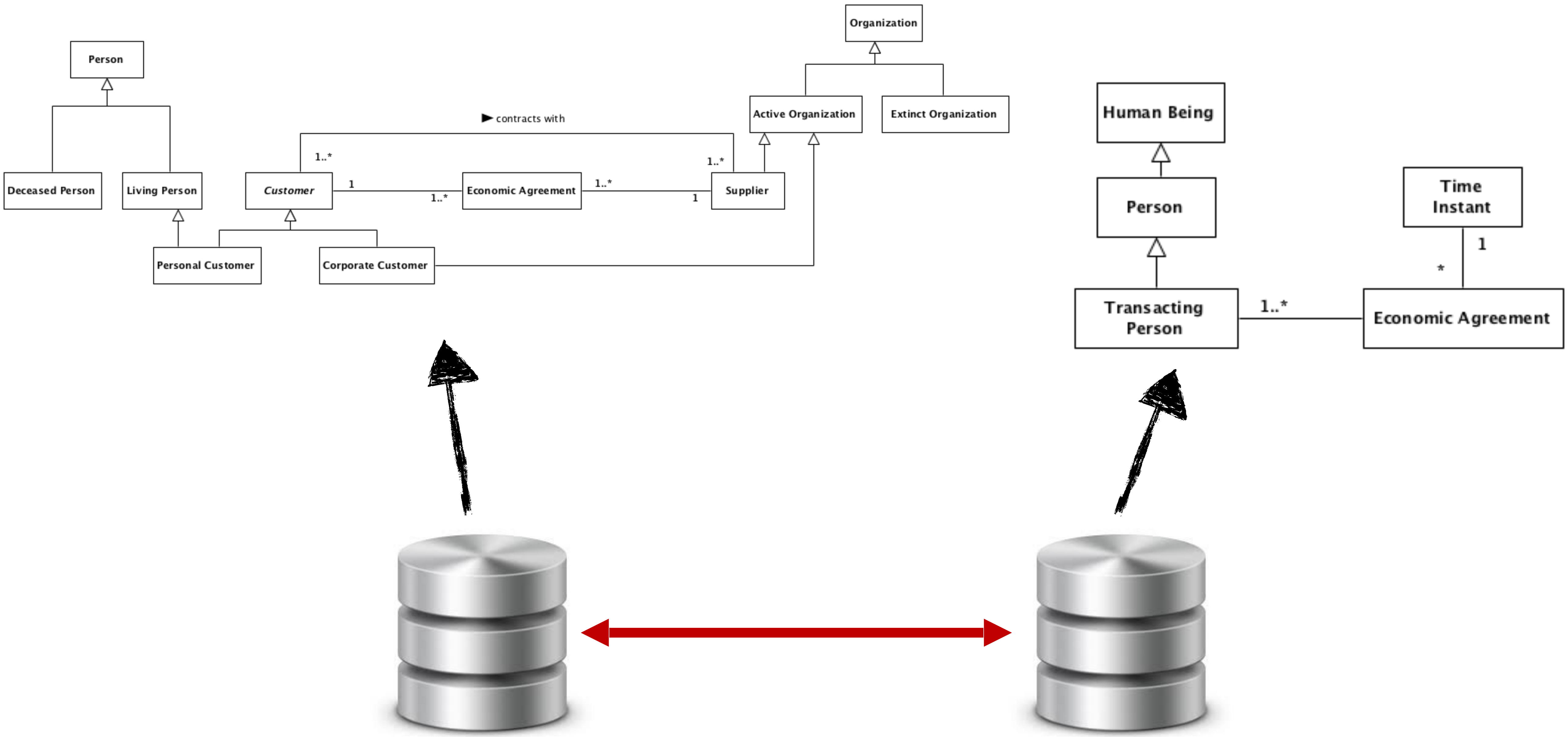
Philanthropist

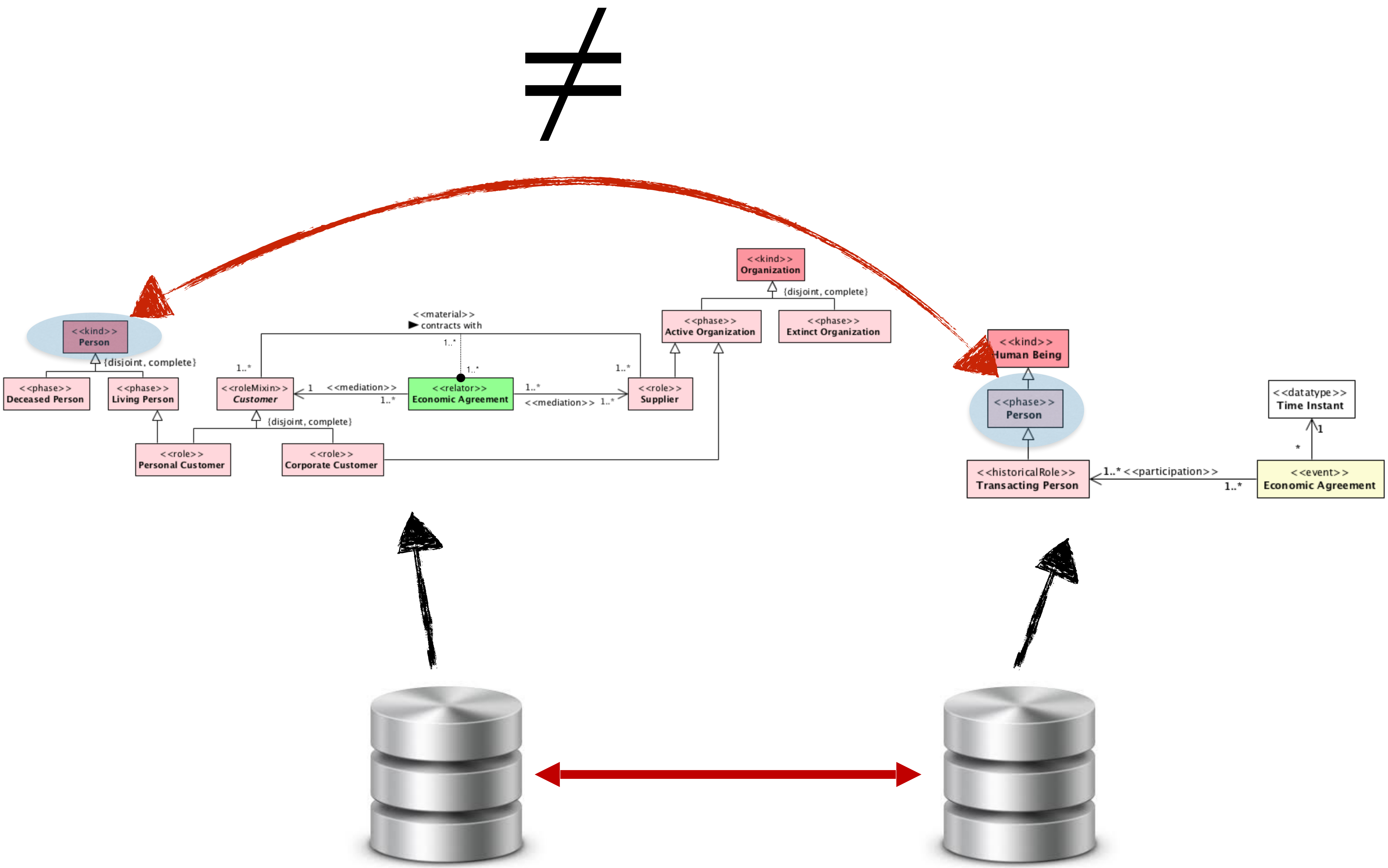
Solution

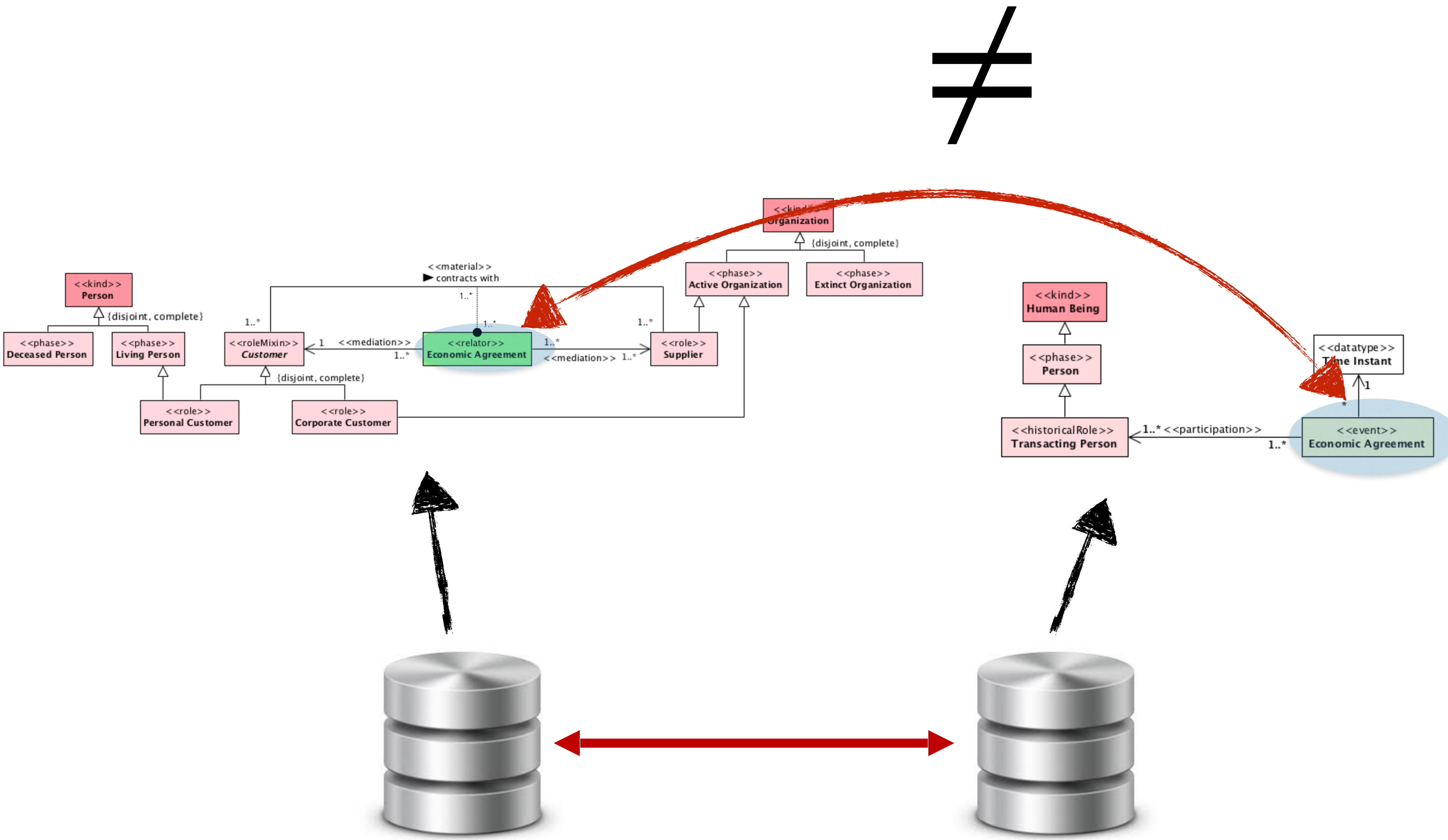
1. Characterizing the difference between:

- NATURAL TYPE/KIND (e.g., **PERSON**) = **RIGID SORTAL**
- ROLE (e.g., **MINISTER OF SPORTS, FOOTBALL PLAYER, ACTOR, HUSBAND**) = **DYNAMIC + RELATIONALLY DEPENDENT SORTAL**
- PHASE (e.g., **LIVING PERSON, ADULT MAN**) = **DYNAMIC + RELATIONALLY INDEPENDENT SORTAL**
- MIXIN (e.g., **CULTURAL HERITAGE ENTITY, PHYSICAL ENTITY, INSURABLE ITEM**)? = **MIXIN**

2


Organization
Person
Active Organization
Extinct Organization
contracts with
Deceased Person
Living Person
Customer
Economic Agreement
Supplier
Personal Customer
Corporate Customer
1..*
1
1..*
1..*
1
1..*
Human Being
Person
Time Instant
1
*
Transacting Person
1..*
Economic Agreement


≠
<<kind>>
Person
{disjoint, complete}
<<phase>>
Deceased Person
<<phase>>
Living Person
<<role>>
Personal Customer
<<roleMixin>>
Customer
{disjoint, complete}
<<role>>
Corporate Customer
<<material>>
contracts with
<<mediation>>
<<relator>>
Economic Agreement
<<mediation>>
<<role>>
Supplier
<<kind>>
Organization
{disjoint, complete}
<<phase>>
Active Organization
<<phase>>
Extinct Organization
<<kind>>
Human Being
<<phase>>
Person
<<historicalRole>>
Transacting Person
1..* <<participation>>
1..*
<<event>>
Economic Agreement
<<datatype>>
Time Instant



≠
Organization
{disjoint, complete}
<<phase>> Active Organization
<<phase>> Extinct Organization
<<material>>
contracts with
<<kind>> Person
{disjoint, complete}
<<phase>> Deceased Person
<<phase>> Living Person
<<roleMixin>> Customer
<<mediation>>
<<relator>> Economic Agreement
<<mediation>>
<<role>> Supplier
{disjoint, complete}
<<role>> Personal Customer
<<role>> Corporate Customer
1..*
1
<<kind>> Human Being
<<phase>> Person
<<historicalRole>> Transacting Person
1..* <<participation>>
1..*
<<datatype>>
<<event>> Economic Agreement

Person?

Person?

1. Human Being?

2. Legally Recognized Human Being?

3. Cognitively Capable Human Being?

4. Legal Person?

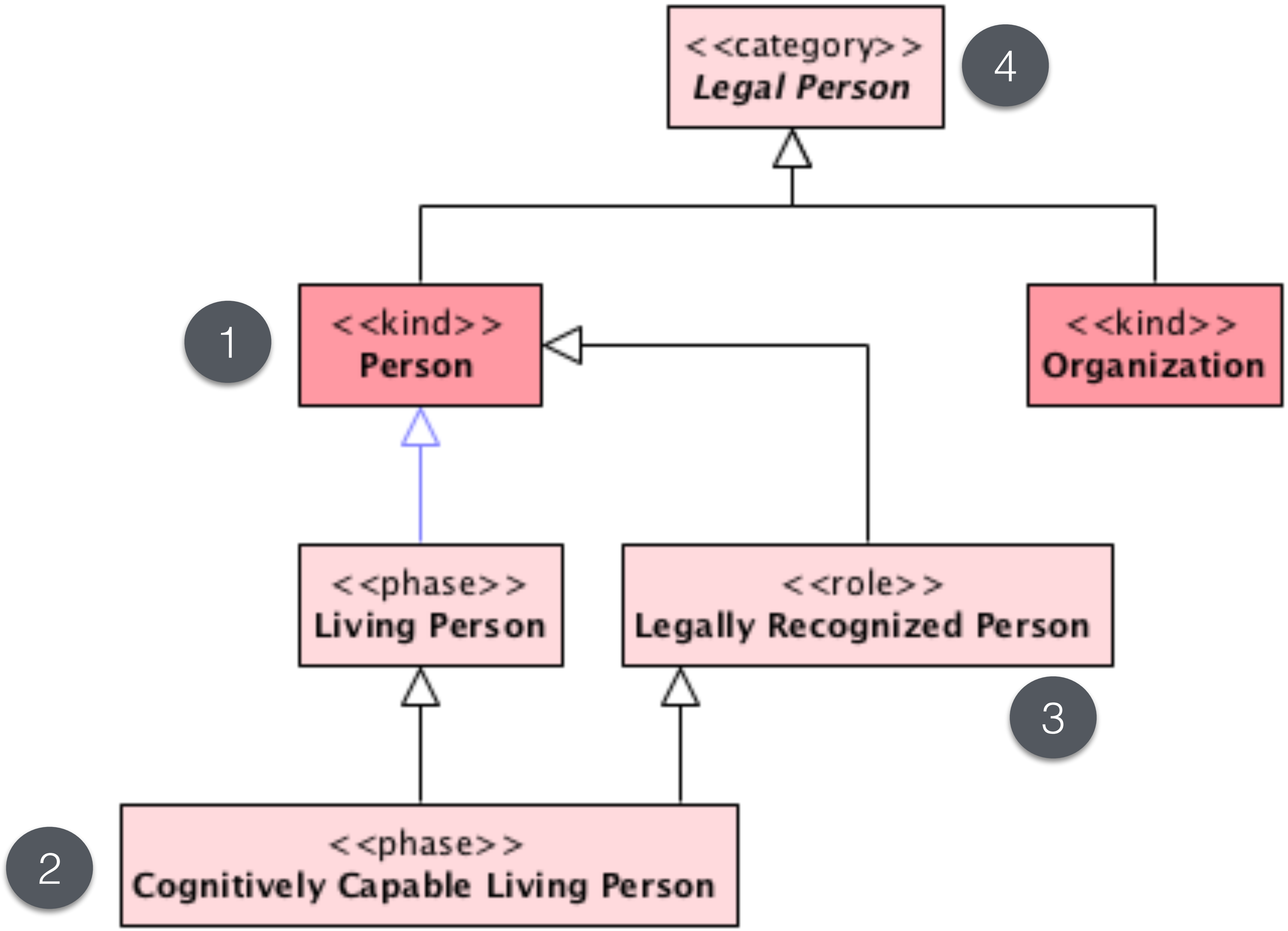
Person?

1. Human Being? **KIND**

2. Legally Recognized Human Being? **ROLE**

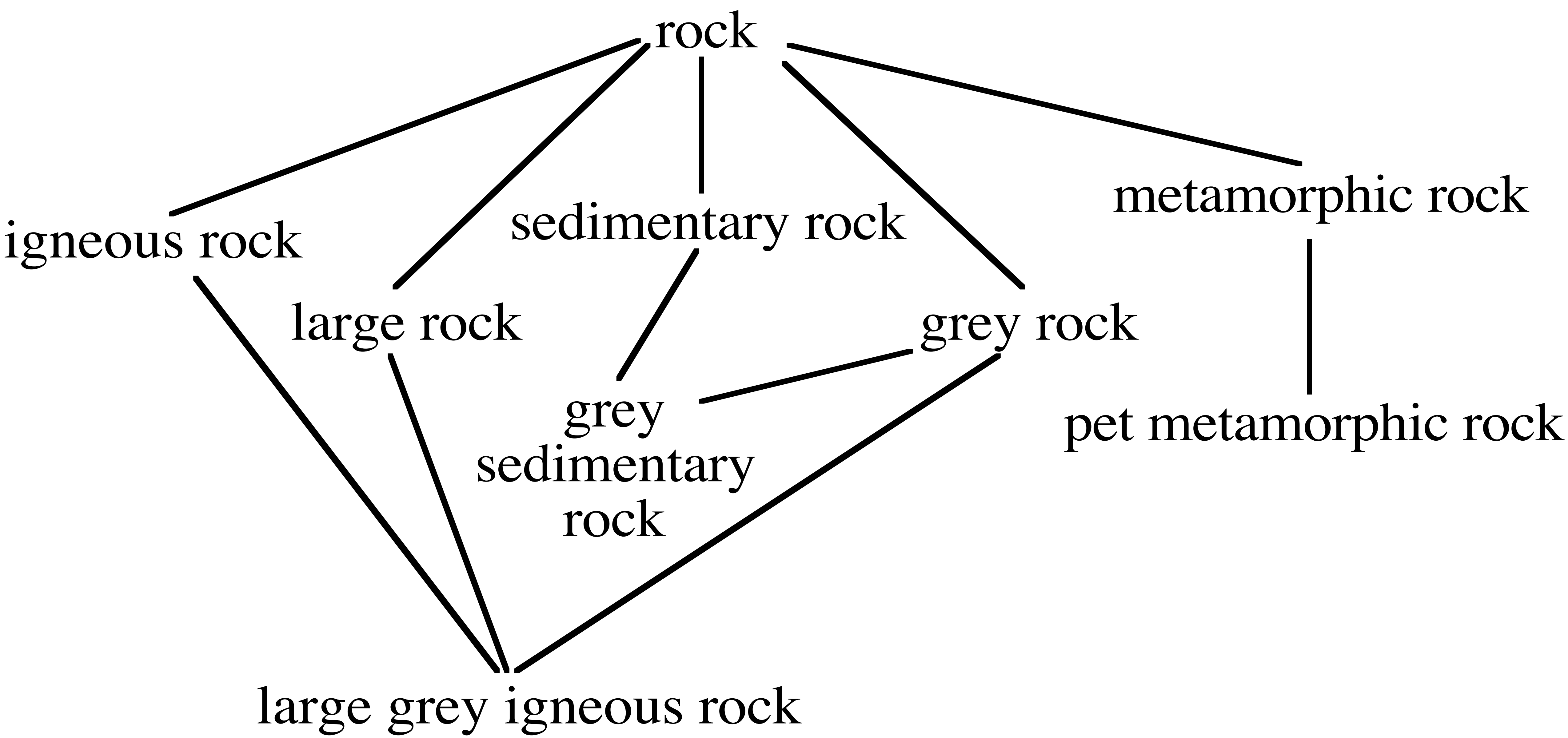
3. Cognitively Capable Human Being? **PHASE**

4. Legal Person? **MIXIN**



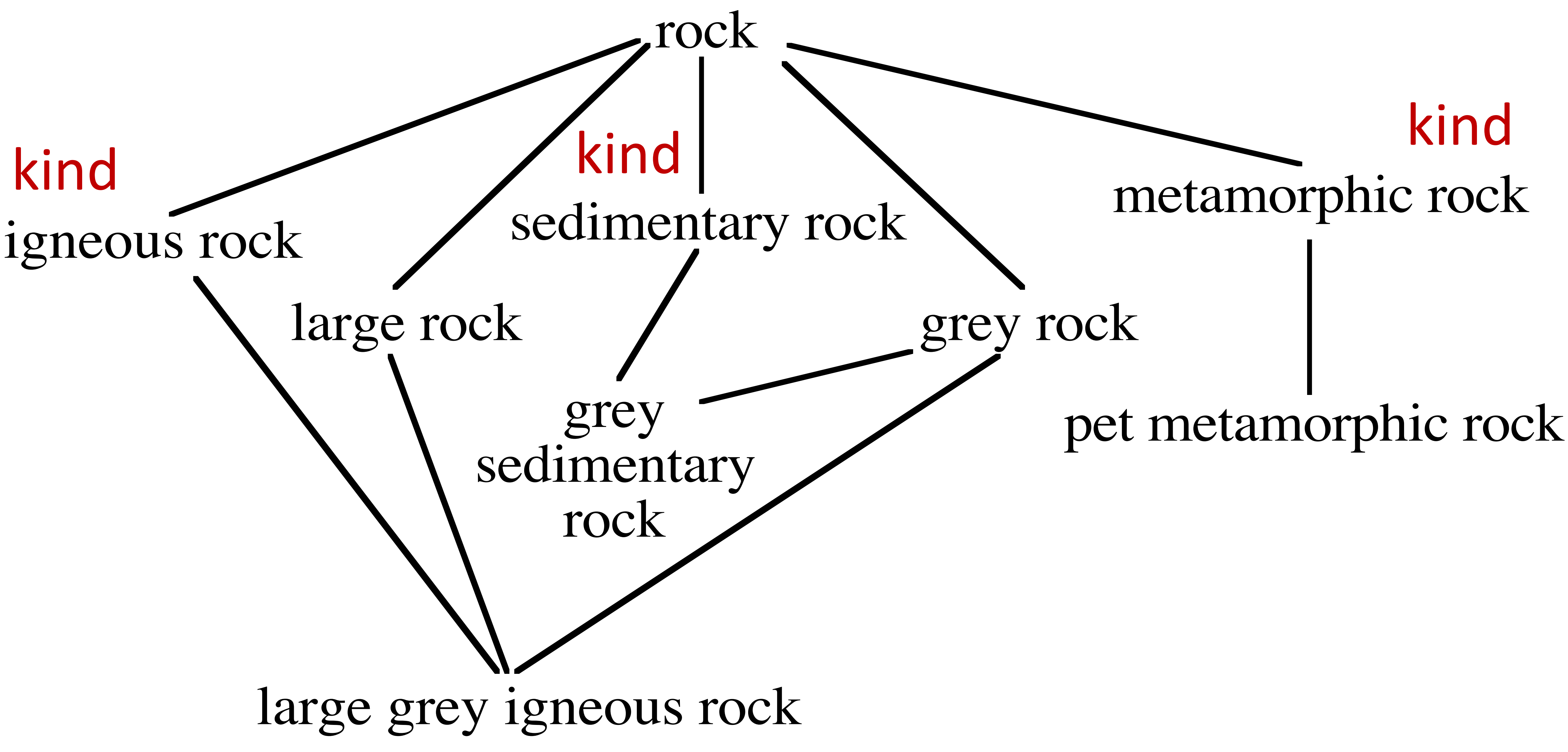
<<category>>
Legal Person
4
1
<<kind>>
Person
<<kind>>
Organization
<<phase>>
Living Person
<<role>>
Legally Recognized Person
3
2
<<phase>>
Cognitively Capable Living Person

How many kinds of rock?



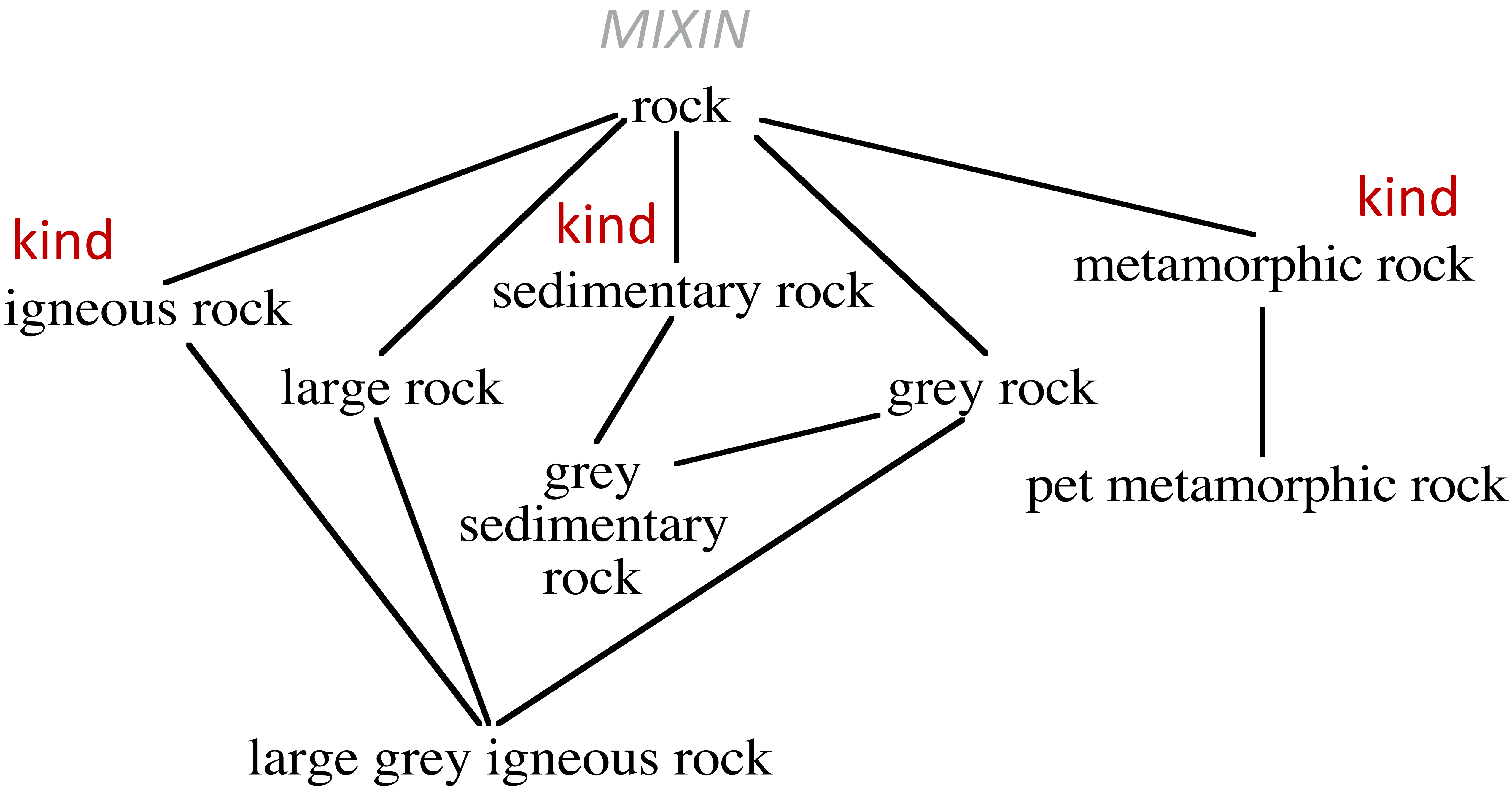
Brachman, Fikes and Levesque, 1985

How many kinds of rock?



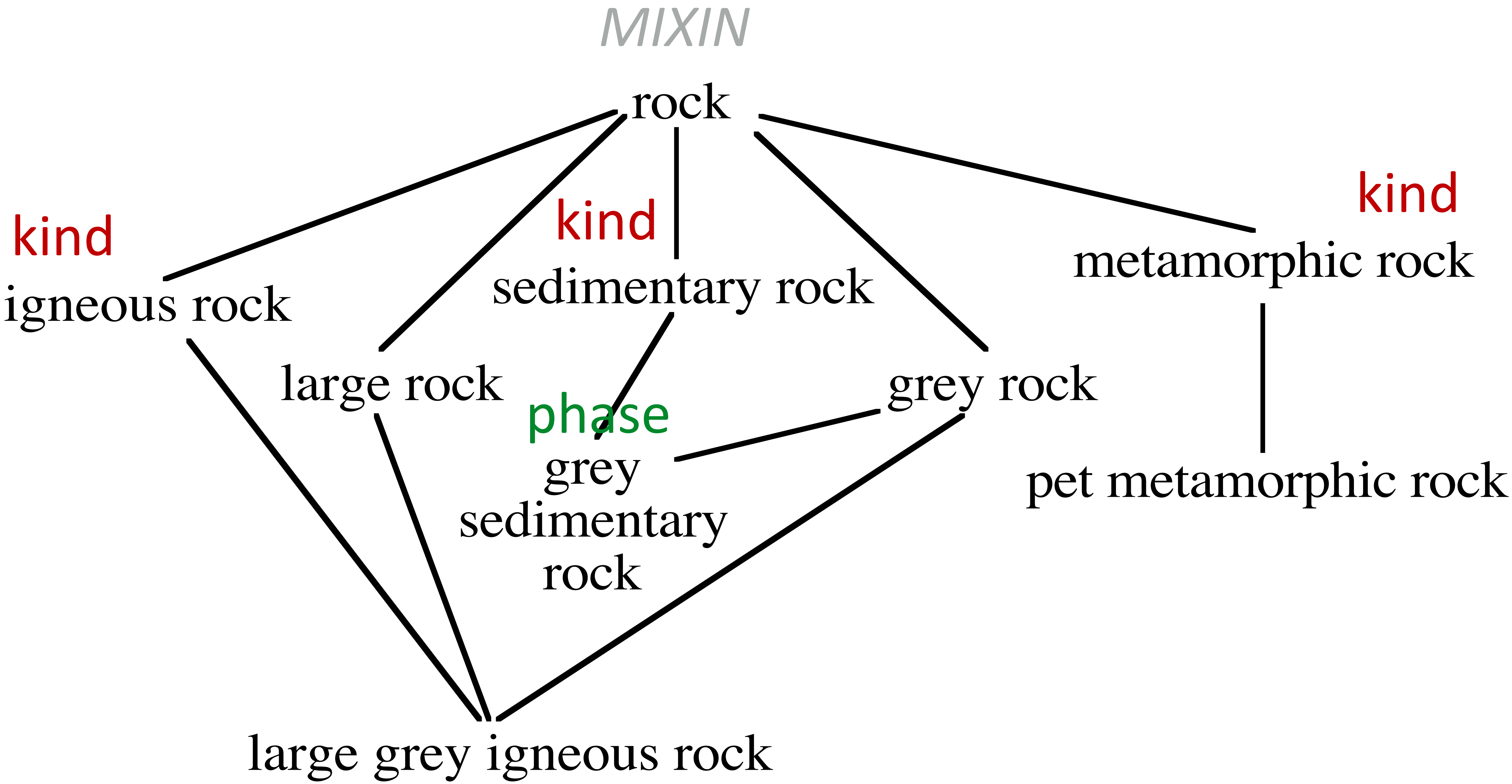
Brachman, Fikes and Levesque, 1985

How many kinds of rock?



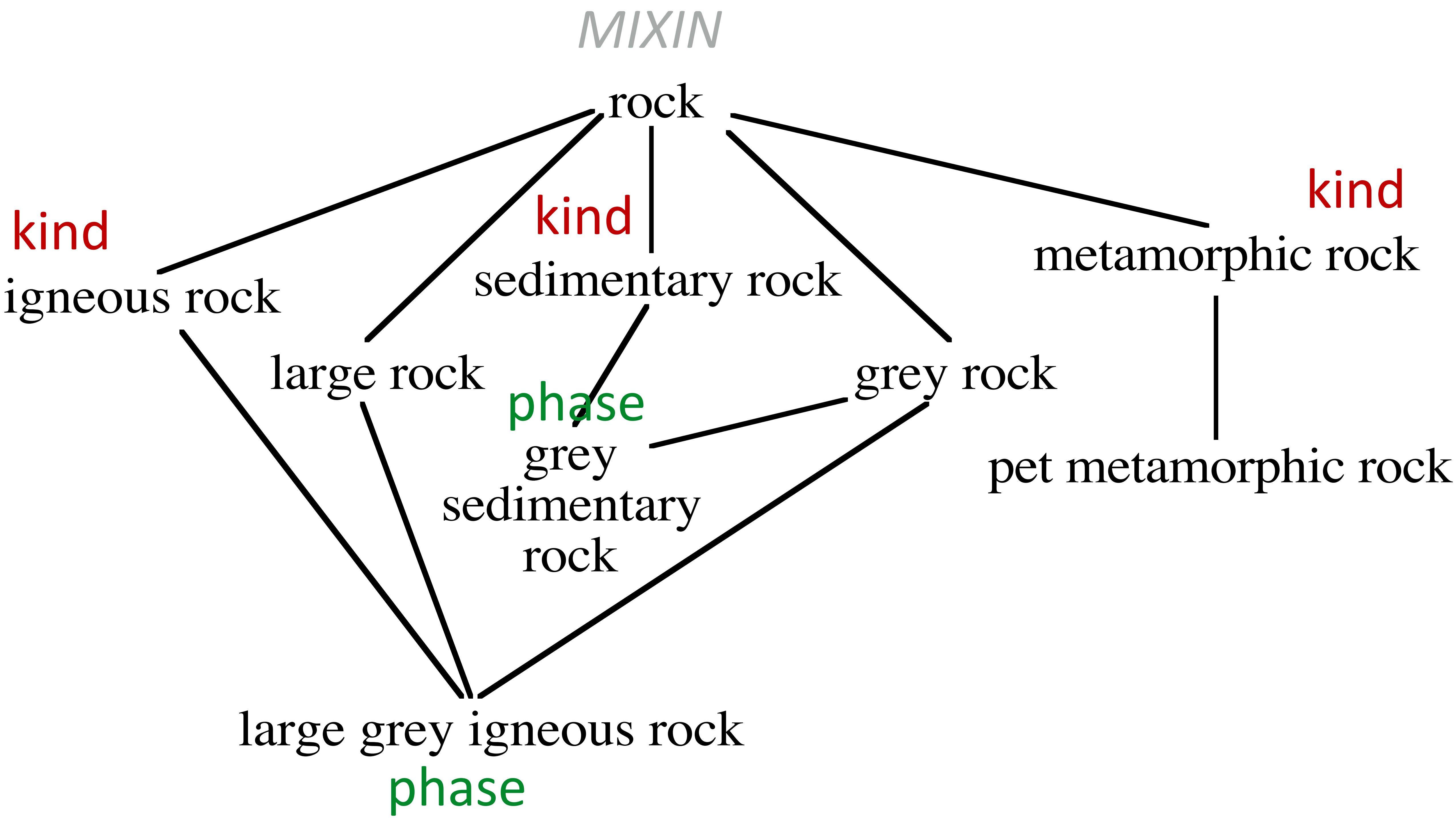
Brachman, Fikes and Levesque, 1985

How many kinds of rock?



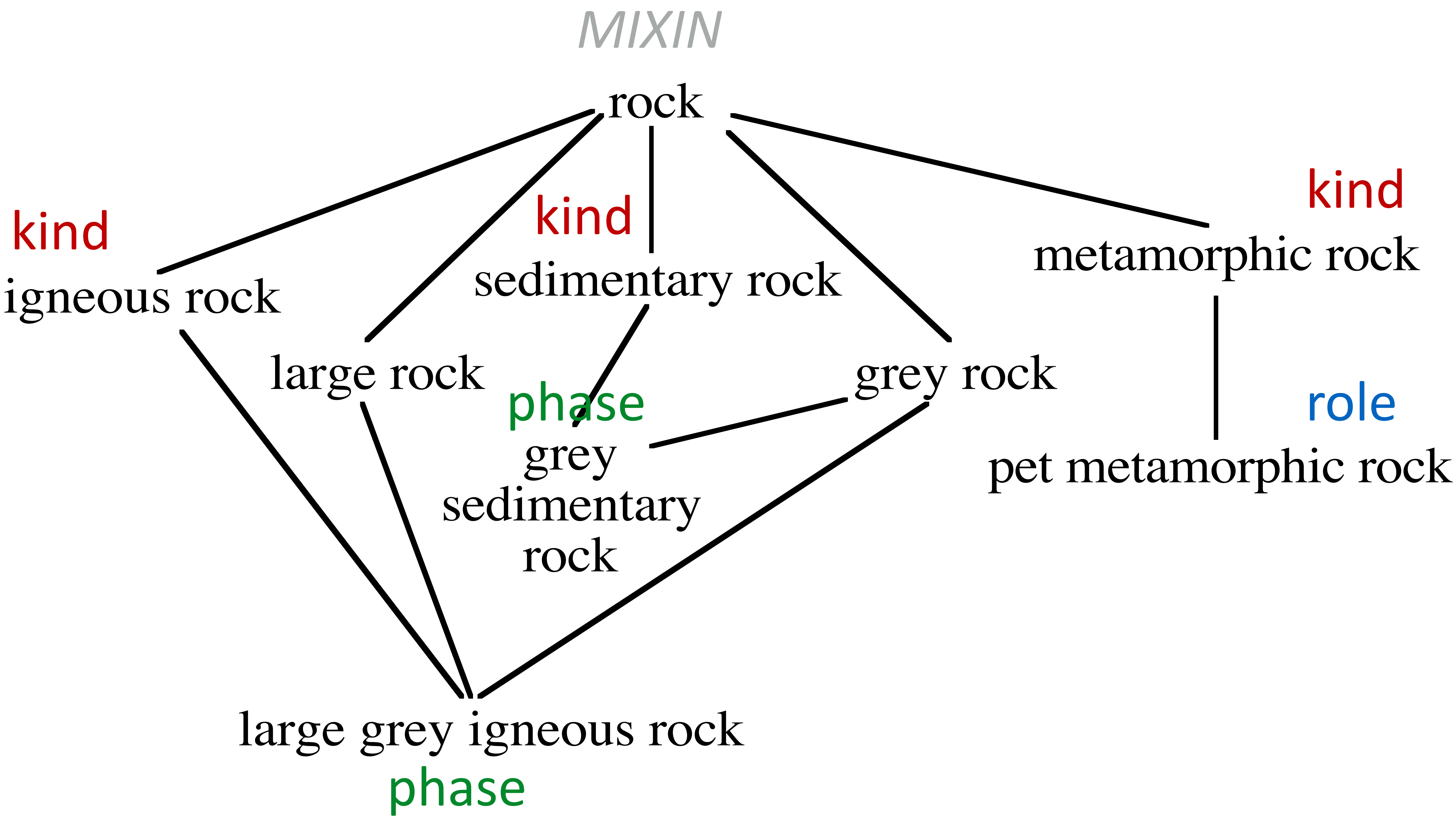
Brachman, Fikes and Levesque, 1985

How many kinds of rock?



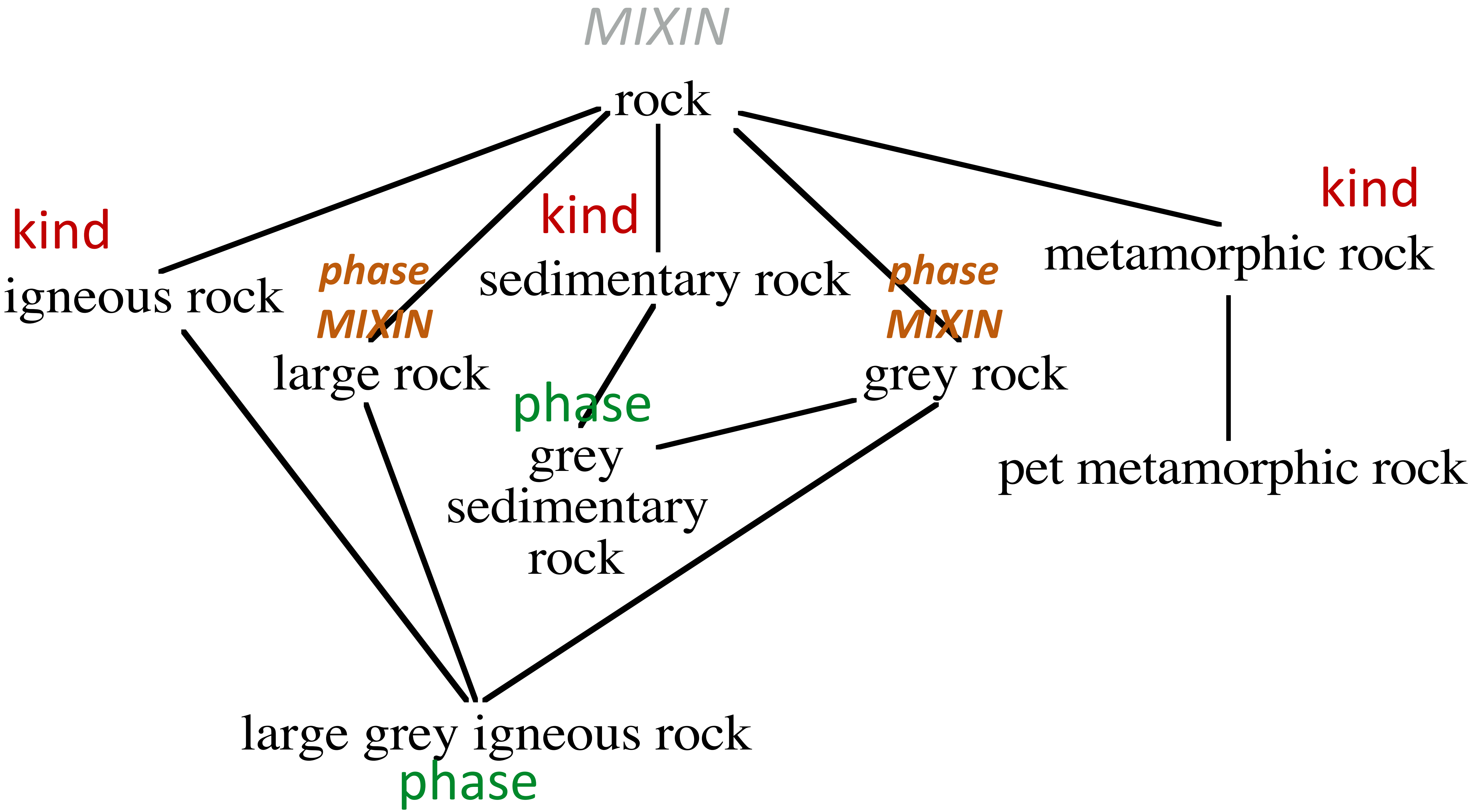
Brachman, Fikes and Levesque, 1985

How many kinds of rock?



Brachman, Fikes and Levesque, 1985

How many kinds of rock?

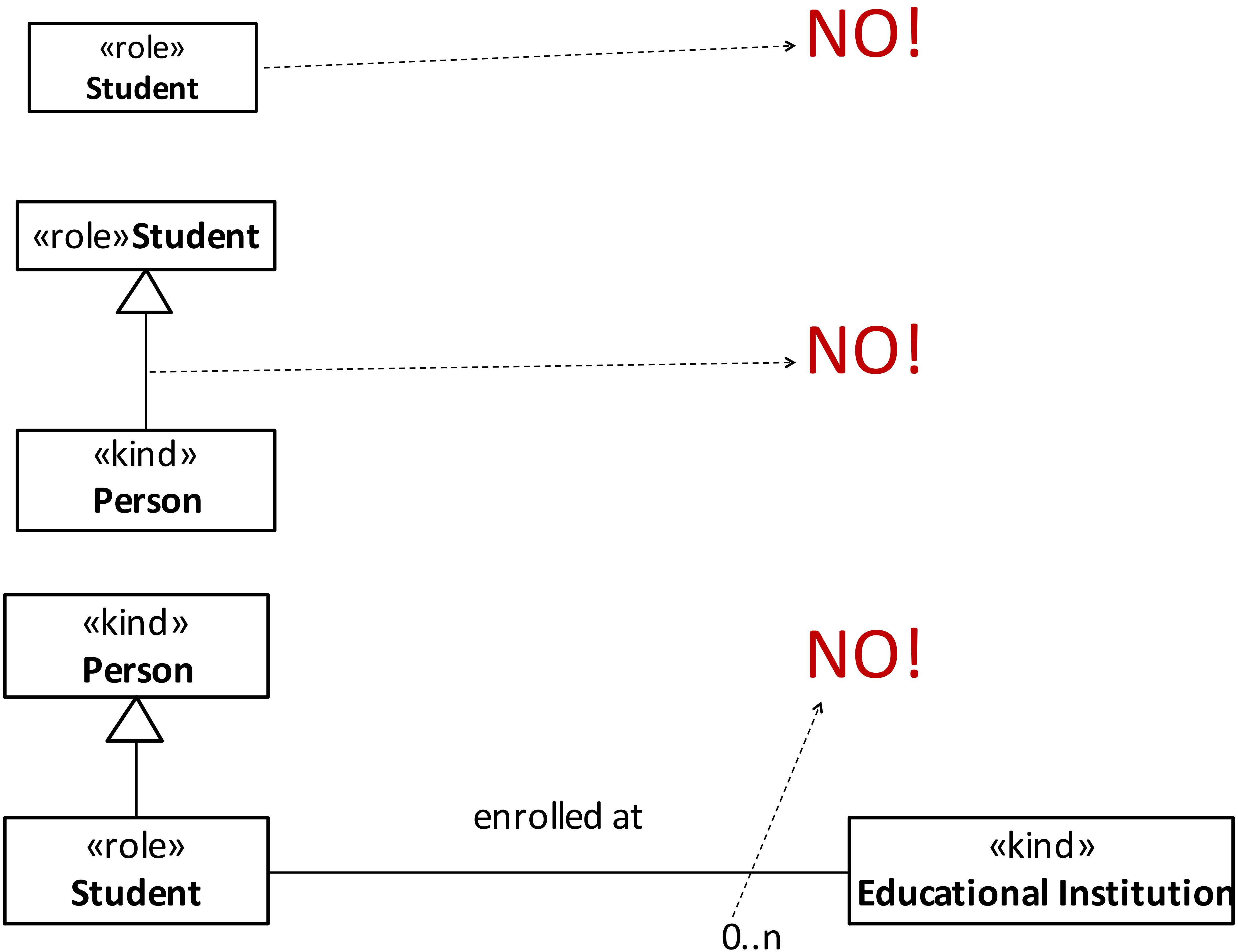


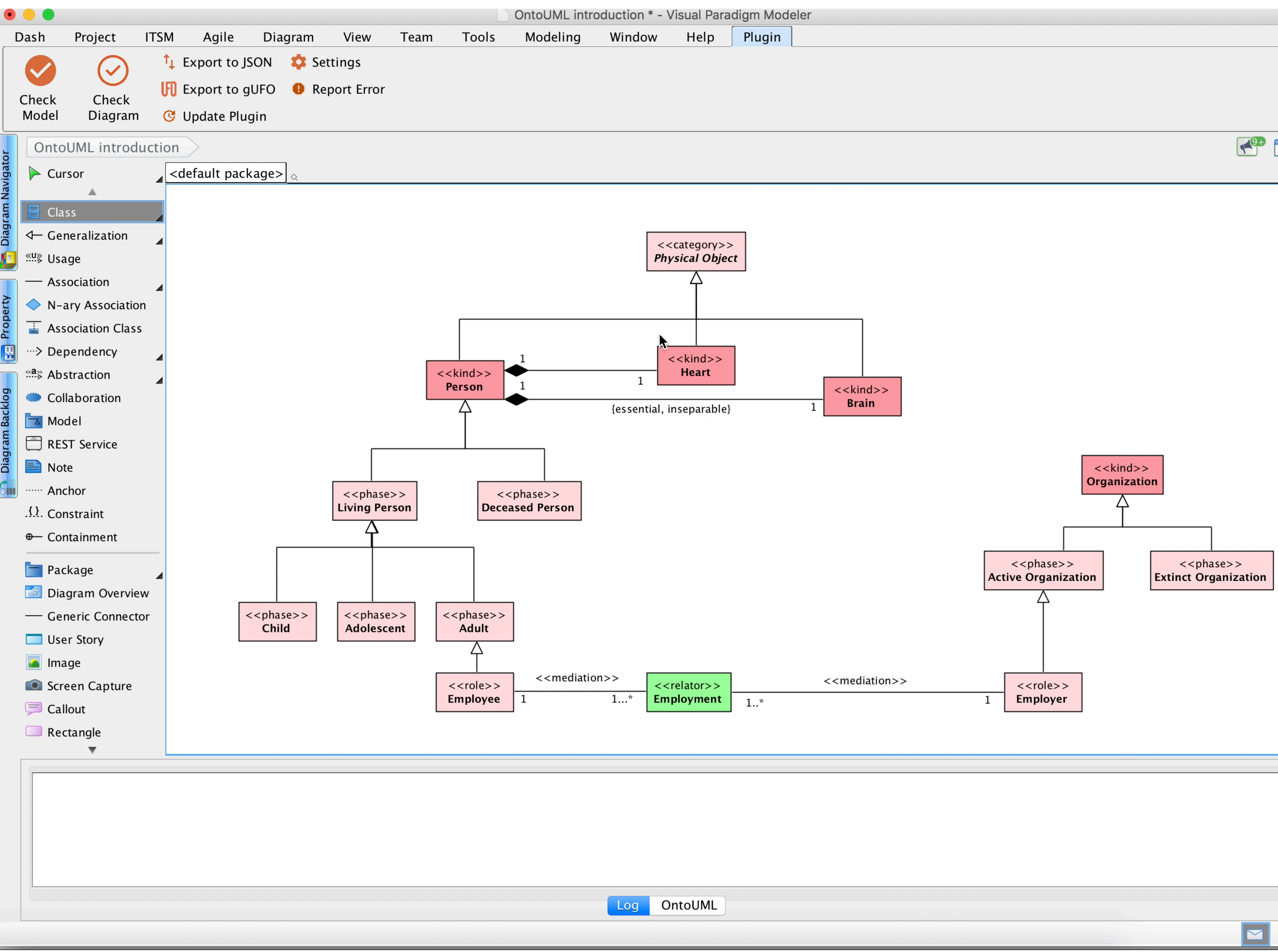
Brachman, Fikes and Levesque, 1985

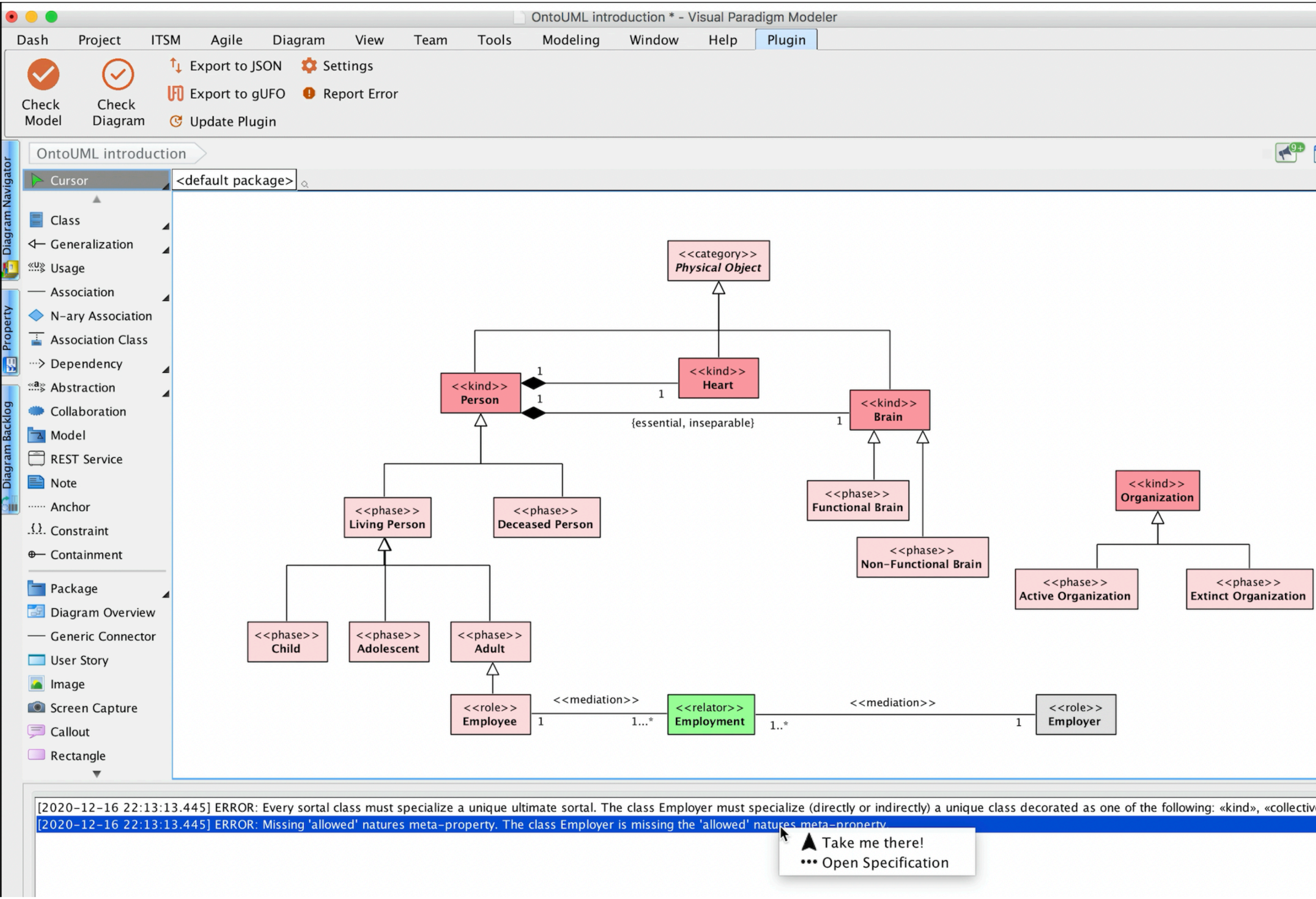
3

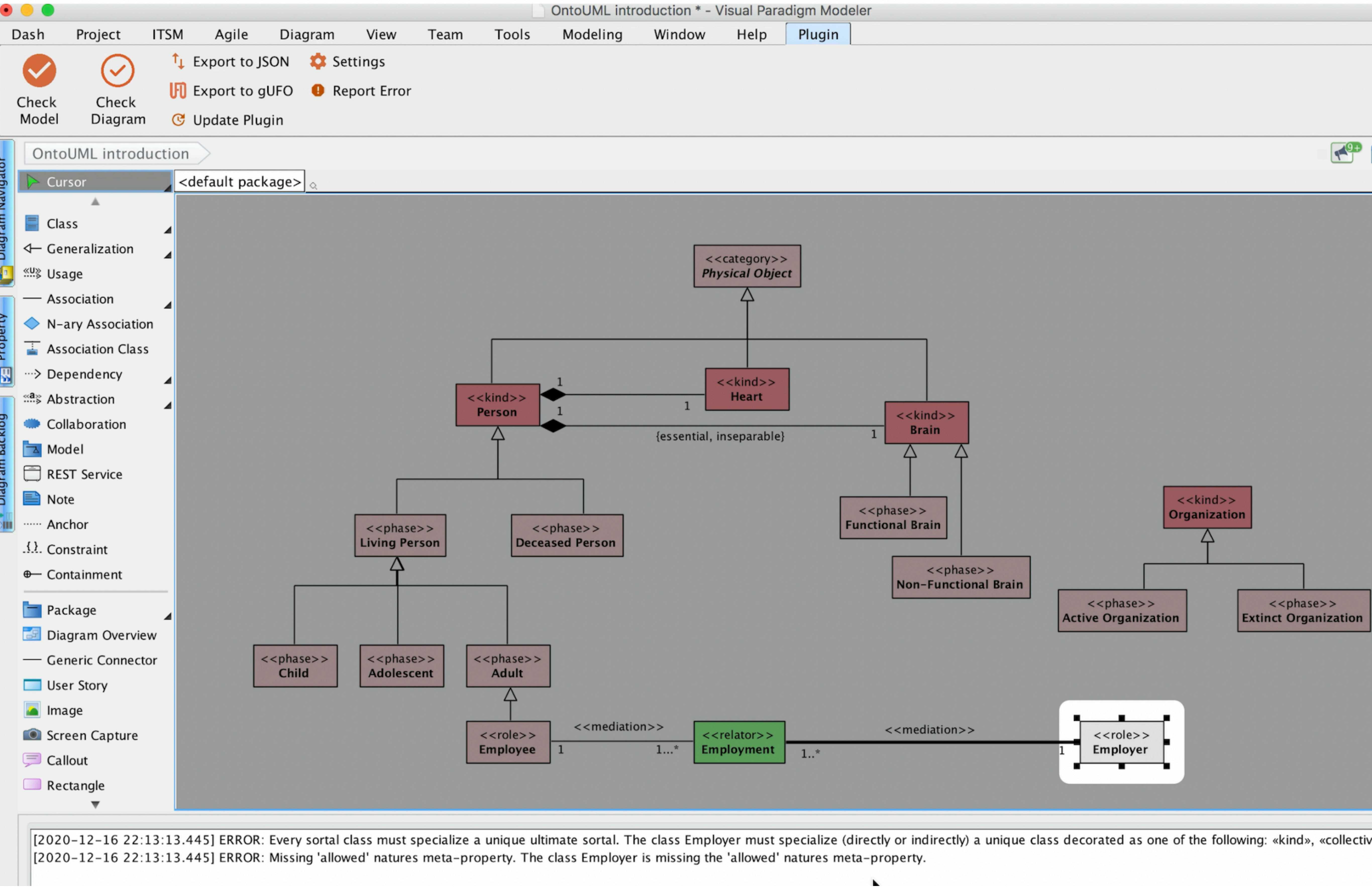
Role

- 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 na Educational Institution)
- A ROLE cannot be a supertype of a Rigid Type

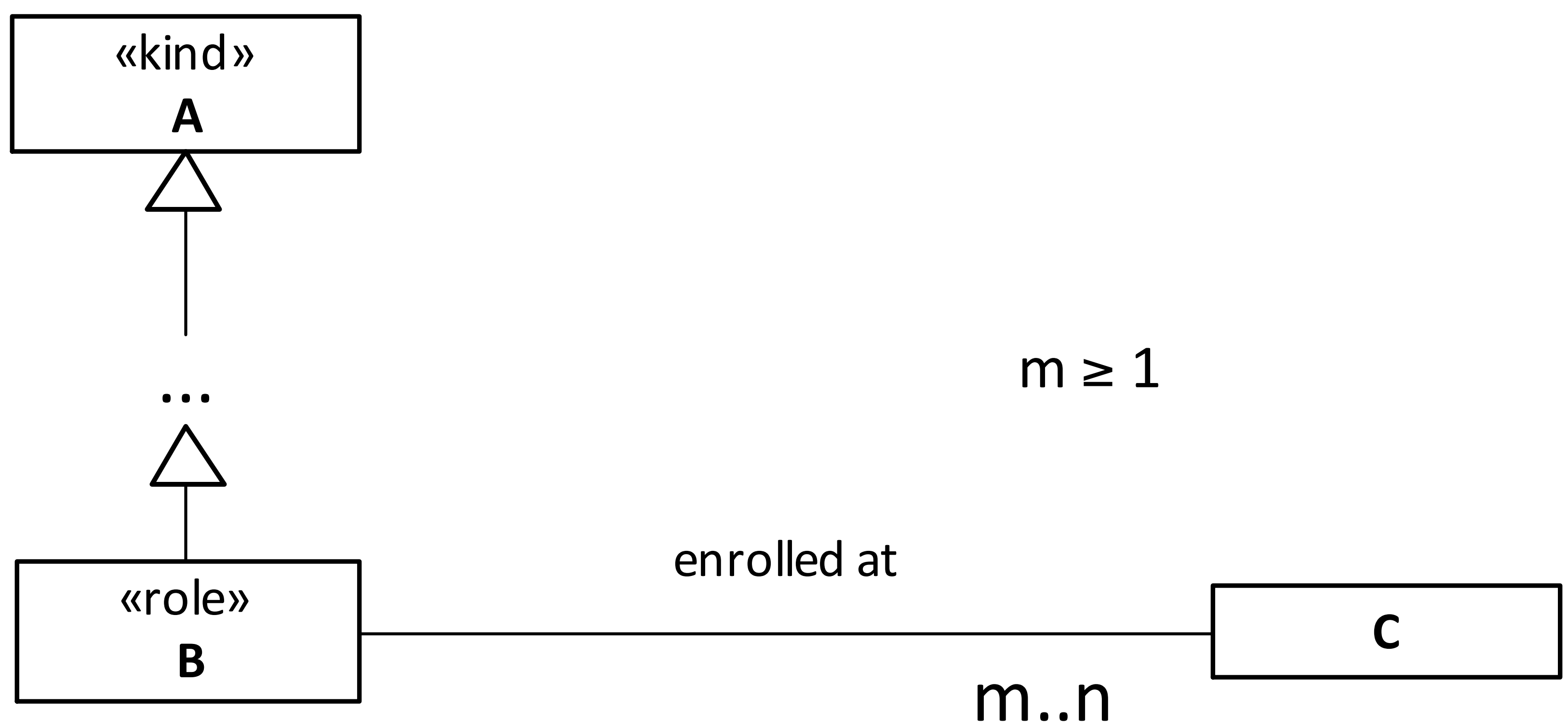

«role»
Student
NO!
«role»Student
NO!
«kind»
Person
«kind»
Person
NO!
enrolled at
«role»
Student
«kind»
Educational Institution
0..n

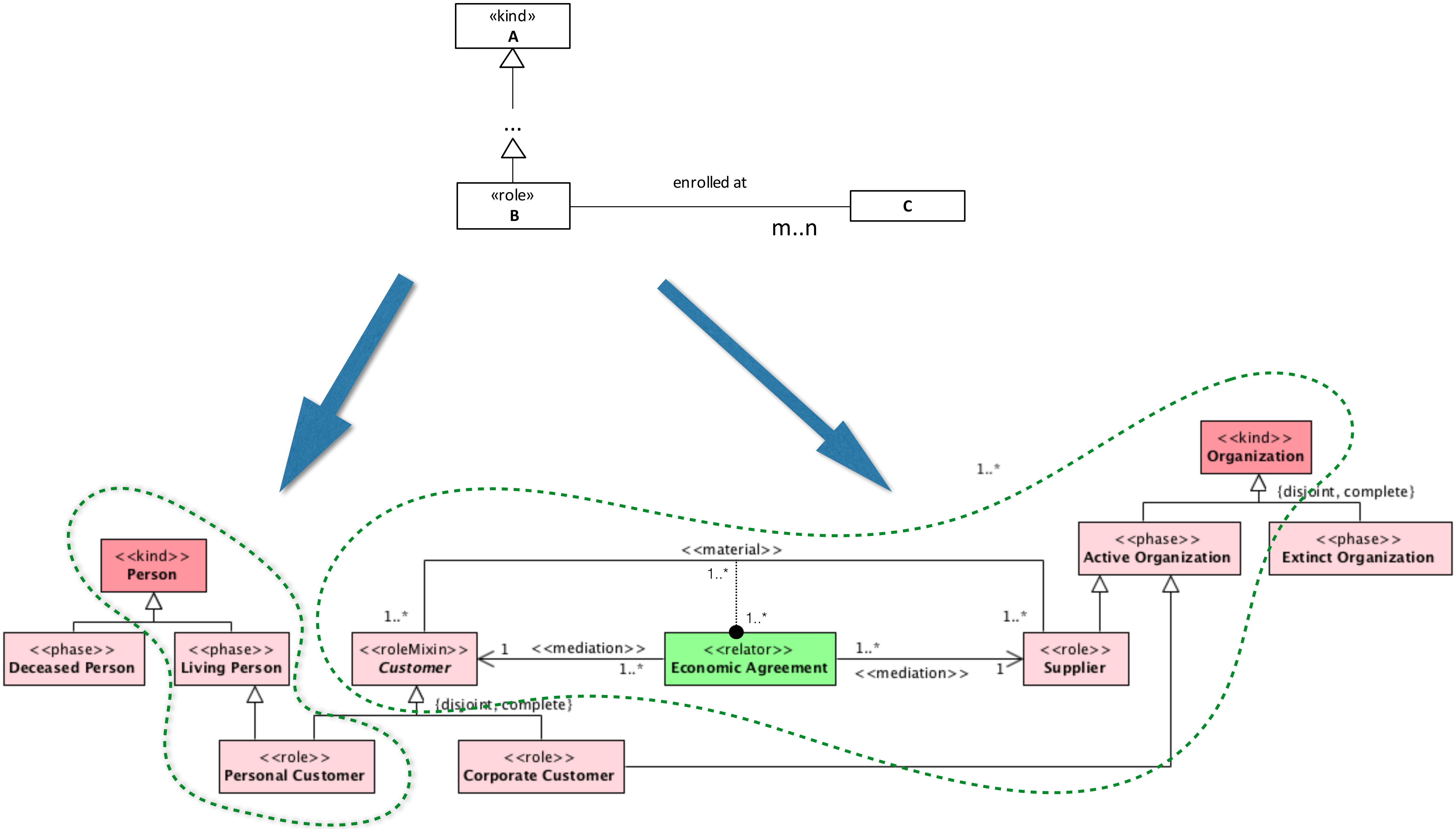

OntoUML introduction * - Visual Paradigm Modeler
Dash
Project
ITSM
Agile
Diagram
View
Team
Tools
Modeling
Window
Help
Plugin
Check Model
Check Diagram
Export to JSON
Export to gUFO
Update Plugin
Settings
Report Error
OntoUML introduction
<default package>
Cursor
Class
Generalization
Usage
Association
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
Diagram Navigator
Property
Diagram Backlog
<<category>> Physical Object
<<kind>> Person
<<kind>> Heart
<<kind>> Brain
{essential, inseparable}
<<phase>> Living Person
<<phase>> Deceased Person
<<phase>> Child
<<phase>> Adolescent
<<phase>> Adult
<<role>> Employee
<<mediation>>
<<relator>> Employment
<<mediation>>
<<role>> Employer
<<kind>> Organization
<<phase>> Active Organization
<<phase>> Extinct Organization
1
1
1
1
1
1...*
1..*
1
Log
OntoUML


OntoUML introduction * - Visual Paradigm Modeler
Dash
Project
ITSM
Agile
Diagram
View
Team
Tools
Modeling
Window
Help
Plugin
Check Model
Check Diagram
Export to JSON
Export to gUFO
Update Plugin
Settings
Report Error
OntoUML introduction
Cursor
<default package>
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
Diagram Navigator
Property
Diagram Backlog
<<category>> Physical Object
<<kind>> Person
<<kind>> Heart
<<kind>> Brain
1
1
1
1
{essential, inseparable}
<<phase>> Living Person
<<phase>> Deceased Person
<<phase>> Functional Brain
<<phase>> Non-Functional Brain
<<kind>> Organization
<<phase>> Active Organization
<<phase>> Extinct Organization
<<phase>> Child
<<phase>> Adolescent
<<phase>> Adult
<<role>> Employee
<<mediation>>
1
1...*
<<relator>> Employment
<<mediation>>
1..*
1
<<role>> Employer
[2020-12-16 22:13:13.445] ERROR: Every sortal class must specialize a unique ultimate sortal. The class Employer must specialize (directly or indirectly) a unique class decorated as one of the following: «kind», «collectiv
[2020-12-16 22:13:13.445] ERROR: Missing 'allowed' natures meta-property. The class Employer is missing the 'allowed' natures meta-property
Take me there!
Open Specification

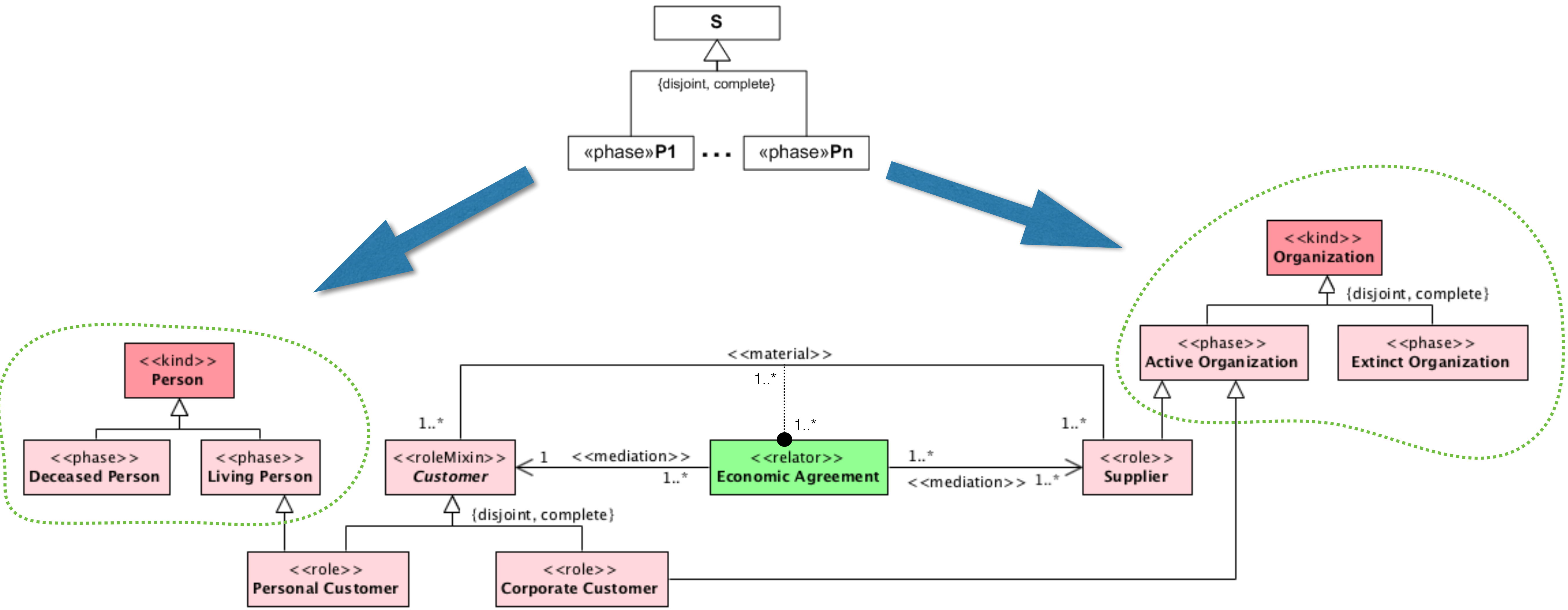

OntoUML introduction * - Visual Paradigm Modeler
Dash Project ITSM Agile Diagram View Team Tools Modeling Window Help Plugin
Check Model
Check Diagram
Export to JSON
Export to gUFO
Update Plugin
Settings
Report Error
OntoUML introduction
Cursor
<default package>
Class
Generalization
Usage
Association
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
<<category>> Physical Object
<<kind>> Person
<<kind>> Heart
<<kind>> Brain
{essential, inseparable}
<<phase>> Living Person
<<phase>> Deceased Person
<<phase>> Functional Brain
<<phase>> Non-Functional Brain
<<kind>> Organization
<<phase>> Active Organization
<<phase>> Extinct Organization
<<phase>> Child
<<phase>> Adolescent
<<phase>> Adult
<<role>> Employee
<<mediation>>
<<relator>> Employment
<<mediation>>
<<role>> Employer
[2020-12-16 22:13:13.445] ERROR: Every sortal class must specialize a unique ultimate sortal. The class Employer must specialize (directly or indirectly) a unique class decorated as one of the following: «kind», «collectiv
[2020-12-16 22:13:13.445] ERROR: Missing 'allowed' natures meta-property. The class Employer is missing the 'allowed' natures meta-property.

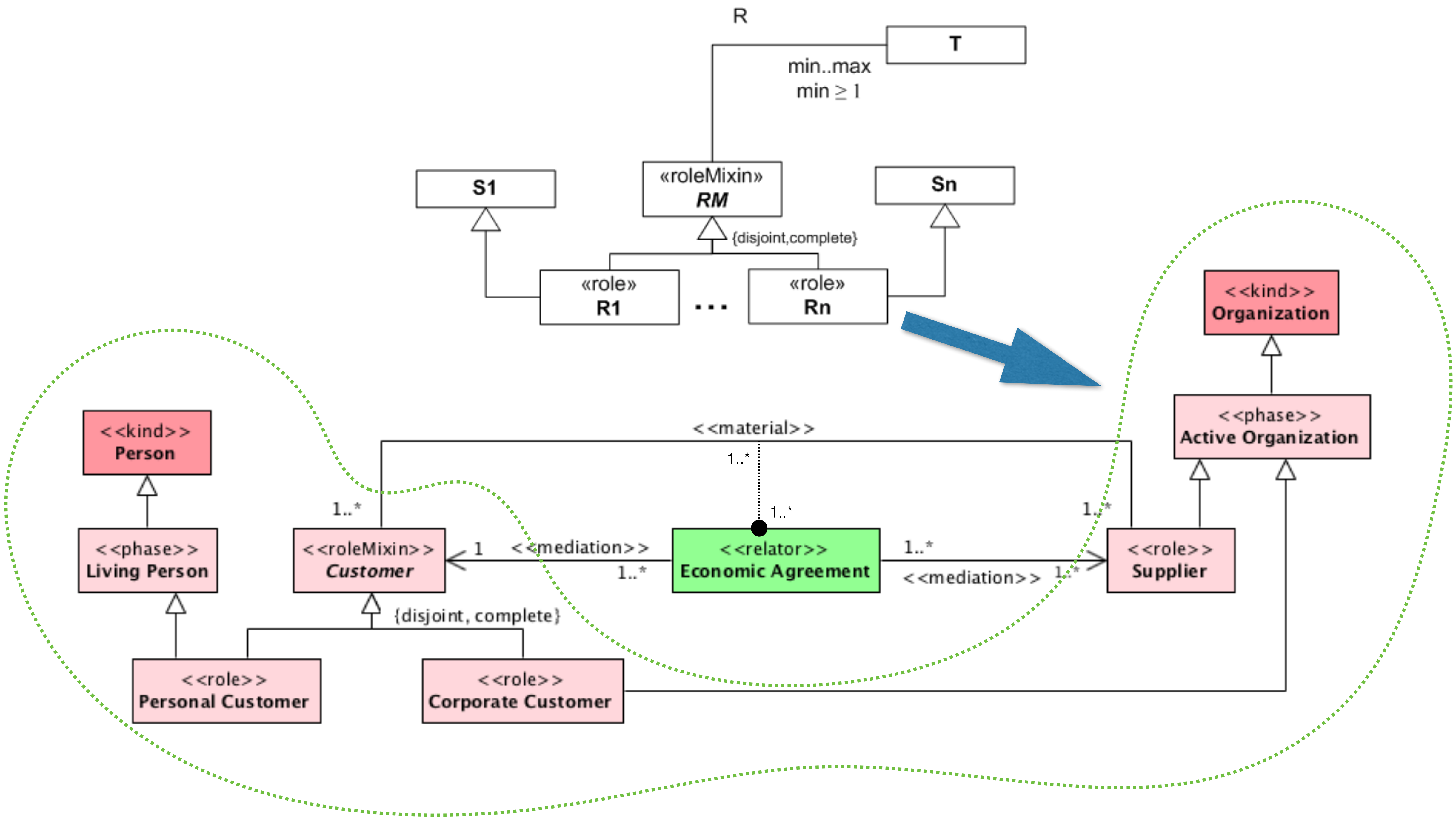
The Emerging **Role** Pattern



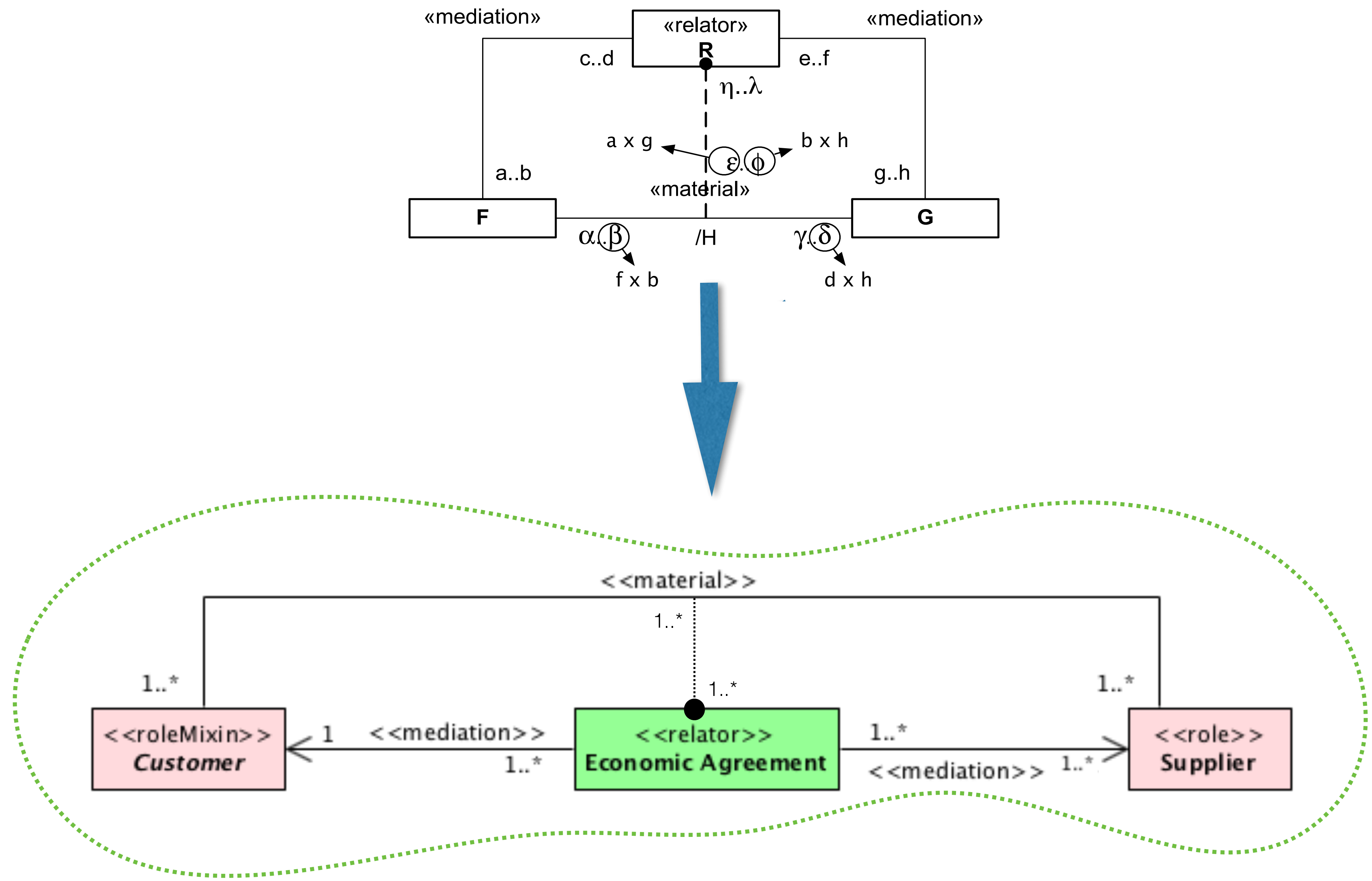


«kind»
A
...
«role»
B
enrolled at
m..n
C
<<kind>>
Person
<<phase>>
Deceased Person
<<phase>>
Living Person
<<role>>
Personal Customer
<<roleMixin>>
Customer
{disjoint, complete}
<<role>>
Corporate Customer
<<material>>
1..*
1..*
1..*
1
<<mediation>>
1..*
<<relator>>
Economic Agreement
1..*
<<mediation>>
1
1..*
<<role>>
Supplier
1..*
<<kind>>
Organization
{disjoint, complete}
<<phase>>
Active Organization
<<phase>>
Extinct Organization

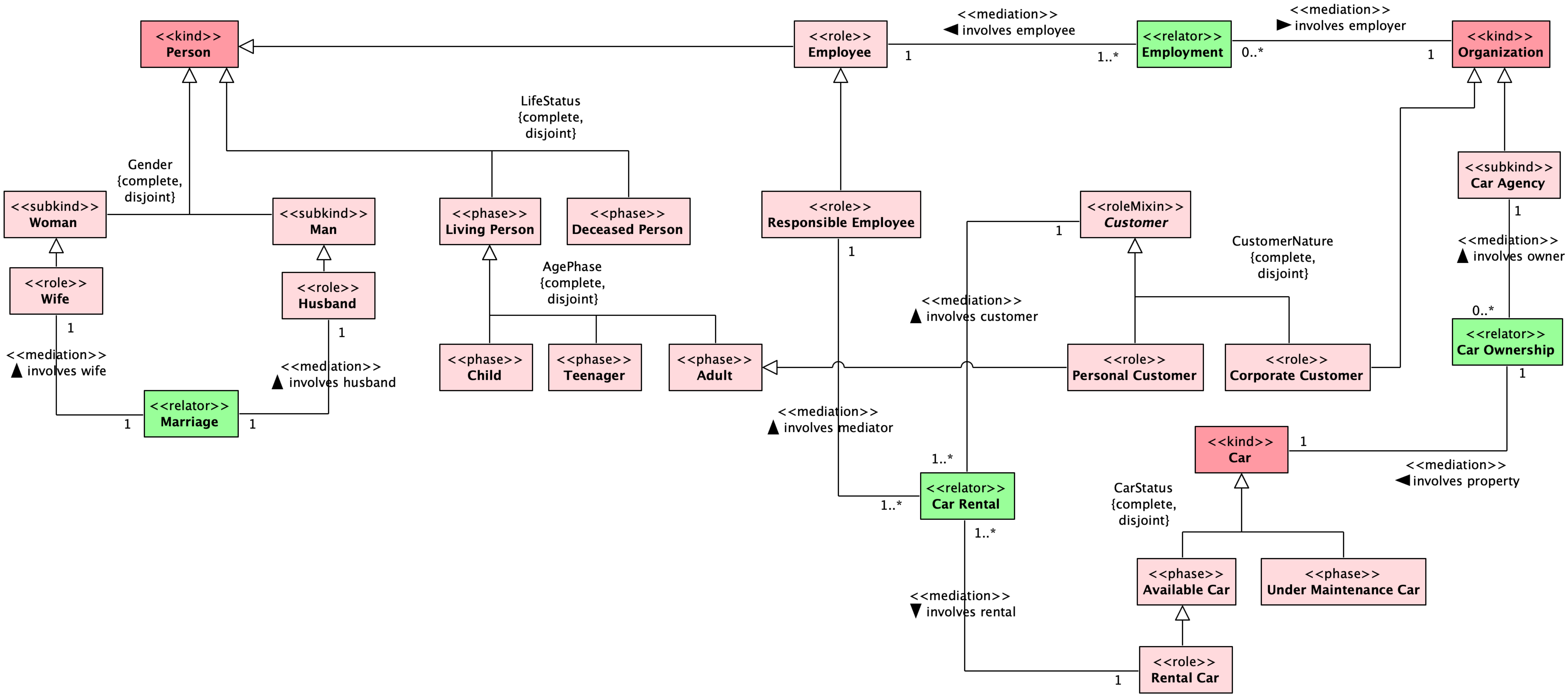

S
{disjoint, complete}
«phase»P1
...
«phase»Pn
<<kind>>
Person
<<phase>>
Deceased Person
<<phase>>
Living Person
<<role>>
Personal Customer
<<roleMixin>>
Customer
{disjoint, complete}
<<role>>
Corporate Customer
<<material>>
1..*
1..*
1..*
1
<<mediation>>
1..*
<<relator>>
Economic Agreement
1..*
<<mediation>>
1..*
1..*
<<role>>
Supplier
<<kind>>
Organization
{disjoint, complete}
<<phase>>
Active Organization
<<phase>>
Extinct Organization

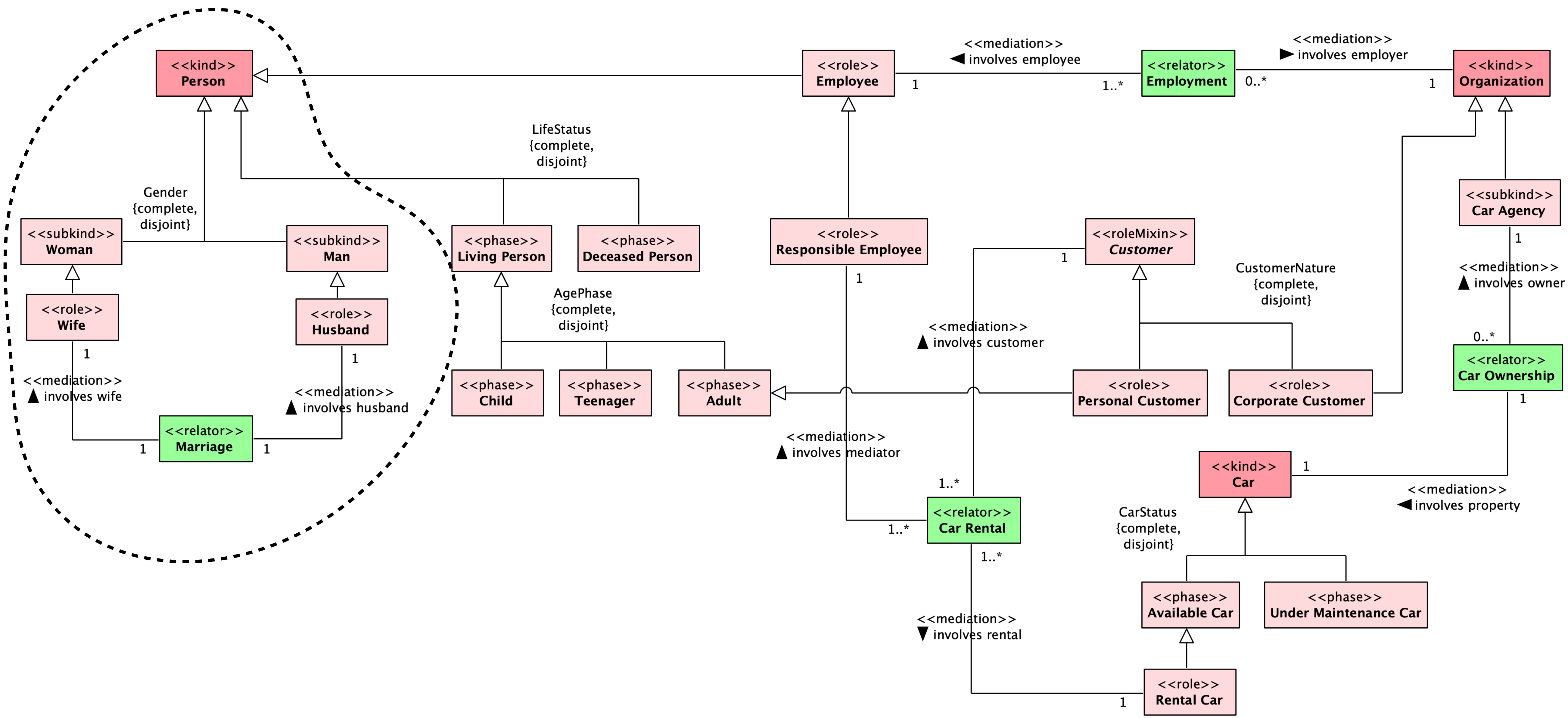


R
T
min..max
min ≥ 1
«roleMixin»
RM
S1
Sn
{disjoint,complete}
«role»
R1
...
«role»
Rn
<<kind>>
Organization
<<phase>>
Active Organization
<<kind>>
Person
<<material>>
1..*
1..*
1..*
1..*
<<phase>>
Living Person
<<roleMixin>>
Customer
1
<<mediation>>
1..*
<<relator>>
Economic Agreement
1..*
<<mediation>>
1..*
<<role>>
Supplier
{disjoint, complete}
<<role>>
Personal Customer
<<role>>
Corporate Customer

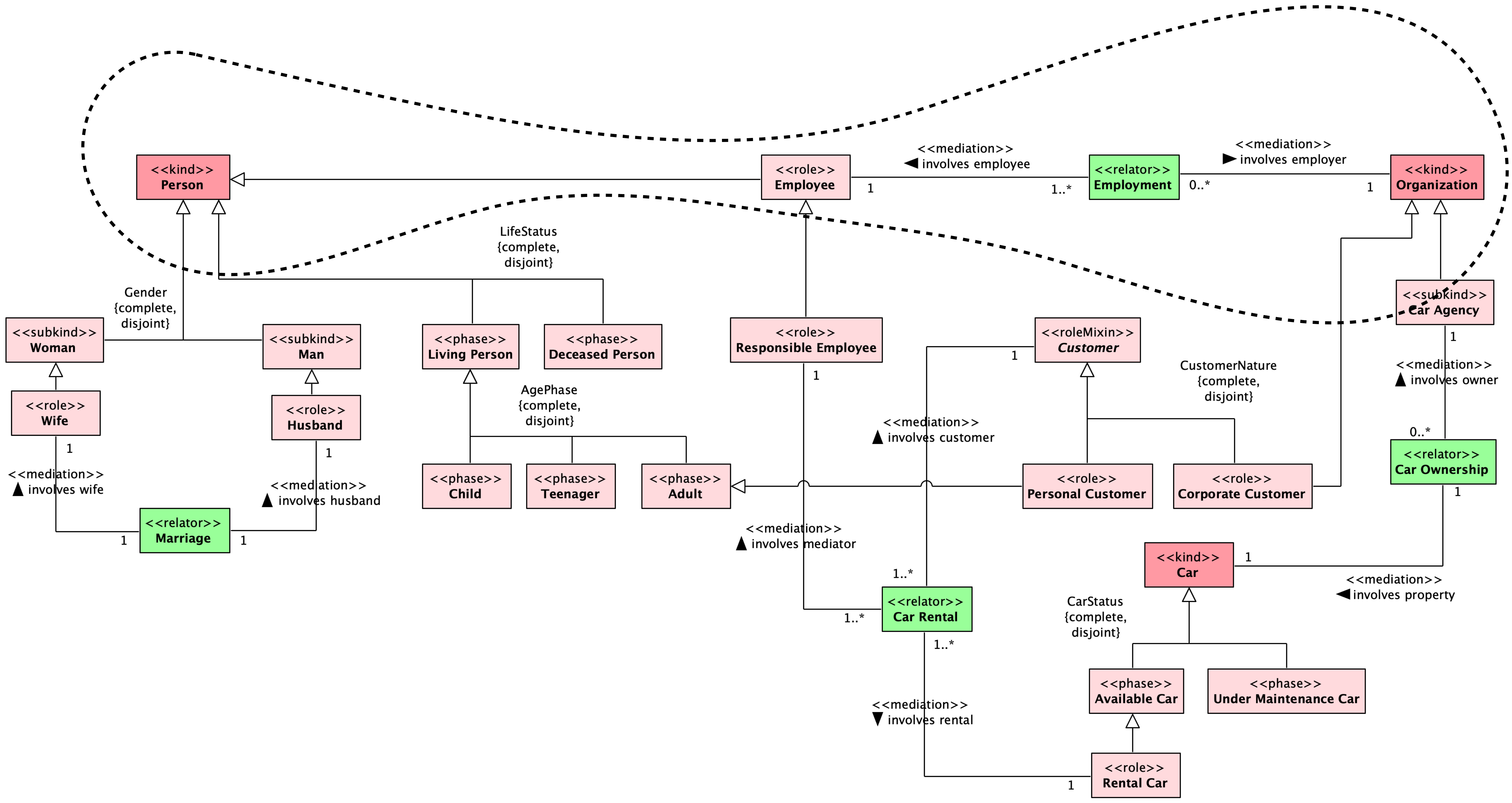

«relator»
R
«mediation»
«mediation»
c..d
e..f
η..λ
a x g
b x h
ε..ϕ
a..b
g..h
«material»
F
G
α..β
/H
γ..δ
f x b
d x h
<<material>>
1..*
1..*
1..*
1..*
<<roleMixin>>
Customer
1
<<mediation>>
1..*
<<relator>>
Economic Agreement
1..*
<<mediation>>
1..*
<<role>>
Supplier

4

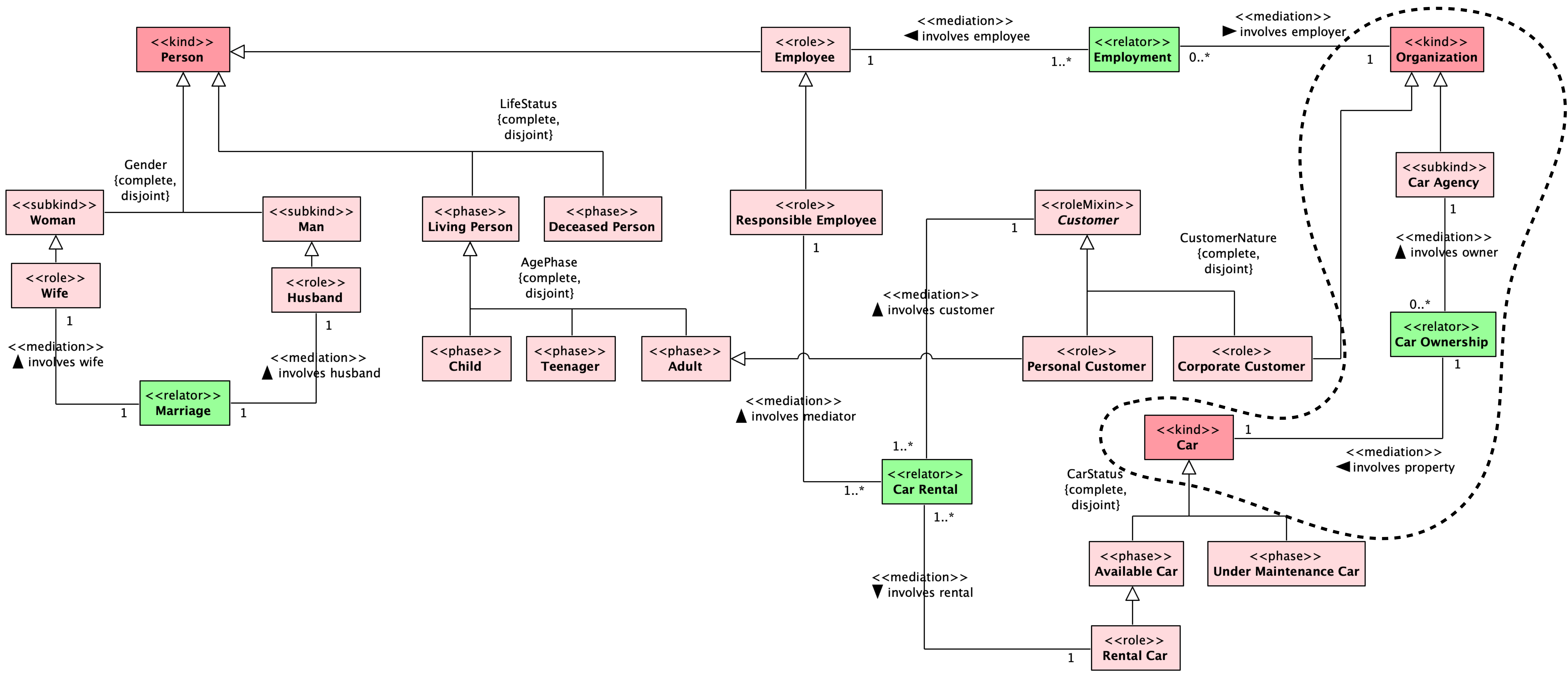

<<kind>>
Person
<<role>>
Employee
<<mediation>>
◀ involves employee
1
1..*
<<relator>>
Employment
<<mediation>>
▶ involves employer
0..*
1
<<kind>>
Organization
LifeStatus
{complete,
disjoint}
Gender
{complete,
disjoint}
<<subkind>>
Woman
<<subkind>>
Man
<<phase>>
Living Person
<<phase>>
Deceased Person
<<role>>
Responsible Employee
<<roleMixin>>
Customer
<<subkind>>
Car Agency
1
<<role>>
Wife
<<role>>
Husband
AgePhase
{complete,
disjoint}
1
1
CustomerNature
{complete,
disjoint}
<<mediation>>
▲ involves owner
<<mediation>>
▲ involves customer
0..*
<<relator>>
Car Ownership
1
<<mediation>>
▲ involves wife
1
<<mediation>>
▲ involves husband
<<phase>>
Child
<<phase>>
Teenager
<<phase>>
Adult
<<role>>
Personal Customer
<<role>>
Corporate Customer
1
<<relator>>
Marriage
1
1
<<mediation>>
▲ involves mediator
<<kind>>
Car
1
<<mediation>>
◀ involves property
1..*
<<relator>>
Car Rental
1..*
1..*
CarStatus
{complete,
disjoint}
<<phase>>
Available Car
<<phase>>
Under Maintenance Car
<<mediation>>
▼ involves rental
<<role>>
Rental Car
1



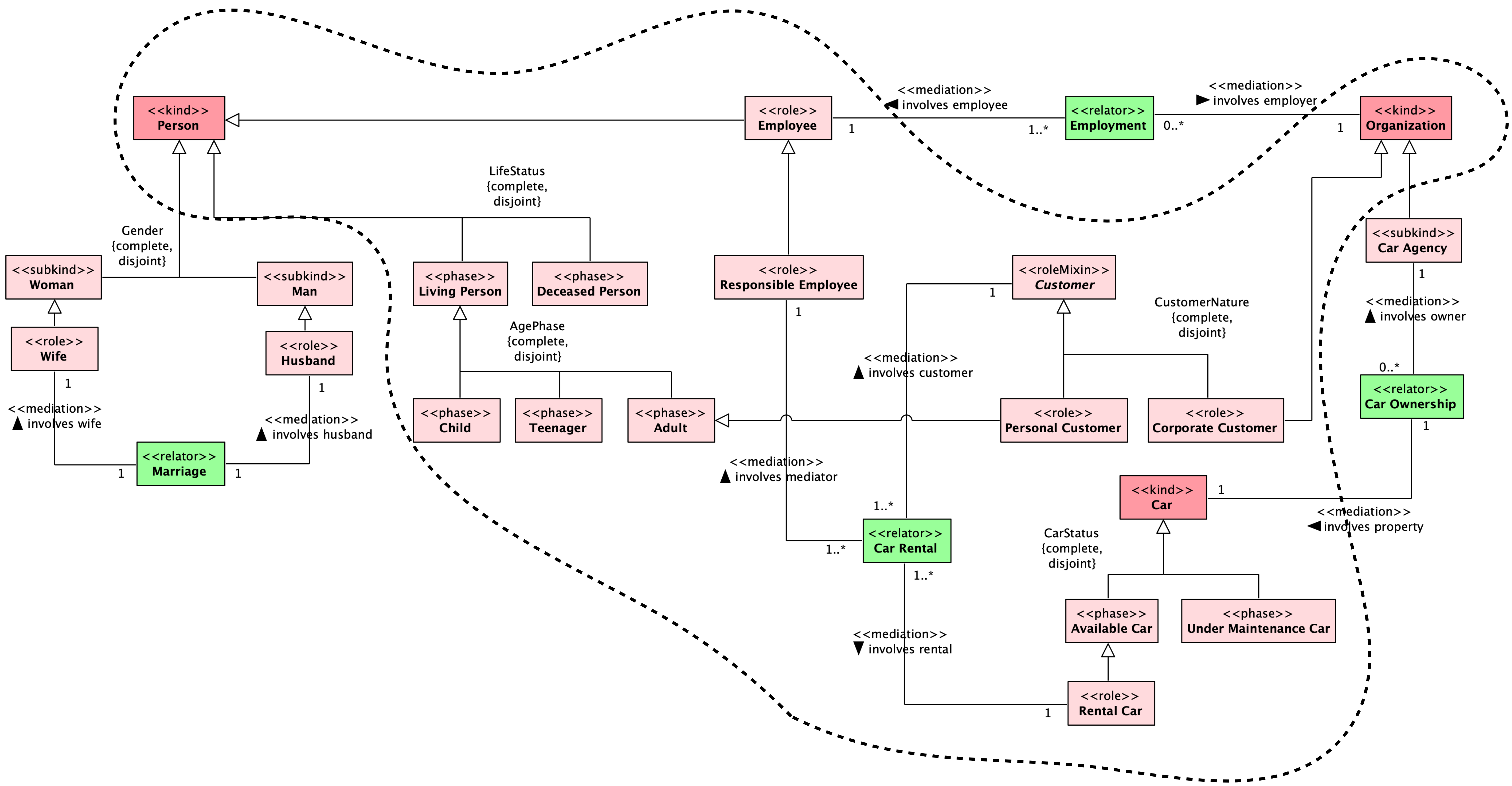
<<kind>> Person
<<role>> Employee
<<mediation>> involves employee
<<relator>> Employment
<<mediation>> involves employer
<<kind>> Organization
1
1..*
0..*
1
LifeStatus {complete, disjoint}
Gender {complete, disjoint}
<<subkind>> Woman
<<subkind>> Man
<<phase>> Living Person
<<phase>> Deceased Person
<<role>> Responsible Employee
<<roleMixin>> Customer
<<subkind>> Car Agency
<<role>> Wife
<<role>> Husband
AgePhase {complete, disjoint}
CustomerNature {complete, disjoint}
<<mediation>> involves owner
<<mediation>> involves customer
<<mediation>> involves wife
<<mediation>> involves husband
<<phase>> Child
<<phase>> Teenager
<<phase>> Adult
<<role>> Personal Customer
<<role>> Corporate Customer
<<relator>> Car Ownership
<<relator>> Marriage
<<mediation>> involves mediator
<<kind>> Car
<<mediation>> involves property
<<relator>> Car Rental
CarStatus {complete, disjoint}
<<phase>> Available Car
<<phase>> Under Maintenance Car
<<mediation>> involves rental
<<role>> Rental Car



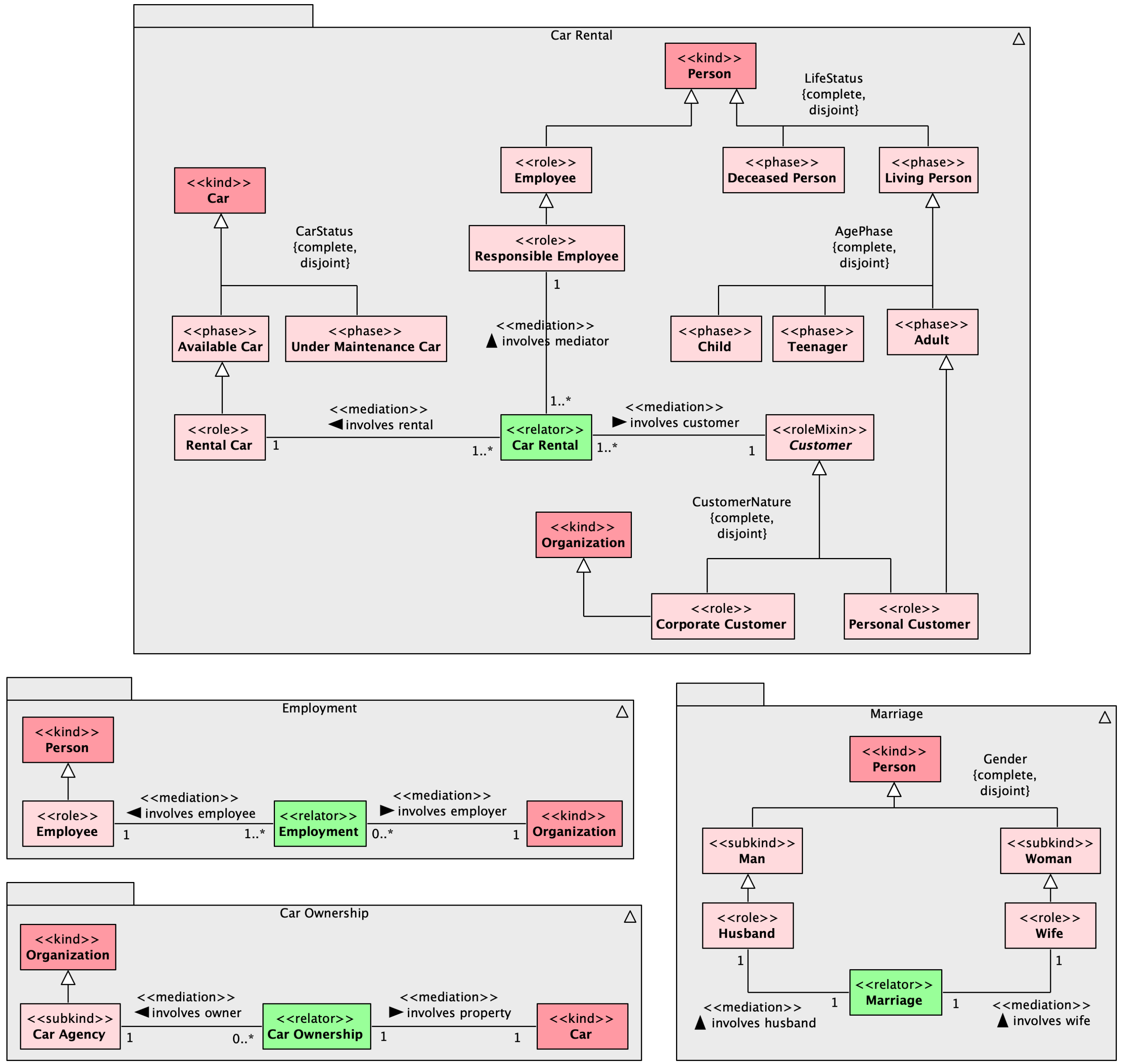
<<kind>> Person
<<role>> Employee
<<mediation>> involves employee
<<relator>> Employment
<<mediation>> involves employer
<<kind>> Organization
1
1..*
0..*
1
LifeStatus {complete, disjoint}
Gender {complete, disjoint}
<<subkind>> Woman
<<subkind>> Man
<<phase>> Living Person
<<phase>> Deceased Person
<<role>> Responsible Employee
<<roleMixin>> Customer
<<subkind>> Car Agency
<<role>> Wife
<<role>> Husband
AgePhase {complete, disjoint}
CustomerNature {complete, disjoint}
<<mediation>> involves owner
<<mediation>> involves customer
<<relator>> Car Ownership
<<mediation>> involves wife
<<mediation>> involves husband
<<phase>> Child
<<phase>> Teenager
<<phase>> Adult
<<role>> Personal Customer
<<role>> Corporate Customer
<<relator>> Marriage
<<mediation>> involves mediator
<<kind>> Car
<<mediation>> involves property
<<relator>> Car Rental
CarStatus {complete, disjoint}
<<phase>> Available Car
<<phase>> Under Maintenance Car
<<mediation>> involves rental
<<role>> Rental Car

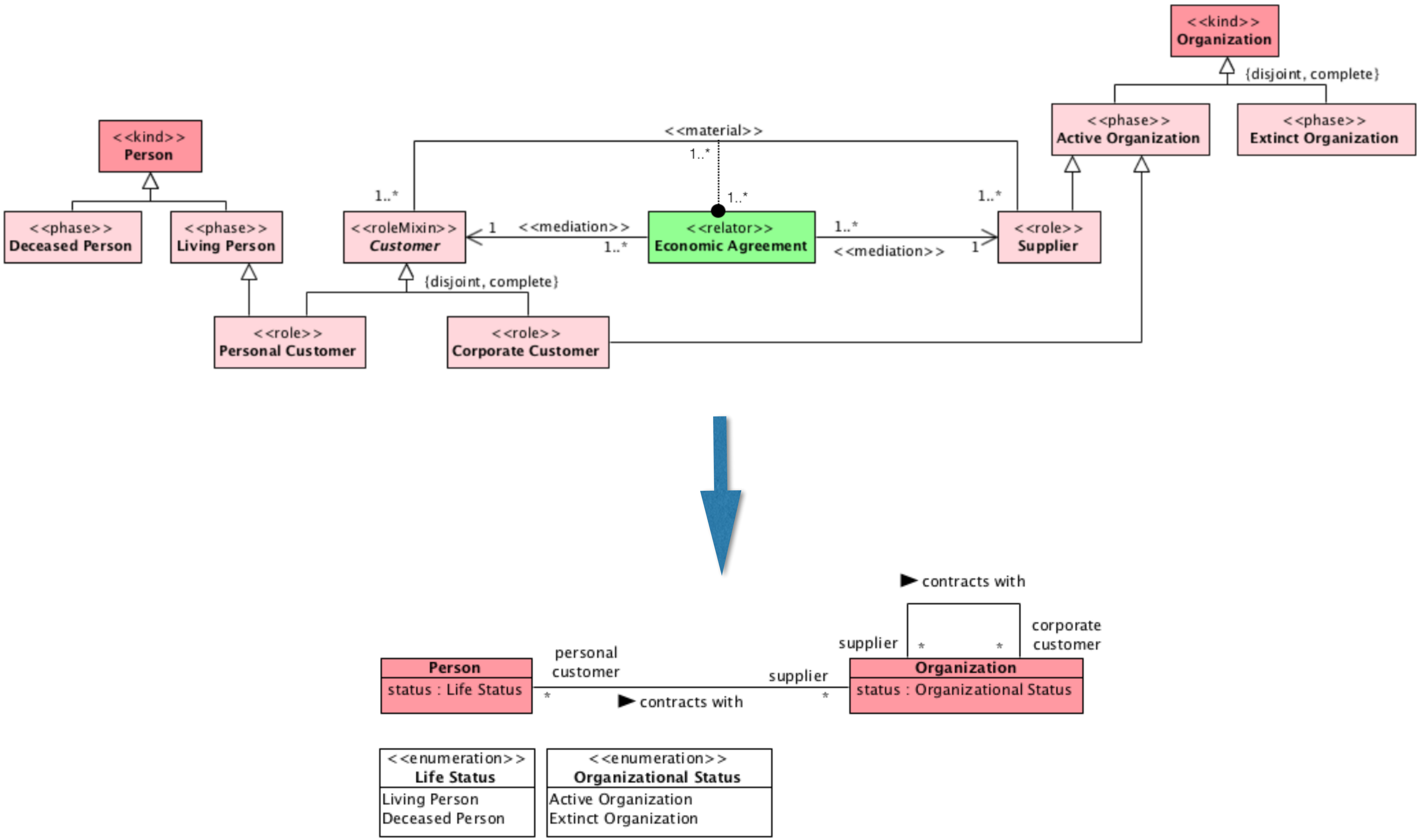


<<kind>> Person
<<role>> Employee
<<mediation>> ◀ involves employee
<<relator>> Employment
<<mediation>> ▶ involves employer
<<kind>> Organization
LifeStatus {complete, disjoint}
Gender {complete, disjoint}
<<subkind>> Woman
<<subkind>> Man
<<phase>> Living Person
<<phase>> Deceased Person
<<role>> Responsible Employee
<<roleMixin>> Customer
<<subkind>> Car Agency
<<role>> Wife
<<role>> Husband
AgePhase {complete, disjoint}
CustomerNature {complete, disjoint}
<<mediation>> ▲ involves owner
<<mediation>> ▲ involves customer
<<mediation>> ▲ involves wife
<<mediation>> ▲ involves husband
<<phase>> Child
<<phase>> Teenager
<<phase>> Adult
<<role>> Personal Customer
<<role>> Corporate Customer
<<relator>> Car Ownership
<<relator>> Marriage
<<mediation>> ▲ involves mediator
<<kind>> Car
<<mediation>> ◀ involves property
<<relator>> Car Rental
CarStatus {complete, disjoint}
<<phase>> Available Car
<<phase>> Under Maintenance Car
<<mediation>> ▼ involves rental
<<role>> Rental Car



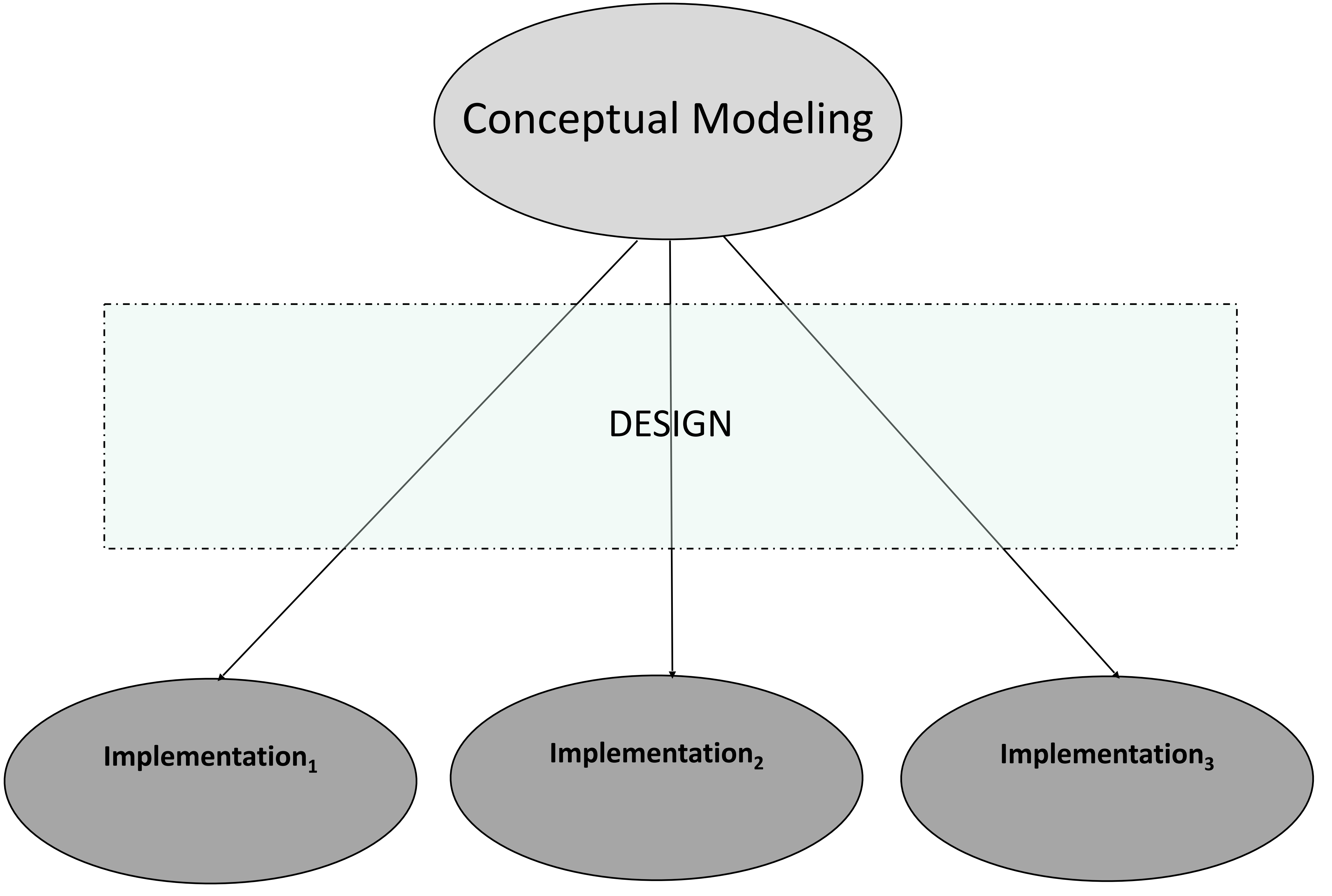
<<kind>> Person
<<role>> Employee
<<relator>> Employment
<<kind>> Organization
<<mediation>> involves employee
<<mediation>> involves employer
LifeStatus {complete, disjoint}
Gender {complete, disjoint}
<<subkind>> Woman
<<subkind>> Man
<<phase>> Living Person
<<phase>> Deceased Person
<<role>> Responsible Employee
<<roleMixin>> Customer
CustomerNature {complete, disjoint}
<<subkind>> Car Agency
<<mediation>> involves owner
<<role>> Wife
<<role>> Husband
AgePhase {complete, disjoint}
<<mediation>> involves customer
<<relator>> Car Ownership
<<mediation>> involves wife
<<mediation>> involves husband
<<phase>> Child
<<phase>> Teenager
<<phase>> Adult
<<role>> Personal Customer
<<role>> Corporate Customer
<<relator>> Marriage
<<mediation>> involves mediator
<<kind>> Car
<<mediation>> involves property
<<relator>> Car Rental
CarStatus {complete, disjoint}
<<phase>> Available Car
<<phase>> Under Maintenance Car
<<mediation>> involves rental
<<role>> Rental Car

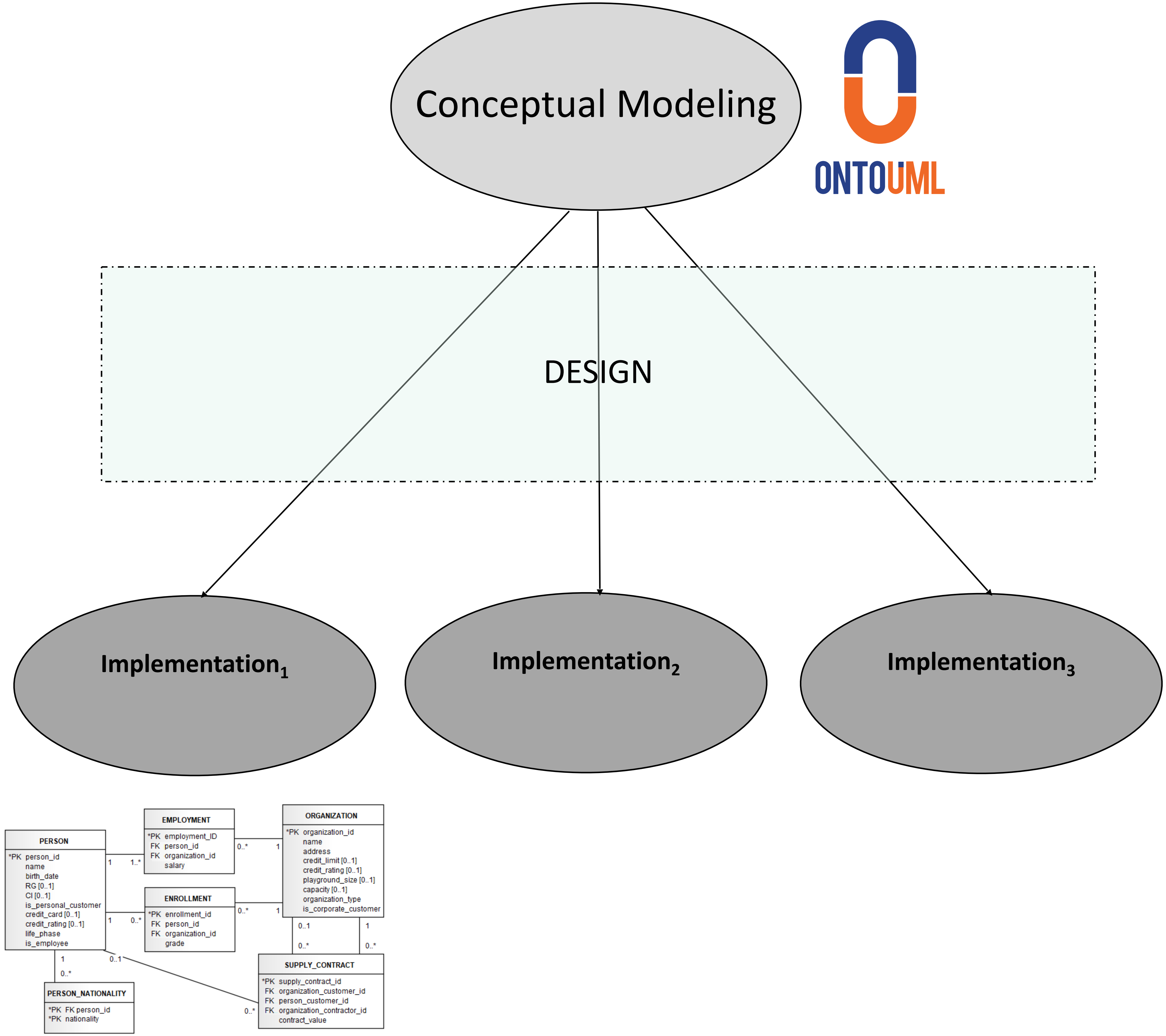

Car Rental
<<kind>> Person
LifeStatus {complete, disjoint}
<<role>> Employee
<<phase>> Deceased Person
<<phase>> Living Person
<<kind>> Car
CarStatus {complete, disjoint}
<<role>> Responsible Employee
AgePhase {complete, disjoint}
<<phase>> Available Car
<<phase>> Under Maintenance Car
<<mediation>> ▲ involves mediator
<<phase>> Child
<<phase>> Teenager
<<phase>> Adult
<<role>> Rental Car
<<mediation>> ◀ involves rental
<<relator>> Car Rental
<<mediation>> ▶ involves customer
<<roleMixin>> Customer
1
1..*
1
1..*
1..*
1
<<kind>> Organization
CustomerNature {complete, disjoint}
<<role>> Corporate Customer
<<role>> Personal Customer
Employment
<<kind>> Person
<<role>> Employee
<<mediation>> ◀ involves employee
<<relator>> Employment
<<mediation>> ▶ involves employer
<<kind>> Organization
1
1..*
0..*
1
Car Ownership
<<kind>> Organization
<<subkind>> Car Agency
<<mediation>> ◀ involves owner
<<relator>> Car Ownership
<<mediation>> ▶ involves property
<<kind>> Car
1
0..*
1
1
Marriage
<<kind>> Person
Gender {complete, disjoint}
<<subkind>> Man
<<subkind>> Woman
<<role>> Husband
<<role>> Wife
<<relator>> Marriage
1
1
1
1
<<mediation>> ▲ involves husband
<<mediation>> ▲ involves wife

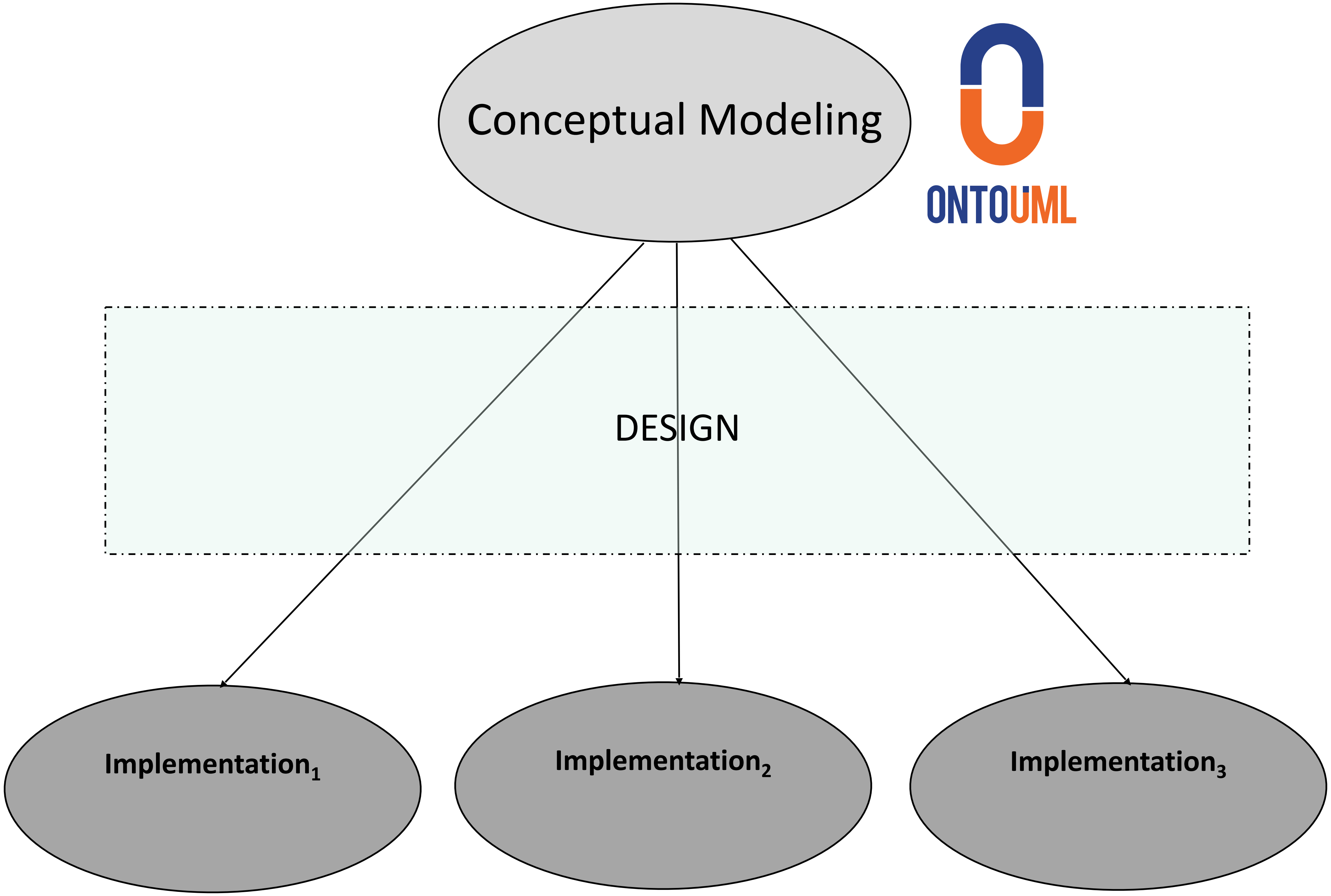


<<kind>>
Person
<<phase>>
Deceased Person
<<phase>>
Living Person
<<roleMixin>>
Customer
<<role>>
Personal Customer
<<role>>
Corporate Customer
{disjoint, complete}
<<material>>
1..*
1..*
1..*
1..*
1
<<mediation>>
1..*
<<relator>>
Economic Agreement
1..*
<<mediation>>
1
<<role>>
Supplier
<<kind>>
Organization
{disjoint, complete}
<<phase>>
Active Organization
<<phase>>
Extinct Organization
contracts with
supplier
corporate customer
Person
status : Life Status
personal customer
supplier
contracts with
Organization
status : Organizational Status
<<enumeration>>
Life Status
Living Person
Deceased Person
<<enumeration>>
Organizational Status
Active Organization
Extinct Organization

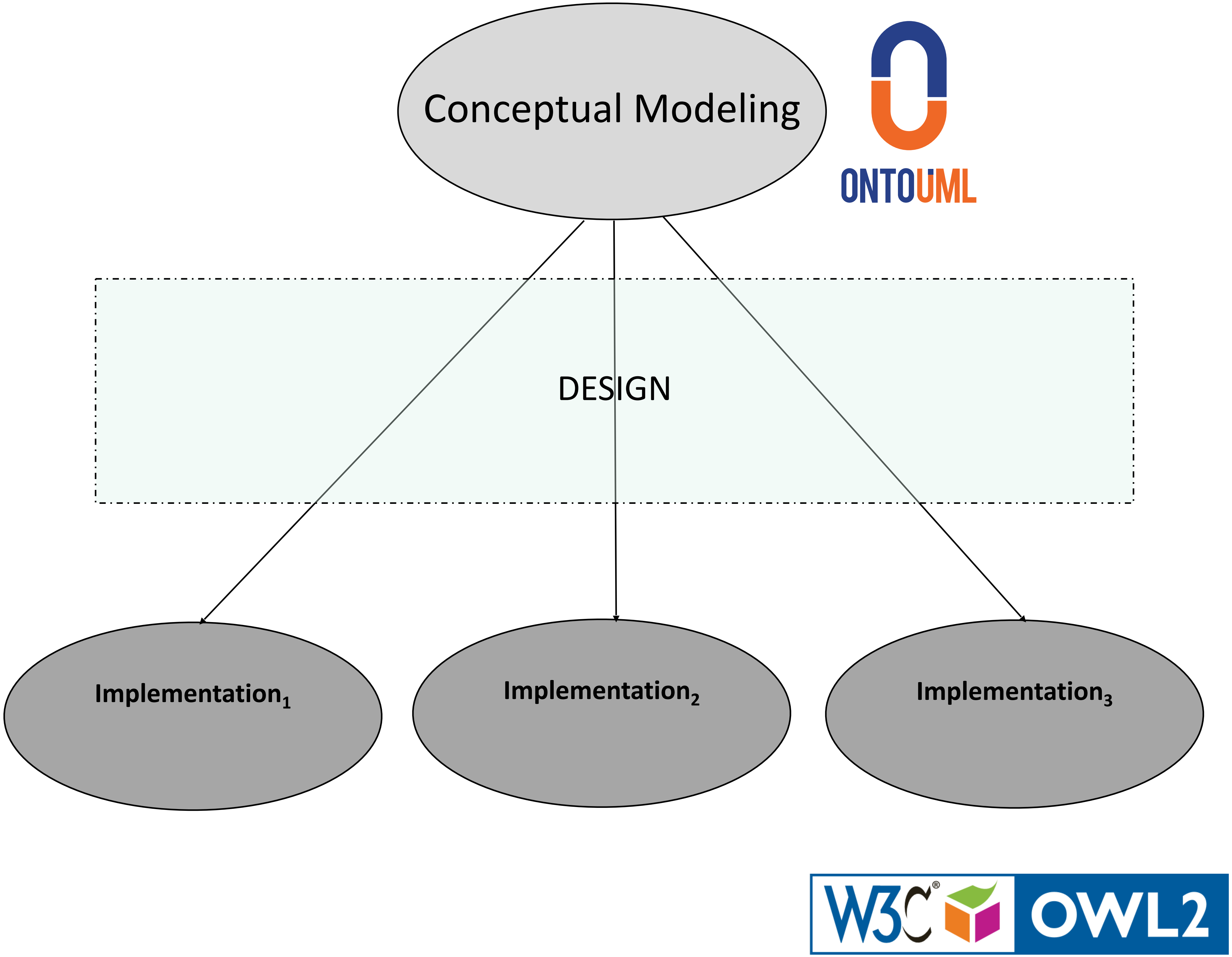
5

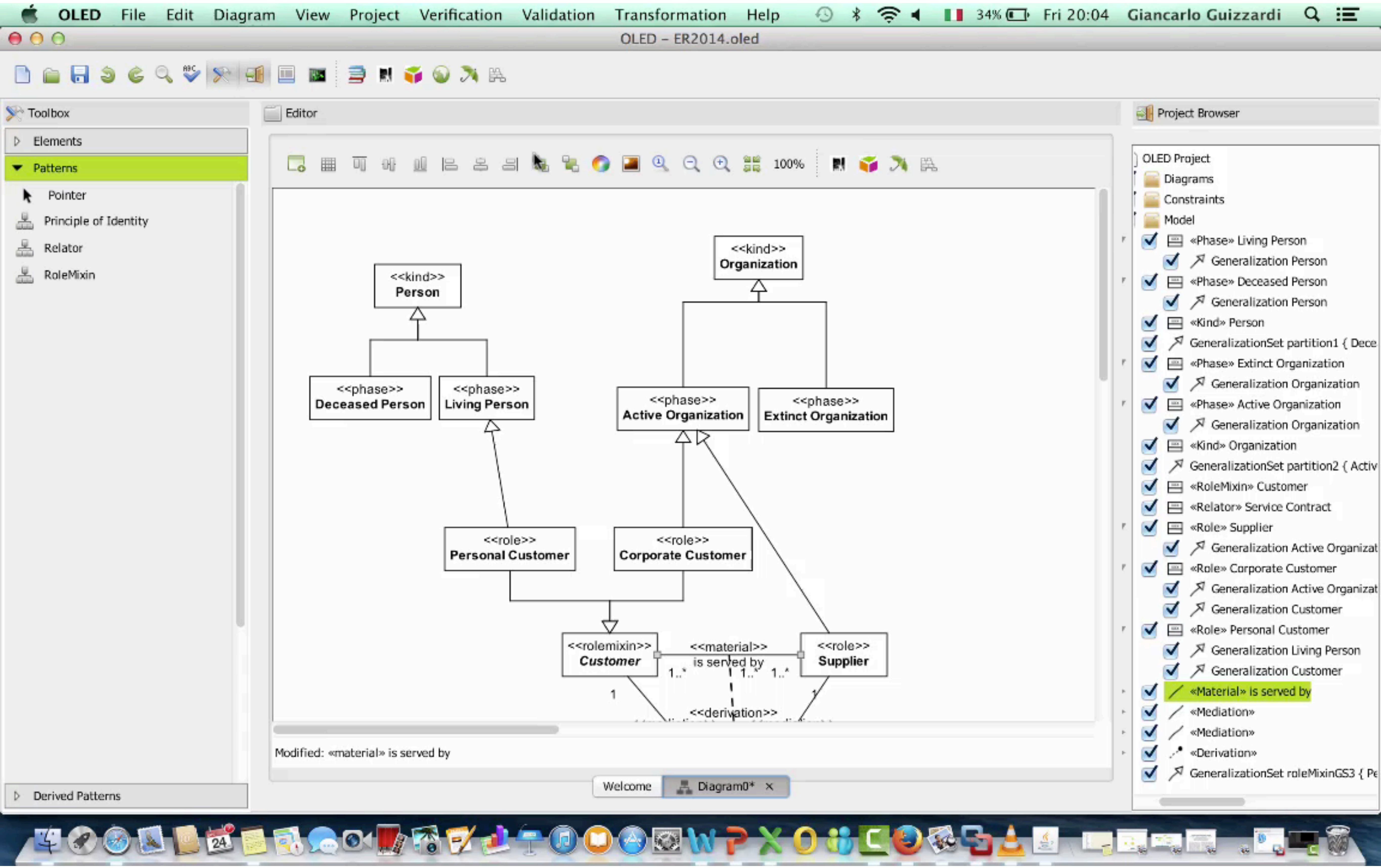

Conceptual Modeling
DESIGN
Implementation$_1$
Implementation$_2$
Implementation$_3$


Conceptual Modeling
ONTOUML
DESIGN
Implementation$_1$
Implementation$_2$
Implementation$_3$
PERSON
*PK person_id
name
birth_date
RG [0..1]
CI [0..1]
is_personal_customer
credit_card [0..1]
credit_rating [0..1]
life_phase
is_employee
EMPLOYMENT
*PK employment_ID
FK person_id
FK organization_id
salary
ENROLLMENT
*PK enrollment_id
FK person_id
FK organization_id
grade
ORGANIZATION
*PK organization_id
name
address
credit_limit [0..1]
credit_rating [0..1]
playground_size [0..1]
capacity [0..1]
organization_type
is_corporate_customer
PERSON_NATIONALITY
*PK FK person_id
*PK nationality
SUPPLY_CONTRACT
*PK supply_contract_id
FK organization_customer_id
FK person_customer_id
FK organization_contractor_id
contract_value

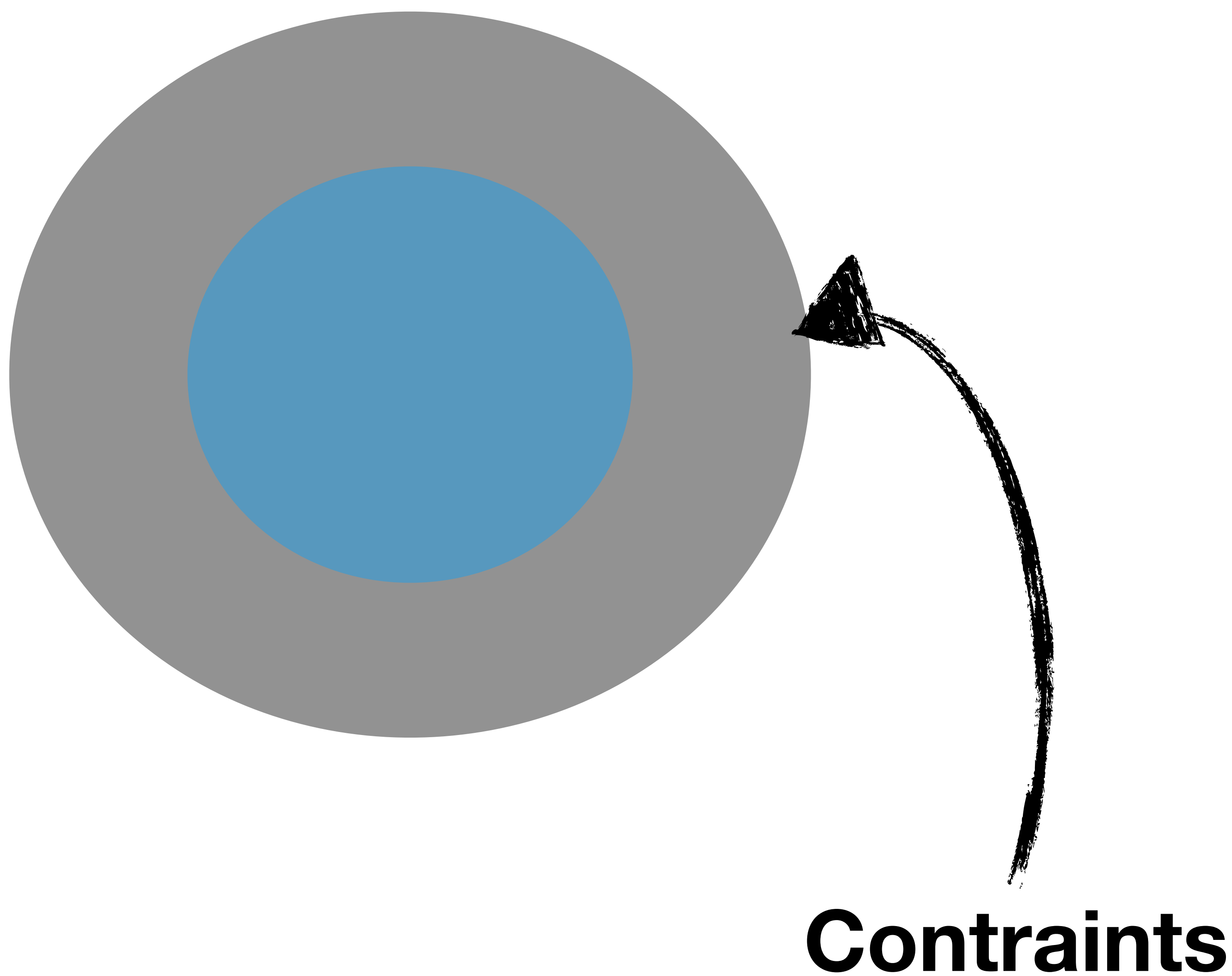


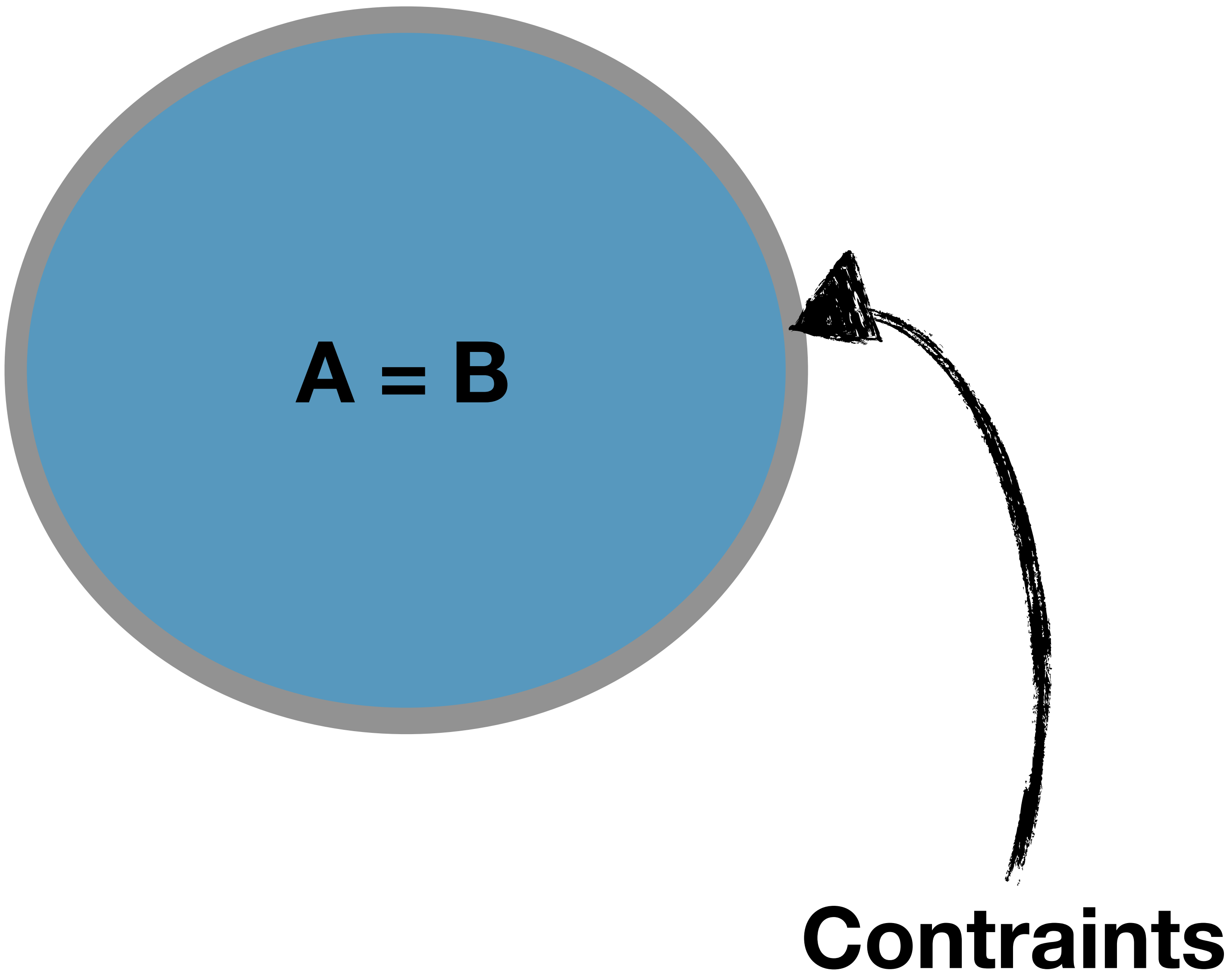

```
sig Person_Set in Concept { Person: some World }
{
  Person in existsIn
  all w1: World | w1 in Person => (all w2:
       w1.access | (w2 in existsIn) => (w2 in
       Person)) -- Rigidity
  some w: World | w in this.Child -- Phase
  some w: World | w in this.Teenager -- Phase
  some w: World | w in this.Adult -- Phase
  ⋮
}
```

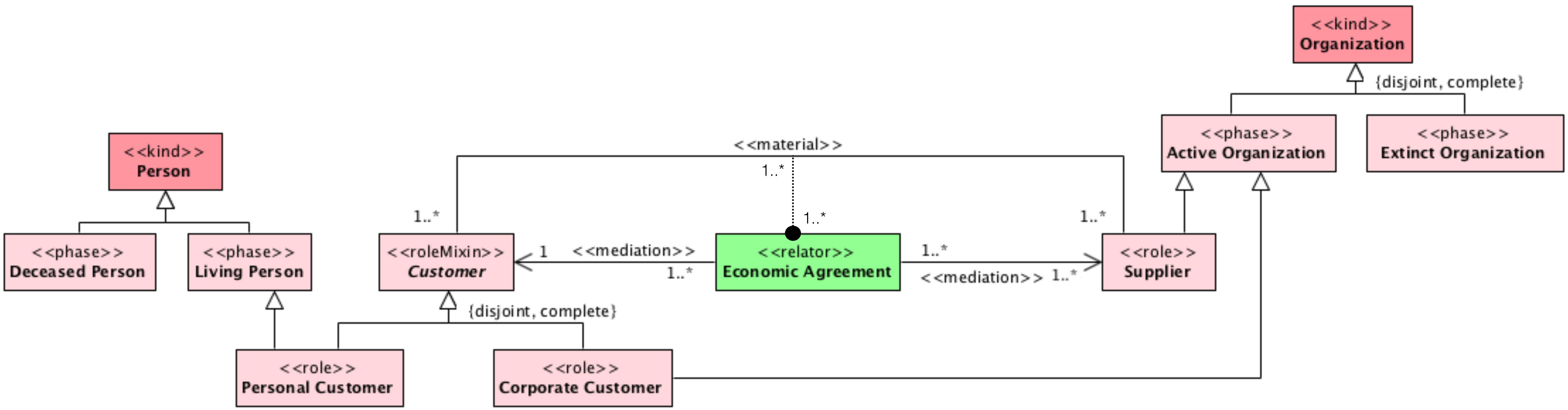

Conceptual Modeling
ONTOUML
DESIGN
Implementation$_1$
Implementation$_2$
Implementation$_3$
W3C
OWL2


OLED File Edit Diagram View Project Verification Validation Transformation Help
34% Fri 20:04 Giancarlo Guizzardi
OLED – ER2014.oled
Toolbox
Elements
Patterns
Pointer
Principle of Identity
Relator
RoleMixin
Derived Patterns
Editor
100%
<<kind>>
Person
<<kind>>
Organization
<<phase>>
Deceased Person
<<phase>>
Living Person
<<phase>>
Active Organization
<<phase>>
Extinct Organization
<<role>>
Personal Customer
<<role>>
Corporate Customer
<<rolemixin>>
Customer
<<material>>
is served by
<<role>>
Supplier
<<derivation>>
Modified: «material» is served by
Welcome
Diagram0*
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

6


Contraints


A = B
Contraints

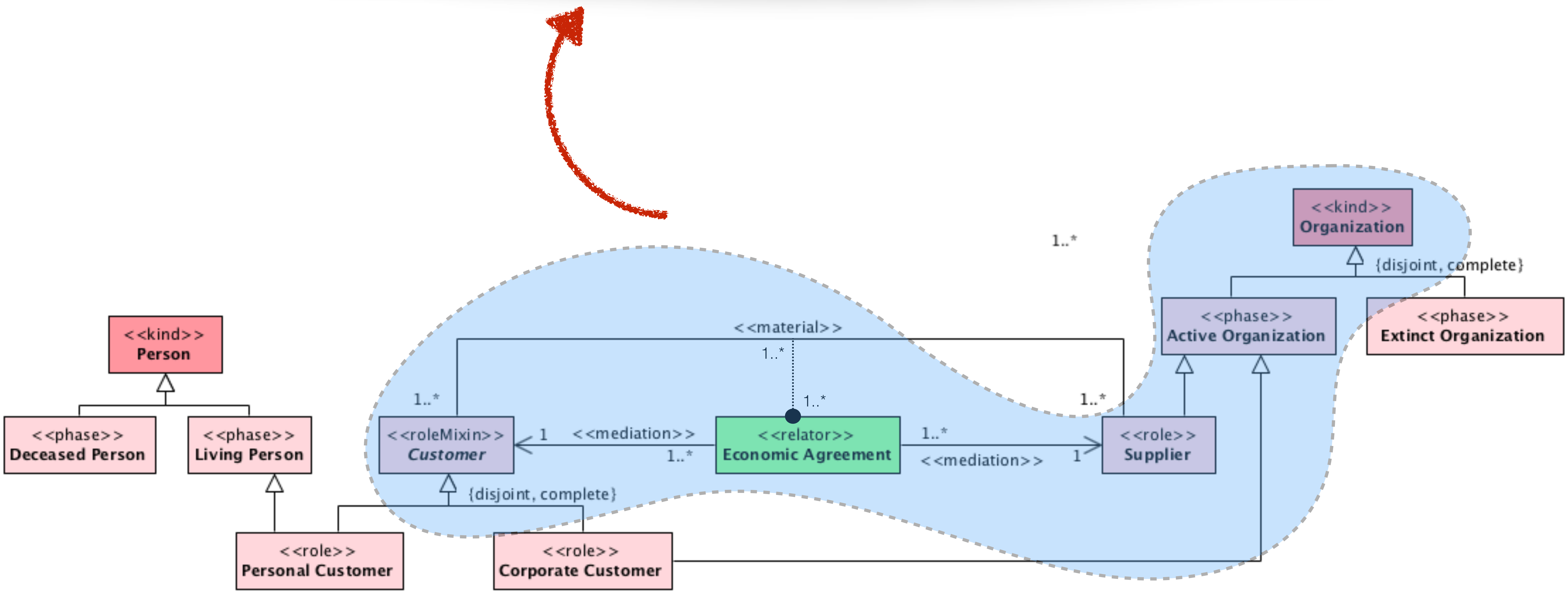


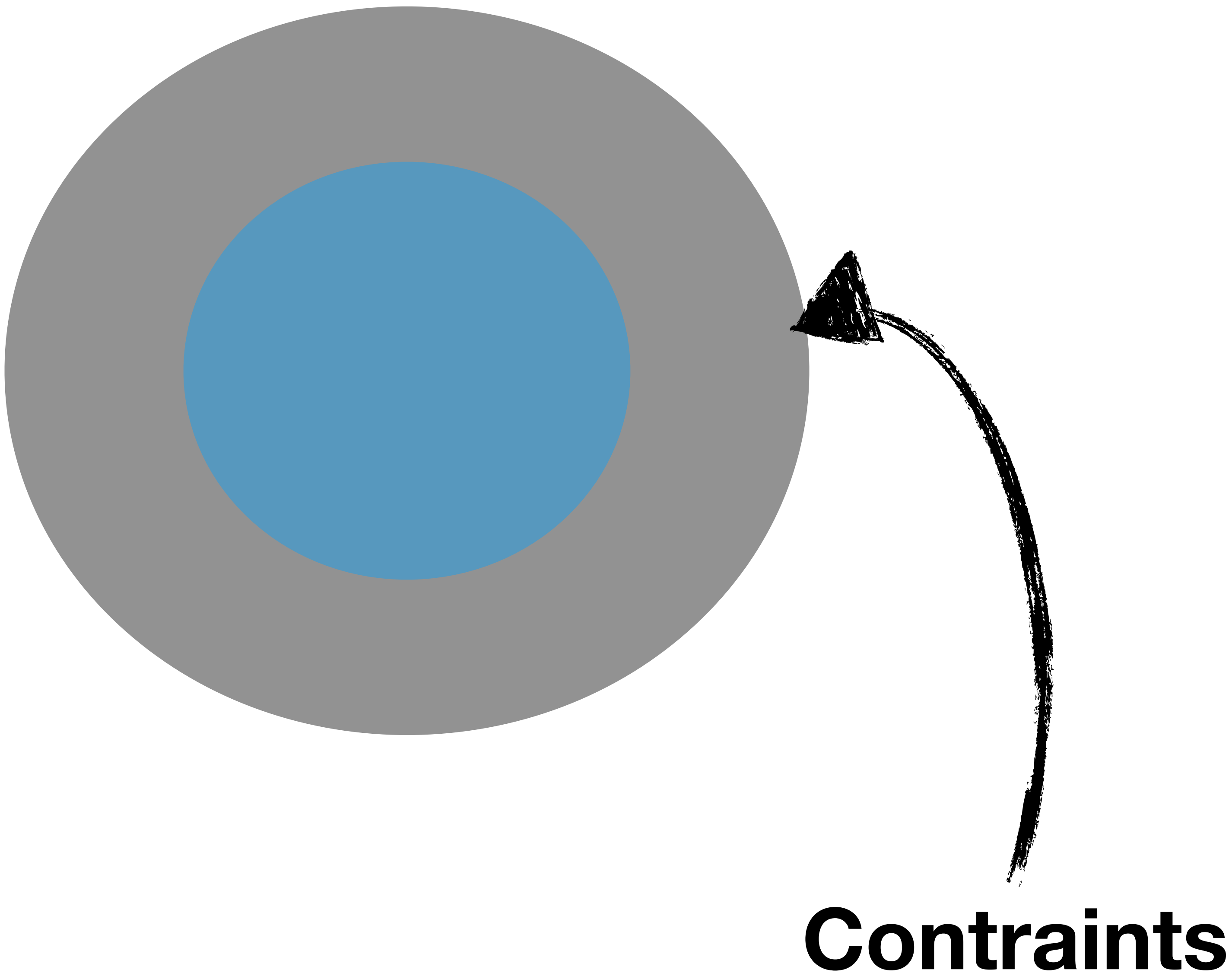
<<kind>>
Organization
{disjoint, complete}
<<phase>>
Active Organization
<<phase>>
Extinct Organization
<<kind>>
Person
<<material>>
1..*
1..*
1..*
1..*
<<phase>>
Deceased Person
<<phase>>
Living Person
<<roleMixin>>
Customer
1
<<mediation>>
1..*
<<relator>>
Economic Agreement
1..*
<<mediation>>
1..*
<<role>>
Supplier
{disjoint, complete}
<<role>>
Personal Customer
<<role>>
Corporate Customer

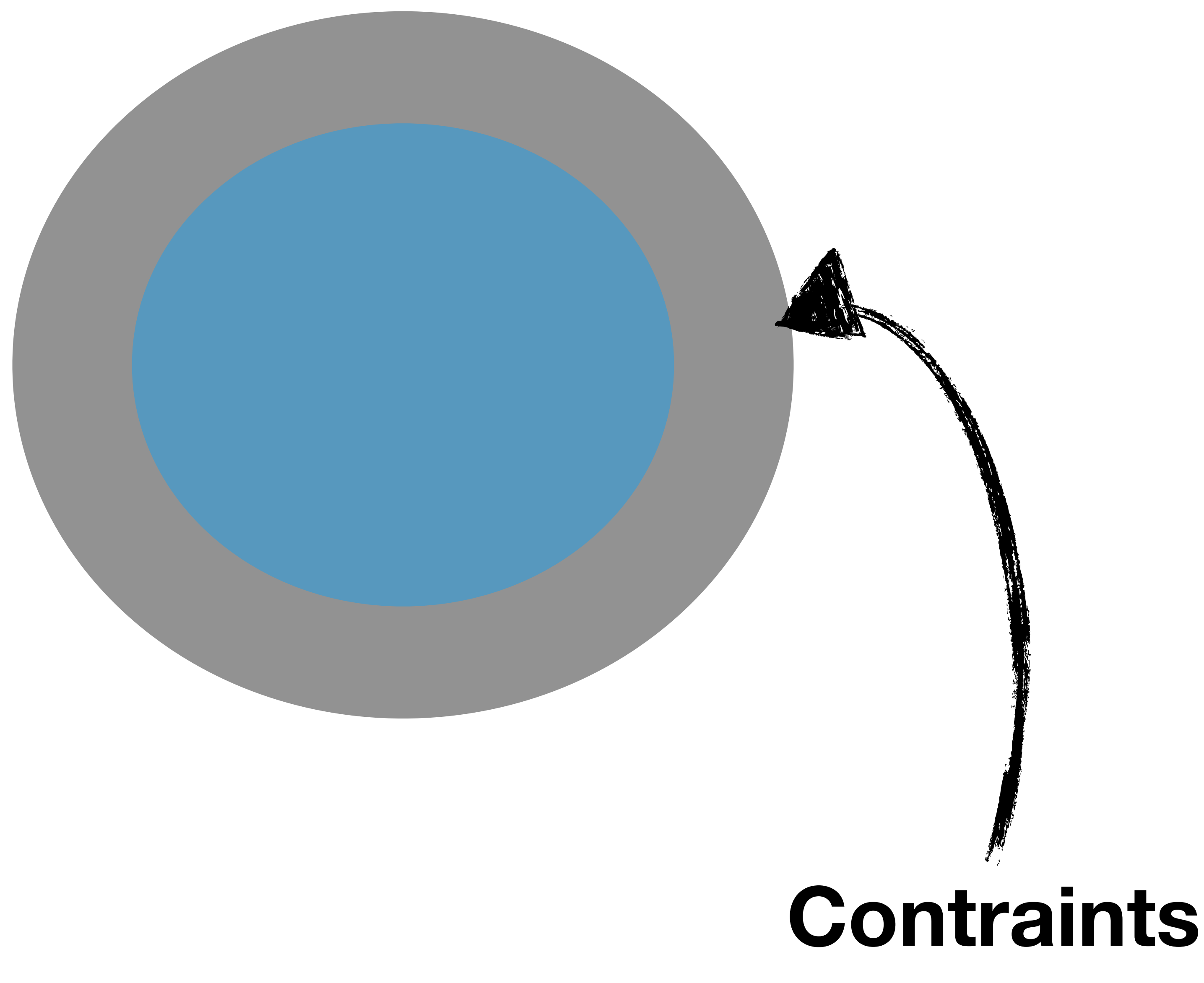
$$\forall x Supplier(x) \rightarrow ActiveOrganization(x)$$

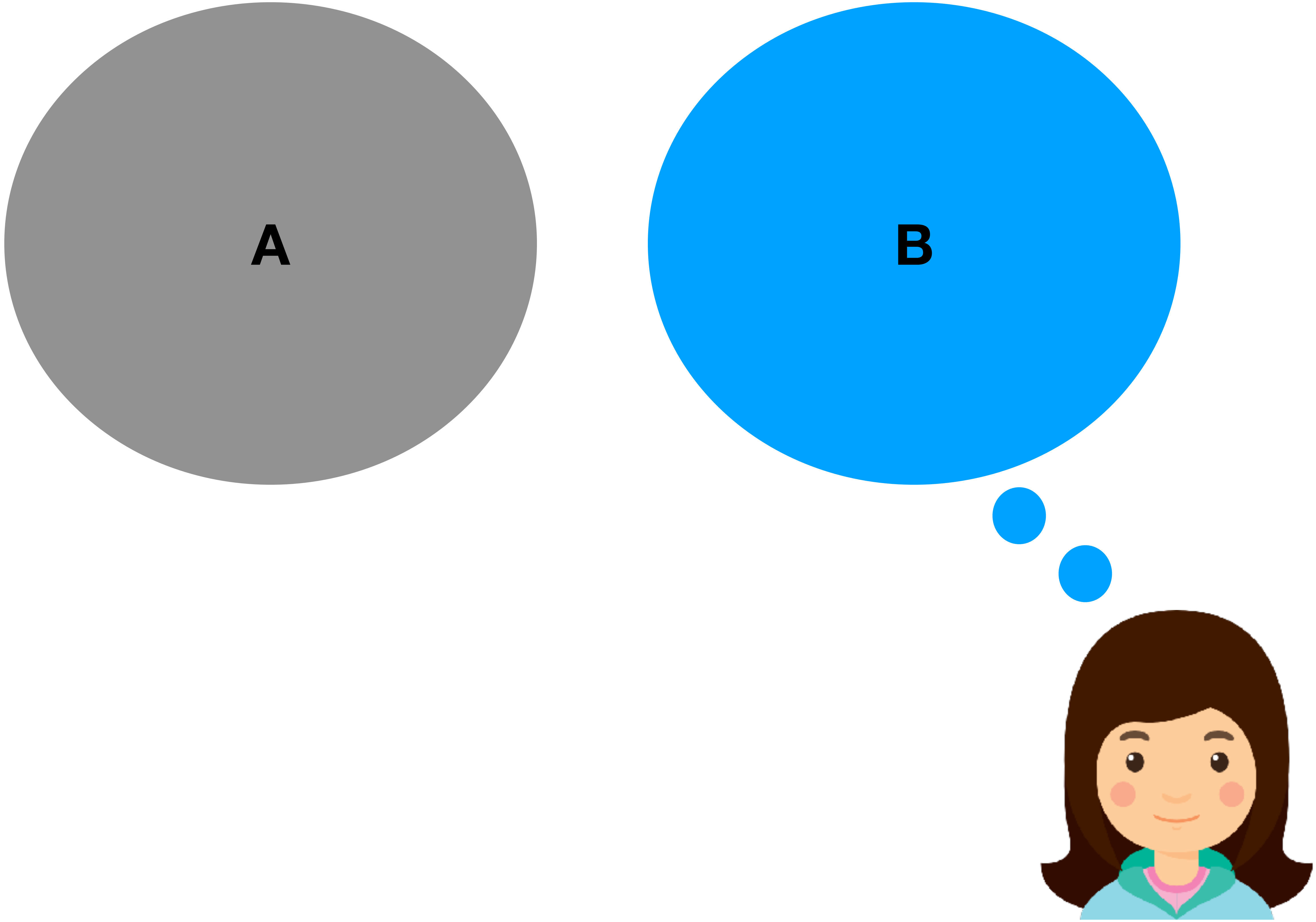
$$\forall x Supplier(x) \rightarrow \Diamond \neg Supplier(x)$$

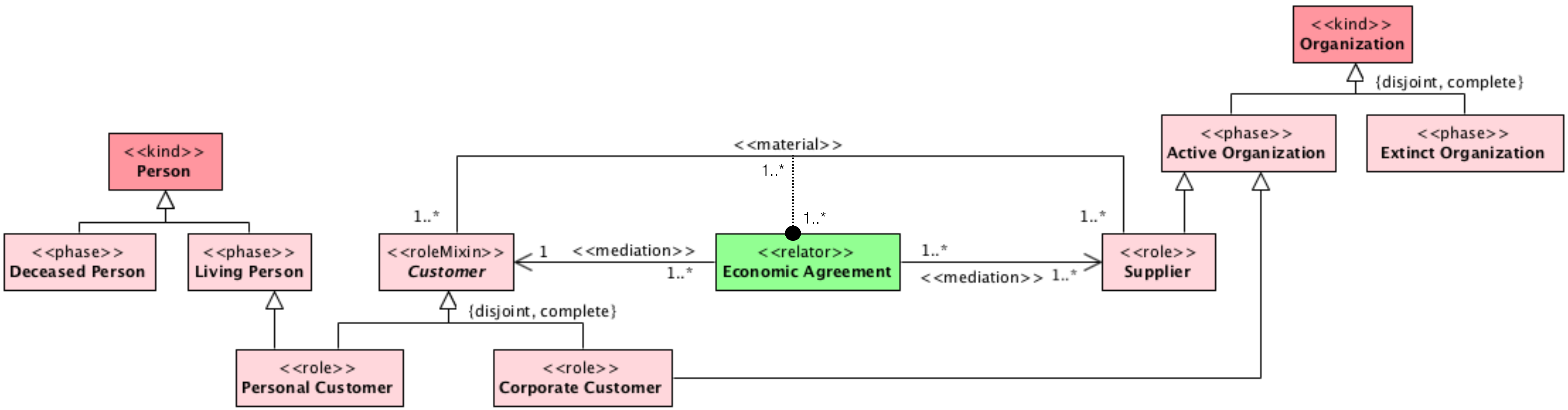
$$\Box (\forall x Supplier(x) \rightarrow \exists y Customer(y) \wedge contractsWith(y, x))$$



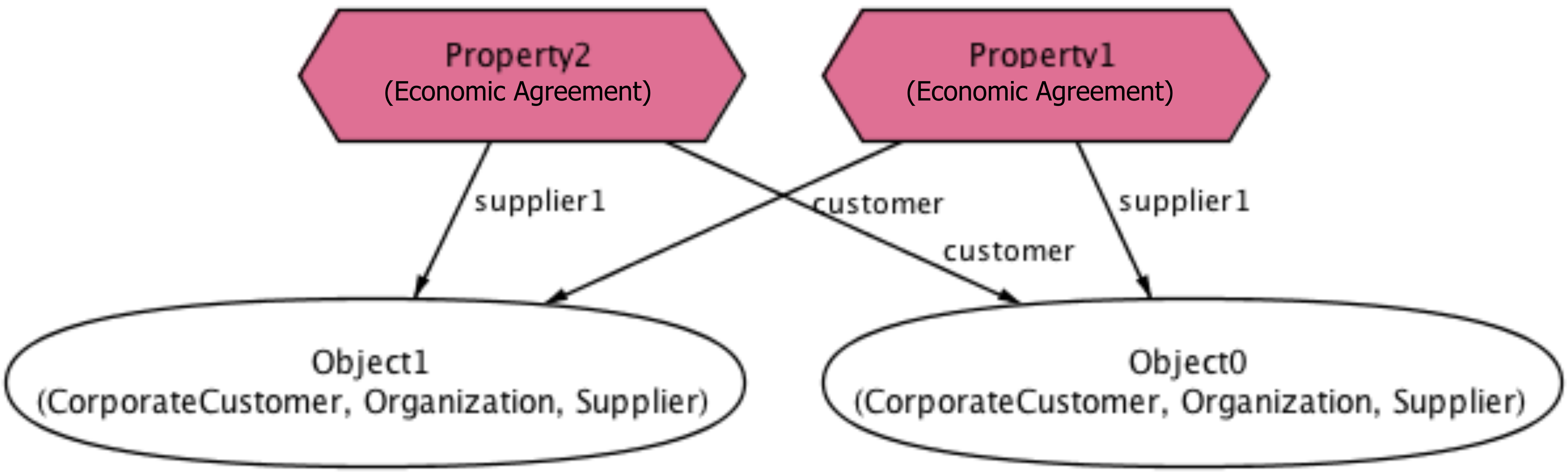

Contraints

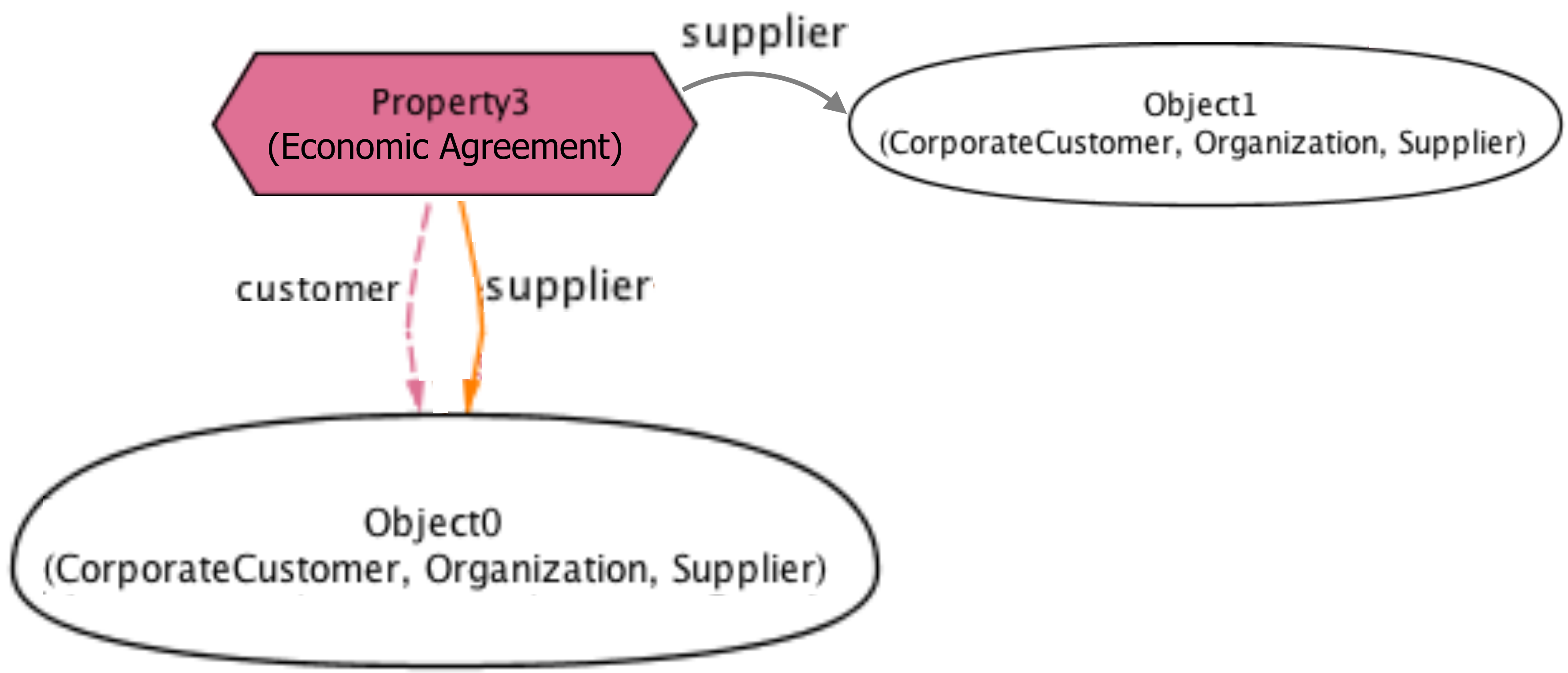

Contraints

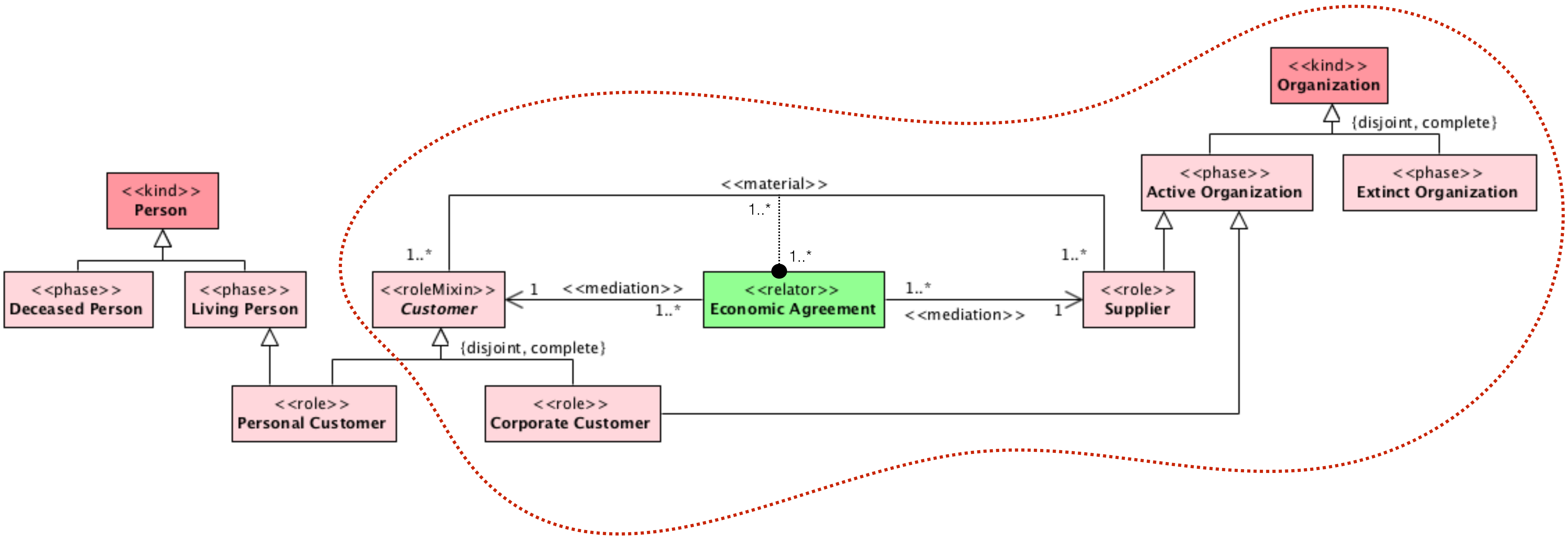

A
B



<<kind>>
Organization
{disjoint, complete}
<<phase>>
Active Organization
<<phase>>
Extinct Organization
<<kind>>
Person
<<material>>
1..*
1..*
1..*
1..*
<<phase>>
Deceased Person
<<phase>>
Living Person
<<roleMixin>>
Customer
1
<<mediation>>
1..*
<<relator>>
Economic Agreement
1..*
<<mediation>>
1..*
<<role>>
Supplier
{disjoint, complete}
<<role>>
Personal Customer
<<role>>
Corporate Customer

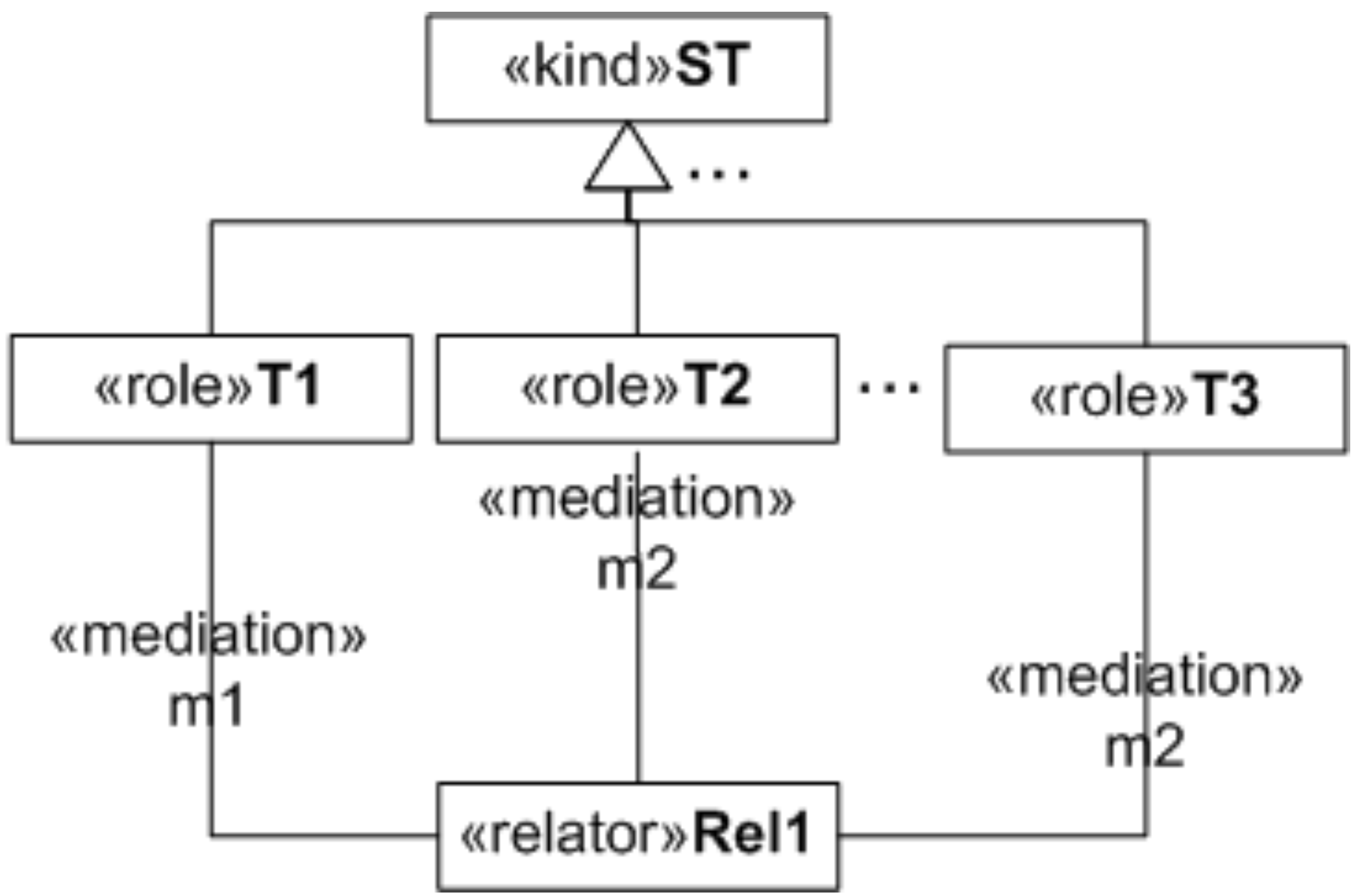

Property2
(Economic Agreement)
Property1
(Economic Agreement)
supplier1
customer
customer
supplier1
Object1
(CorporateCustomer, Organization, Supplier)
Object0
(CorporateCustomer, Organization, Supplier)


supplier
Property3
(Economic Agreement)
Object1
(CorporateCustomer, Organization, Supplier)
customer
supplier
Object0
(CorporateCustomer, Organization, Supplier)

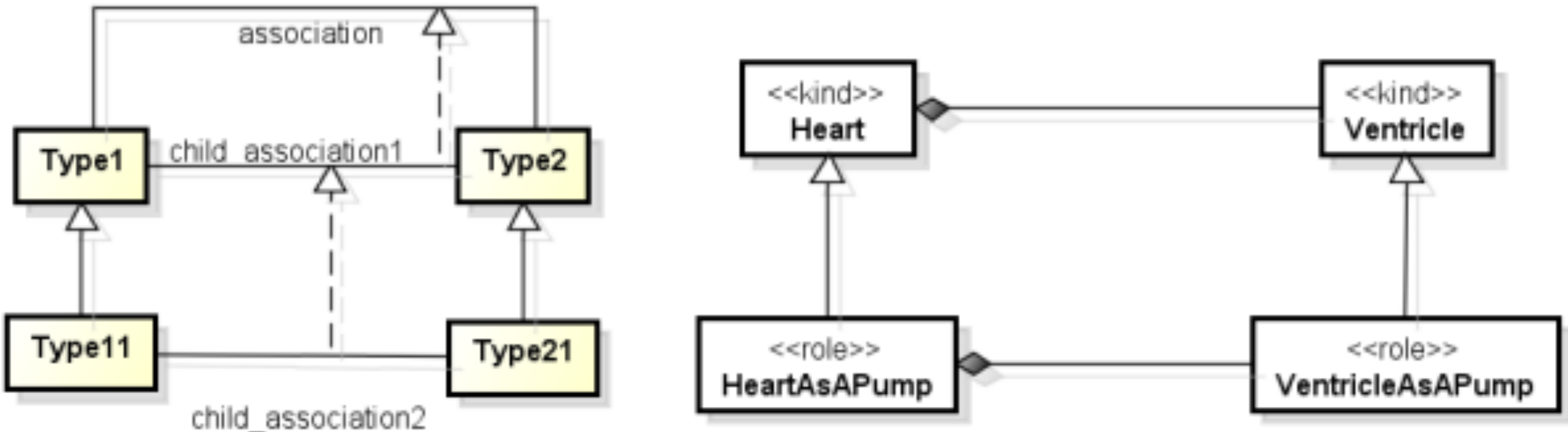


<<kind>>
Person
<<phase>>
Deceased Person
<<phase>>
Living Person
<<role>>
Personal Customer
<<roleMixin>>
Customer
{disjoint, complete}
<<role>>
Corporate Customer
<<material>>
1..*
1..*
1..*
1..*
1
<<mediation>>
1..*
<<relator>>
Economic Agreement
1..*
<<mediation>>
1
<<role>>
Supplier
<<kind>>
Organization
{disjoint, complete}
<<phase>>
Active Organization
<<phase>>
Extinct Organization

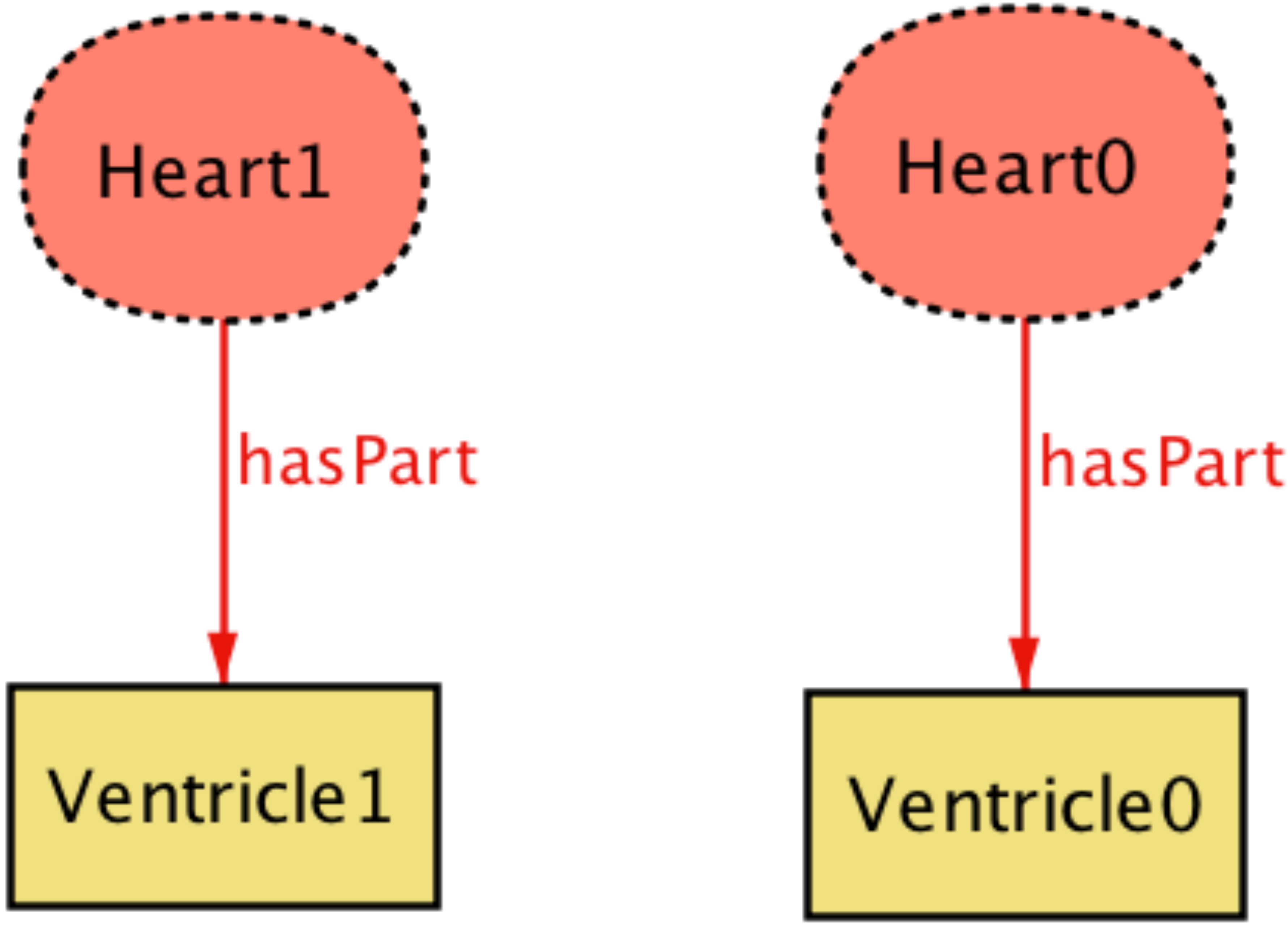
The Emerging Anti-Pattern: Relation Between Overlapping Types (**RelOver**)



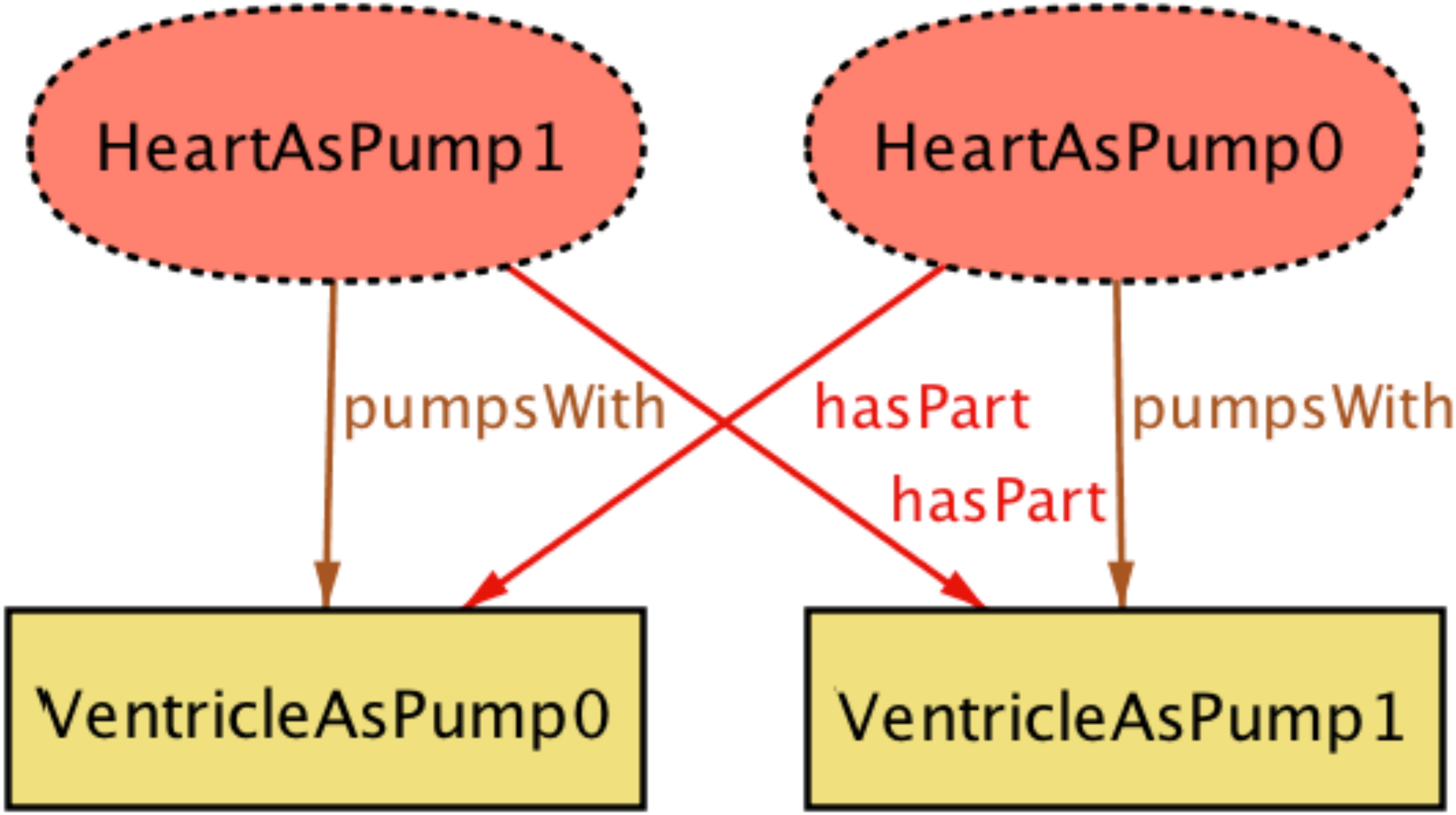
Relation Specialization (RS)



(a) (b)



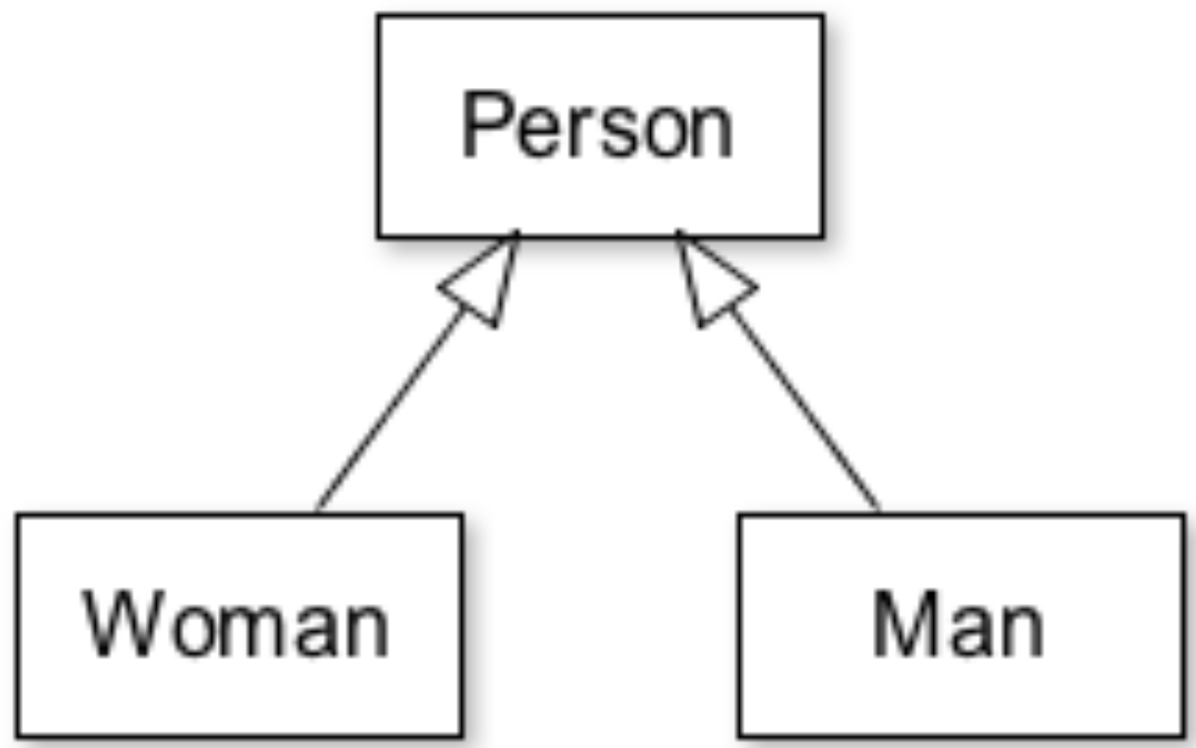
Heart1
hasPart
Ventricle1
Heart0
hasPart
Ventricle0


HeartAsPump1
HeartAsPump0
pumpsWith
hasPart
pumpsWith
hasPart
VentricleAsPump0
VentricleAsPump1

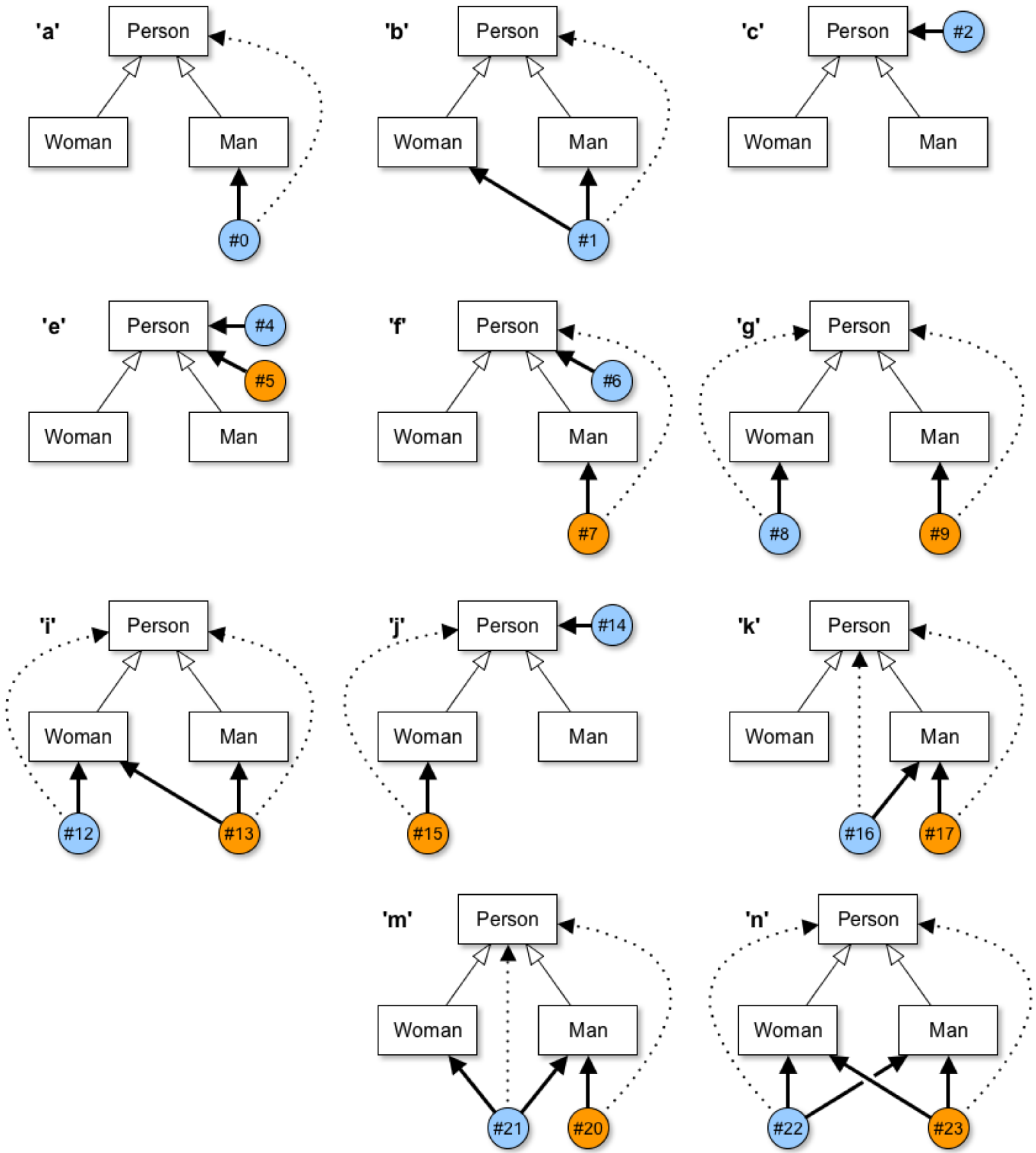
Anti-Pattern Catalogue

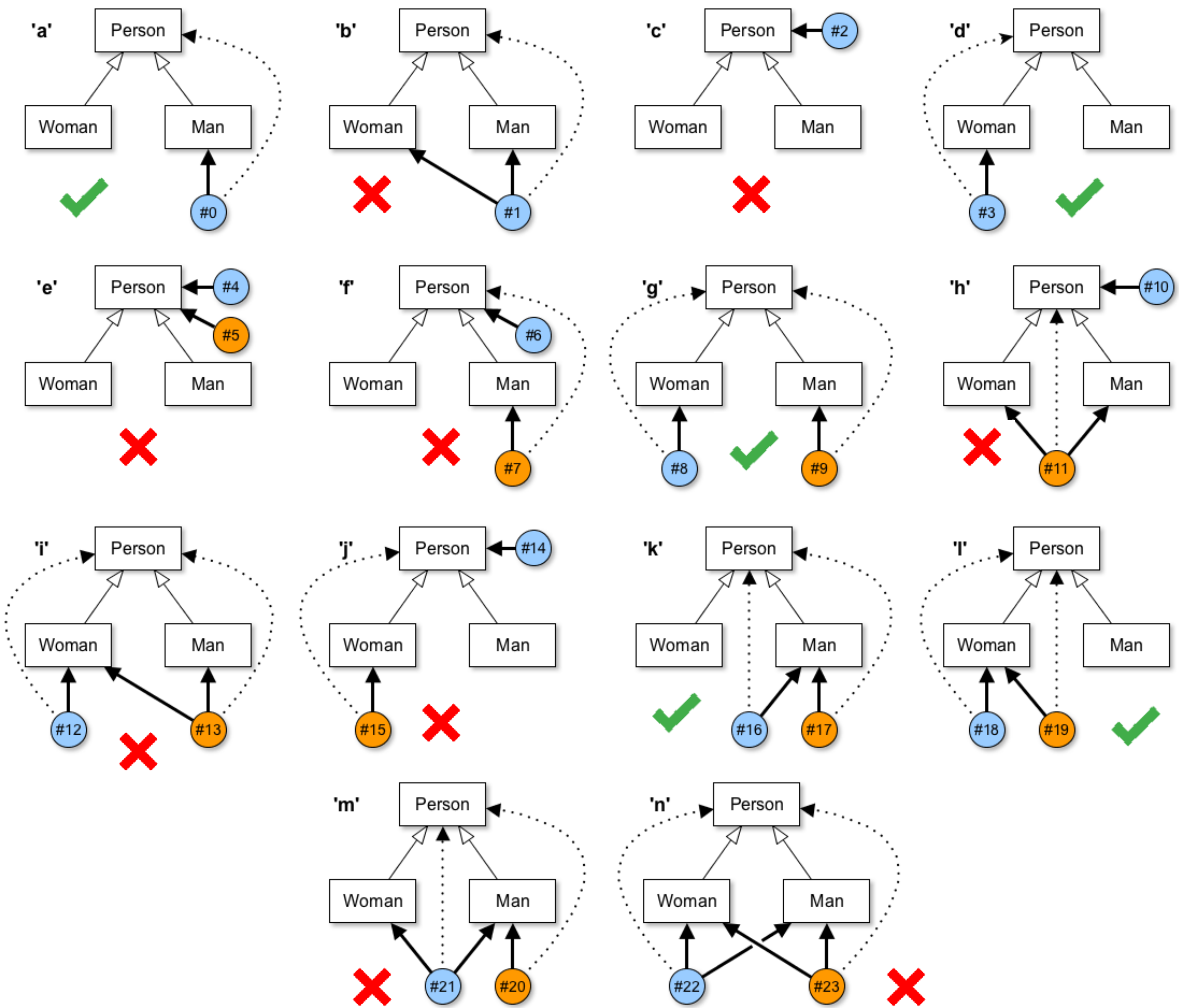
- Association Cycle
- Binary Relation Between Over. Types
- Deceiving Intersection
- Free Role Specialization
- Imprecise Abstraction
- Multiple Relational Dependency
- Part Composing Over. Roles
- Whole Composed by Over. Parts
- Relator Mediating Over. Types
- Relation Composition
- Relator Mediating 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

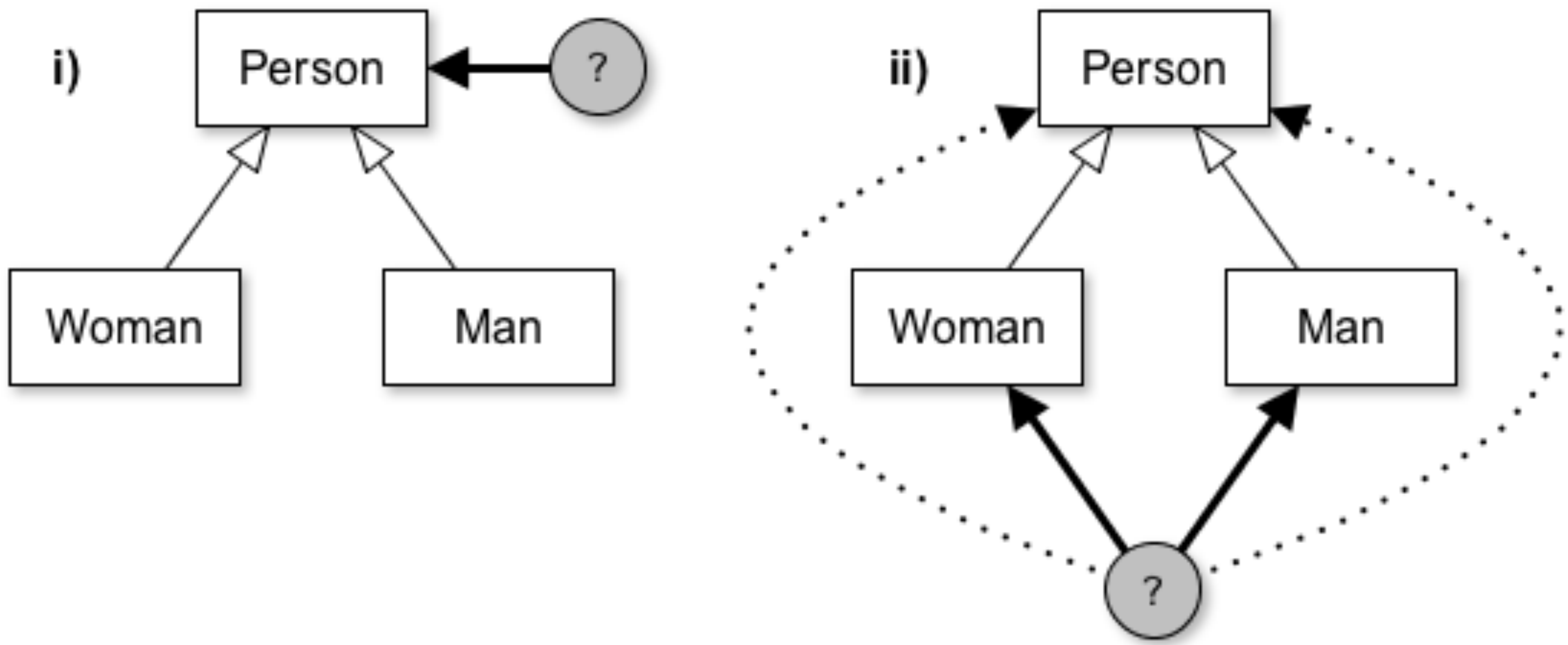
7



$$M = \{\forall x\, Woman(x) \rightarrow Person(x), \forall x\, Man(x) \rightarrow Person(x)\}$$


'a'
Person
Woman
Man
#0
'b'
Person
Woman
Man
#1
'c'
Person
#2
Woman
Man
'd'
Person
Woman
Man
#3
'e'
Person
#4
#5
Woman
Man
'f'
Person
#6
Woman
Man
#7
'g'
Person
Woman
Man
#8
#9
'h'
Person
#10
Woman
Man
#11
'i'
Person
Woman
Man
#12
#13
'j'
Person
#14
Woman
Man
#15
'k'
Person
Woman
Man
#16
#17
'l'
Person
Woman
Man
#18
#19
'm'
Person
Woman
Man
#21
#20
'n'
Person
Woman
Man
#22
#23


'a'
Person
Woman
Man
#0
'b'
Person
Woman
Man
#1
'c'
Person
Woman
Man
#2
'd'
Person
Woman
Man
#3
'e'
Person
Woman
Man
#4
#5
'f'
Person
Woman
Man
#6
#7
'g'
Person
Woman
Man
#8
#9
'h'
Person
Woman
Man
#10
#11
'i'
Person
Woman
Man
#12
#13
'j'
Person
Woman
Man
#14
#15
'k'
Person
Woman
Man
#16
#17
'l'
Person
Woman
Man
#18
#19
'm'
Person
Woman
Man
#21
#20
'n'
Person
Woman
Man
#22
#23



$$M = \{\forall x\, Woman(x) \rightarrow Person(x), \forall x\, Man(x) \rightarrow Person(x)\}$$

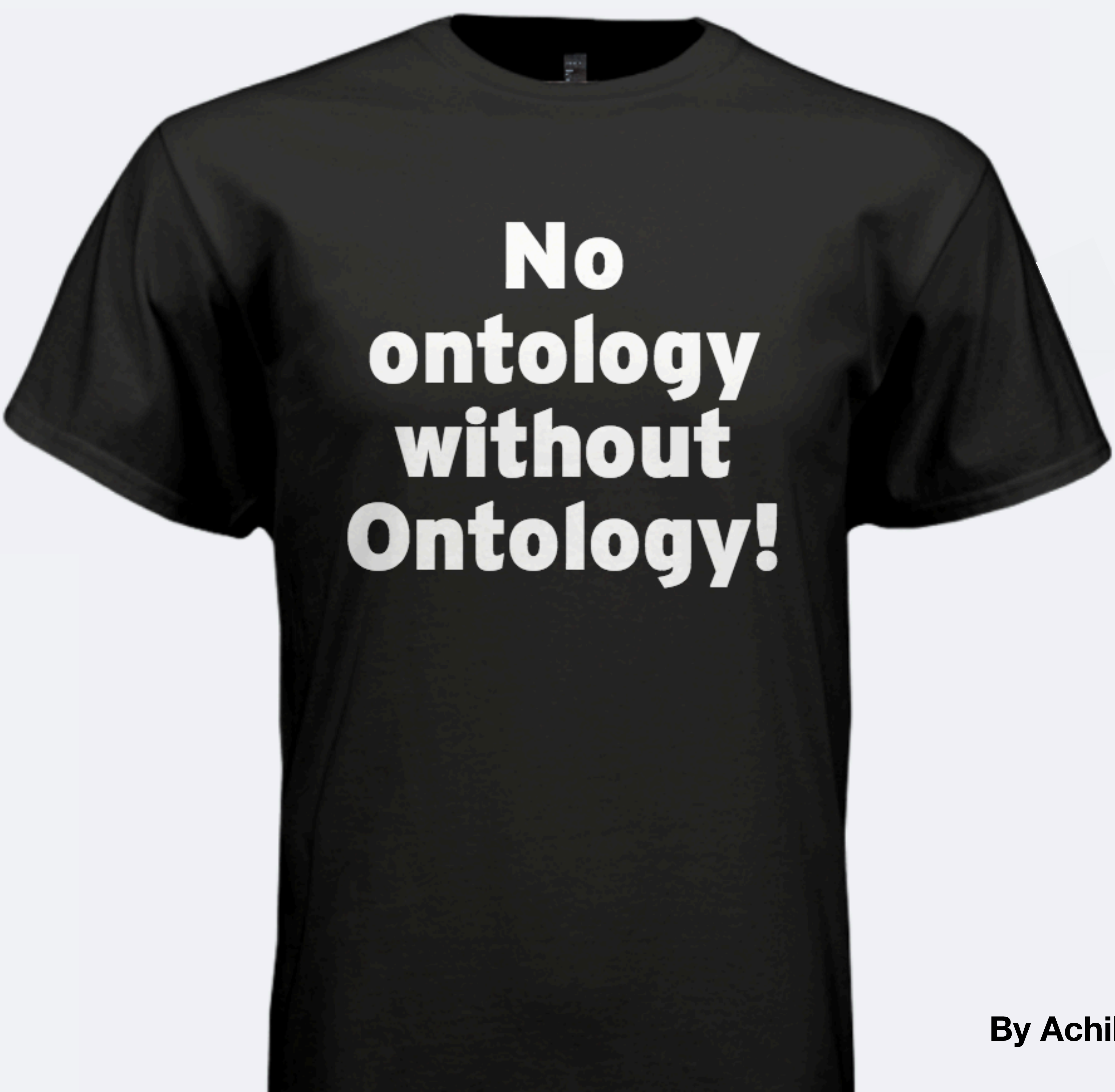
$$M^R = \{M, \forall x\, Person(x) \rightarrow (Woman(x) \vee Man(x)), \forall x\, Man(x) \rightarrow \neg Woman(x)\}$$

Take Away Messages

- conceptual modeling is **about** defining the **ontology of the domain**

- conceptual modeling (domain ontology engineering) is about representing the **result of ontological analysis** over that domain

- All conceptual modeling (domain ontology engineering) **should be Ontology-driven**



By Achille Varzi

References

- All papers can be dowloaded from:
  - tinyurl.com/3a8s4f7z
- Tools:
  - https://github.com/OntoUML/ontouml-vp-plugin
  - https://nemo-ufes.github.io/gufo/
- Some starting points are:

  - Guizzardi, G., Bernasconi, A., Pastor, O., Storey, V., Ontological Unpacking as Explanation: The Case of the Viral Conceptual Model, 40th International Conference on Conceptual Modeling (ER 2021), St. John's, Canada, 2021.
  - GUARINO, N., GUIZZARDI, G., MYLOPOULOS, J., On the Philosophical Foundations of Conceptual Models, Frontiers in Artificial Intelligence and Applications, Information Modelling and Knowledge Base, Vol. 31, Selected Revised Papers of the 29th International Conference on Information Modeling and Knowledge Bases (EJC'19), Lappeenranta, Finland, 2020.
  - GUIZZARDI, G., WAGNER, G., ALMEIDA, J.P.A., GUIZZARDI, R.S.S., Towards Ontological Foundation for Conceptual Modeling: The Unified Foundational Ontology (UFO) Story, Applied Ontology, IOS Press, 2015.
  - GUIZZARDI, G., Ontological Patterns, Anti-Patterns and Pattern Languages for Next-Generation Conceptual Modeling, invited companion paper to the Keynote Speech delivered at the 33rd International Conference on Conceptual Modeling (ER 2014), Atlanta, USA.
  - Guizzardi, G. Ontological Foundations for Structural Conceptual Models, Telematica Instituut Fundamental Research Series, Vol. 15, 2005.

gguizzardi@unibz.it

g.guizzardi@utwente.nl

Freie Universität Bozen
Libera Università di Bolzano
Università Liedia de Bulsan

UNIVERSITEIT TWENTE.