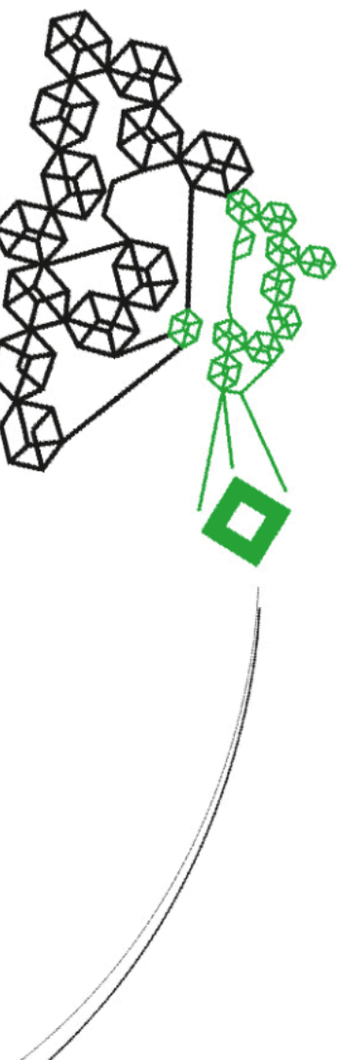
Relations, ~~**Events**~~, and **Explanation**



IC3K 2022, Malta

Knowledge (Discovery, Engineering and Management)

Giancarlo Guizzardi

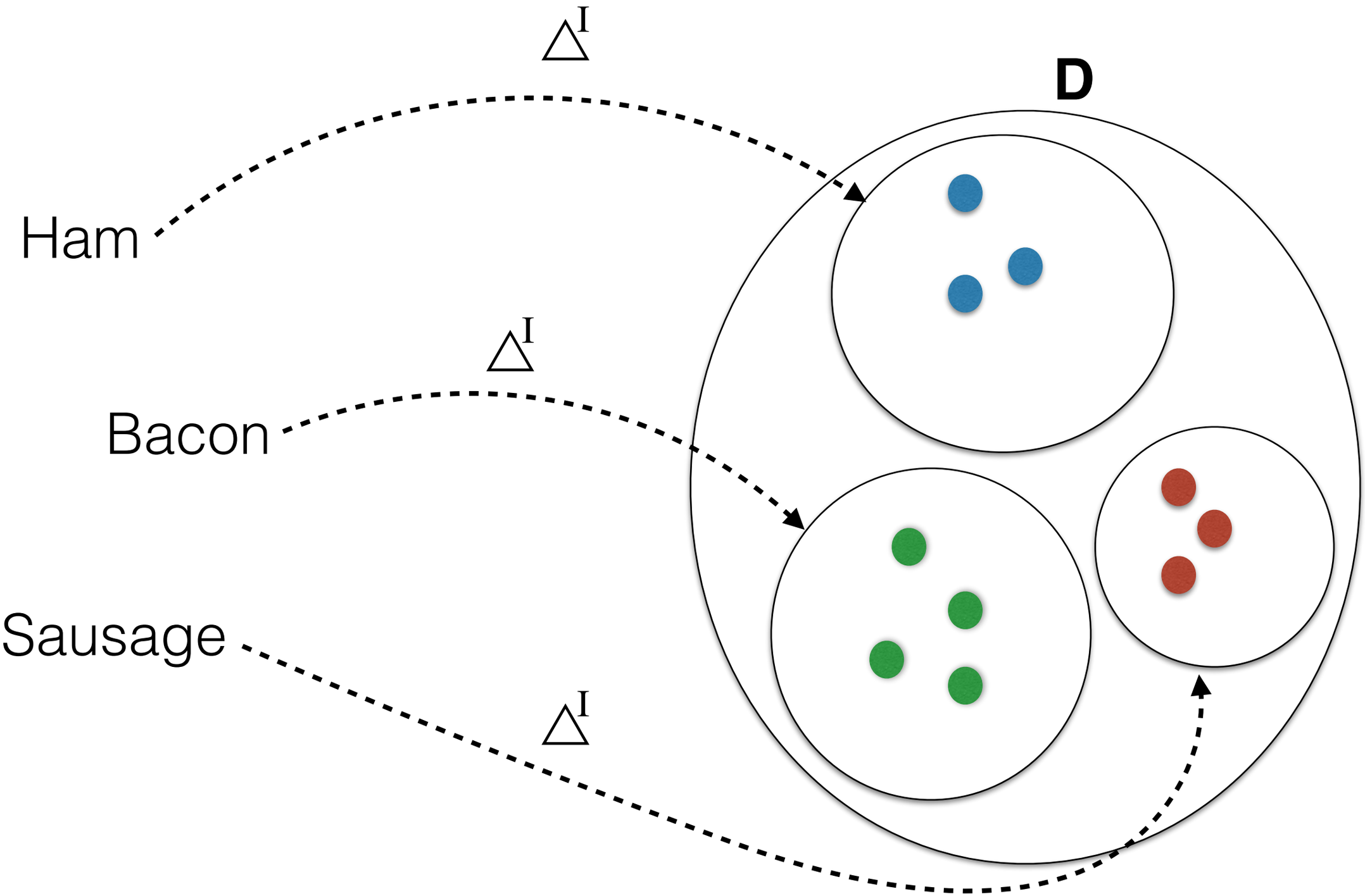
Semantics, Cybersecurity & Services

UNIVERSITEIT TWENTE.

GG et alia:

João Paulo Almeida, Anna Bernasconi, Diego Calvanese, Claudenir Fonseca, Alberto Garcia, Nicola Guarino, Oscar Pastor, Daniele Porello, Elena Romanenko, Tiago Sales, Veda Storey

Semantics, $\binom{o}{o}$**ntology** and **Explanation**


Ham
Bacon
Sausage
I
I
I
D

Formal Semantics

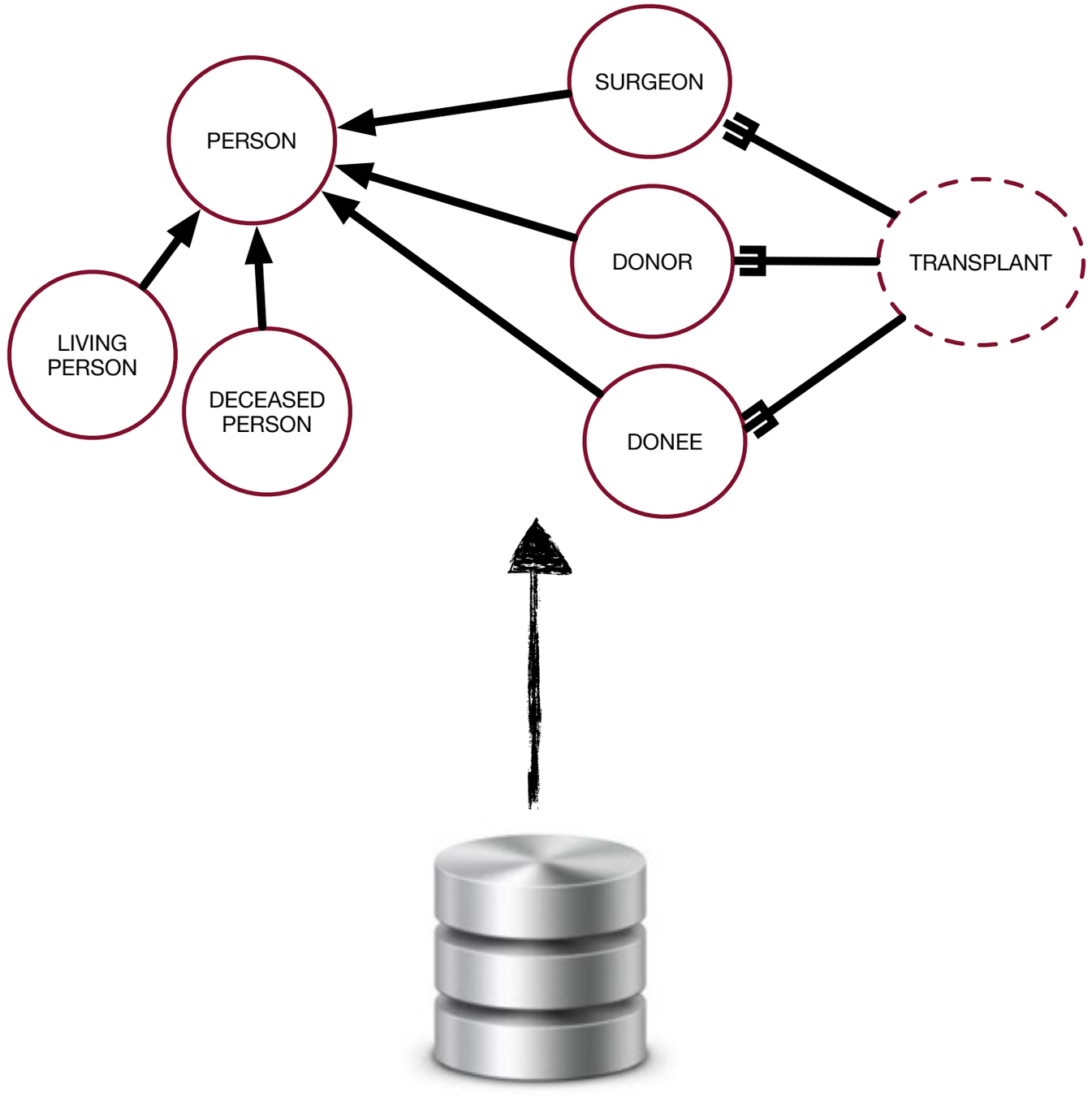
X

Real-World

(or **Ontological**)

Semantics


Isolatorweg
50
Sloterdijk
De Vlugtlaan
Jan van Galenstraat
Postjesweg
Lelylaan
Heemstedestraat
Henk Sneevlietweg
Amstelveenseweg
De Boelelaan / VU
A.J. Ernststraat
Van Boshuizenstraat
Uilenstede
Kronenburg
Zonnestein
Onderuit
Oranjebaan
Amstelveen Centrum
Ouderkerkerlaan
Sportlaan
Marne
Gondel
Meent
Brink
Poortwachter
Spinnerij
Sacharovlaan
Westwijk
51
IJ
Singelgracht
Prinsengracht
Keizersgracht
Herengracht
Singel
52
Noord
Noorderpark
Rokin
Vijzelgracht
De Pijp
Europaplein
Zuid
RAI
Overamstel
Amstel
51 53 54
Centraal Station
Nieuwmarkt
Waterlooplein
Weesperplein
Wibautstraat
Amstel
Spaklerweg
IJmeer
Van der Madeweg
Duivendrecht
Strandvliet
Bijlmer ArenA
Bullewijk
Holendrecht
Reigersbos
Gein
50 54
Veensepolder
Diemen Zuid
Verrijn Stuartweg
Ganzenhoef
Kraaiennest
Gaasperplas
53


PERSON
SURGEON
DONOR
TRANSPLANT
LIVING PERSON
DECEASED PERSON
DONEE

Another look at data

by GEORGE H. MEALY
Computer Consultant
Scituate, Massachusetts

INTRODUCTION

particular ontology, we can avoid a quarrel by adopt-

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

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-

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

INTRODUCTION

particular ontology, we can avoid a quarrel by adopt-

*"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.**"*

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-

Toward a theory of data

Relations

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

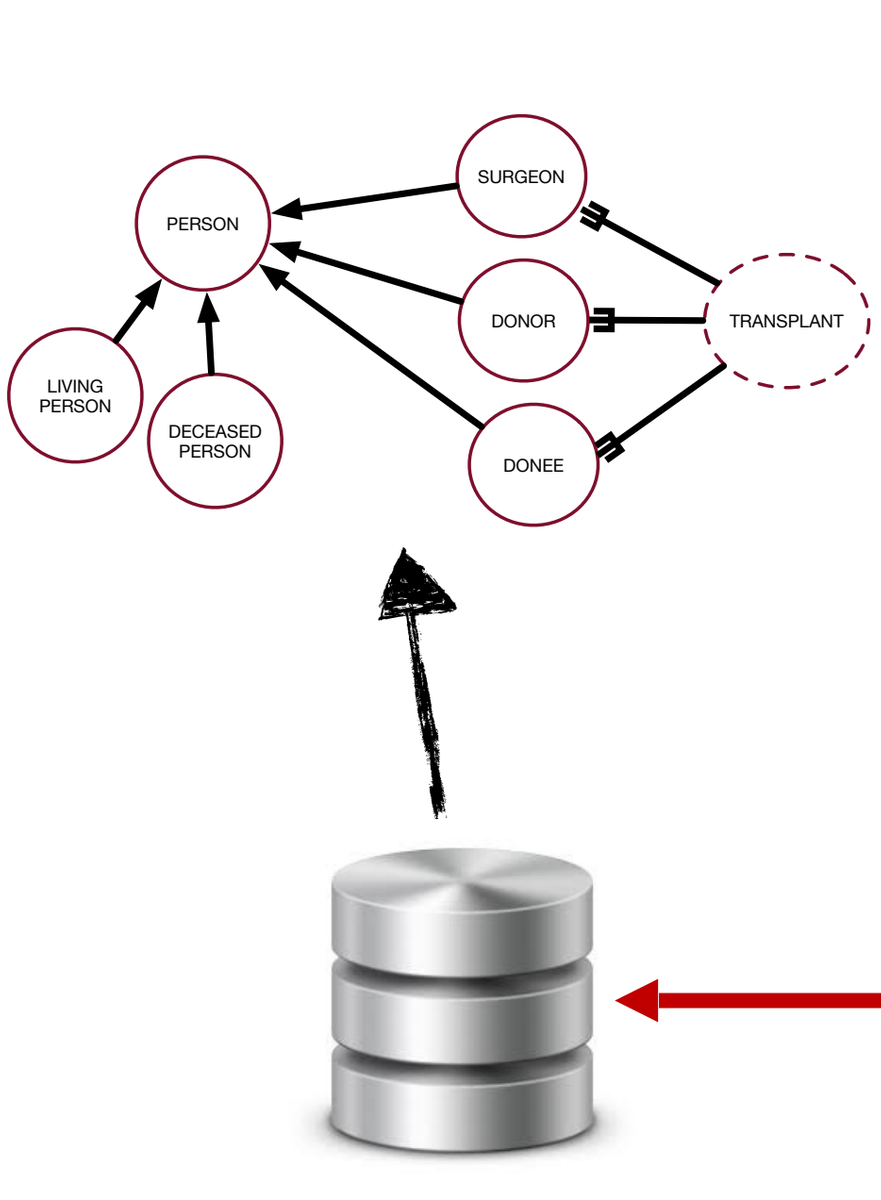
ontology ≈

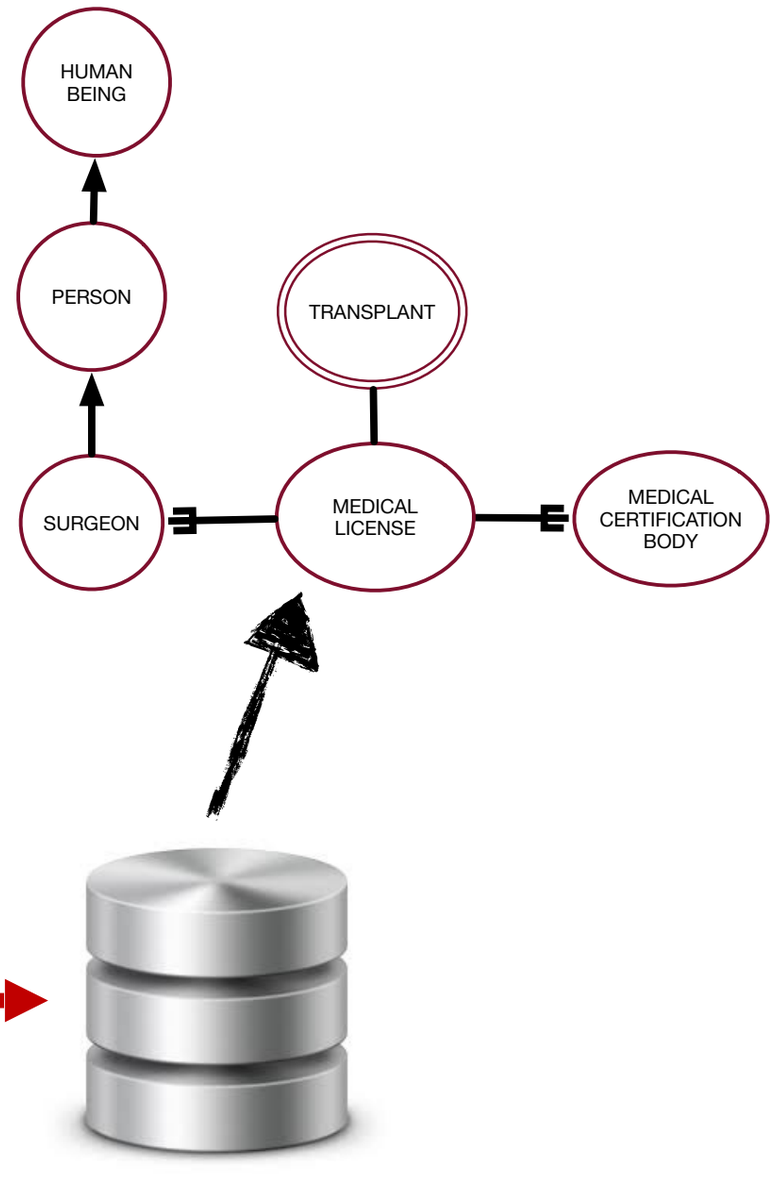
A theory about the kinds of entities and their ties that are assumed to exist by a given description of reality

Semantic Interoperability

=

relating different
worldviews, i.e., different
ontologies


PERSON
SURGEON
DONOR
TRANSPLANT
LIVING PERSON
DECEASED PERSON
DONEE


HUMAN BEING
PERSON
TRANSPLANT
SURGEON
MEDICAL LICENSE
MEDICAL CERTIFICATION BODY

?

PERSON

SURGEON

DONOR

DONEE

TRANSPLANT

LIVING PERSON

DECEASED PERSON

HUMAN BEING

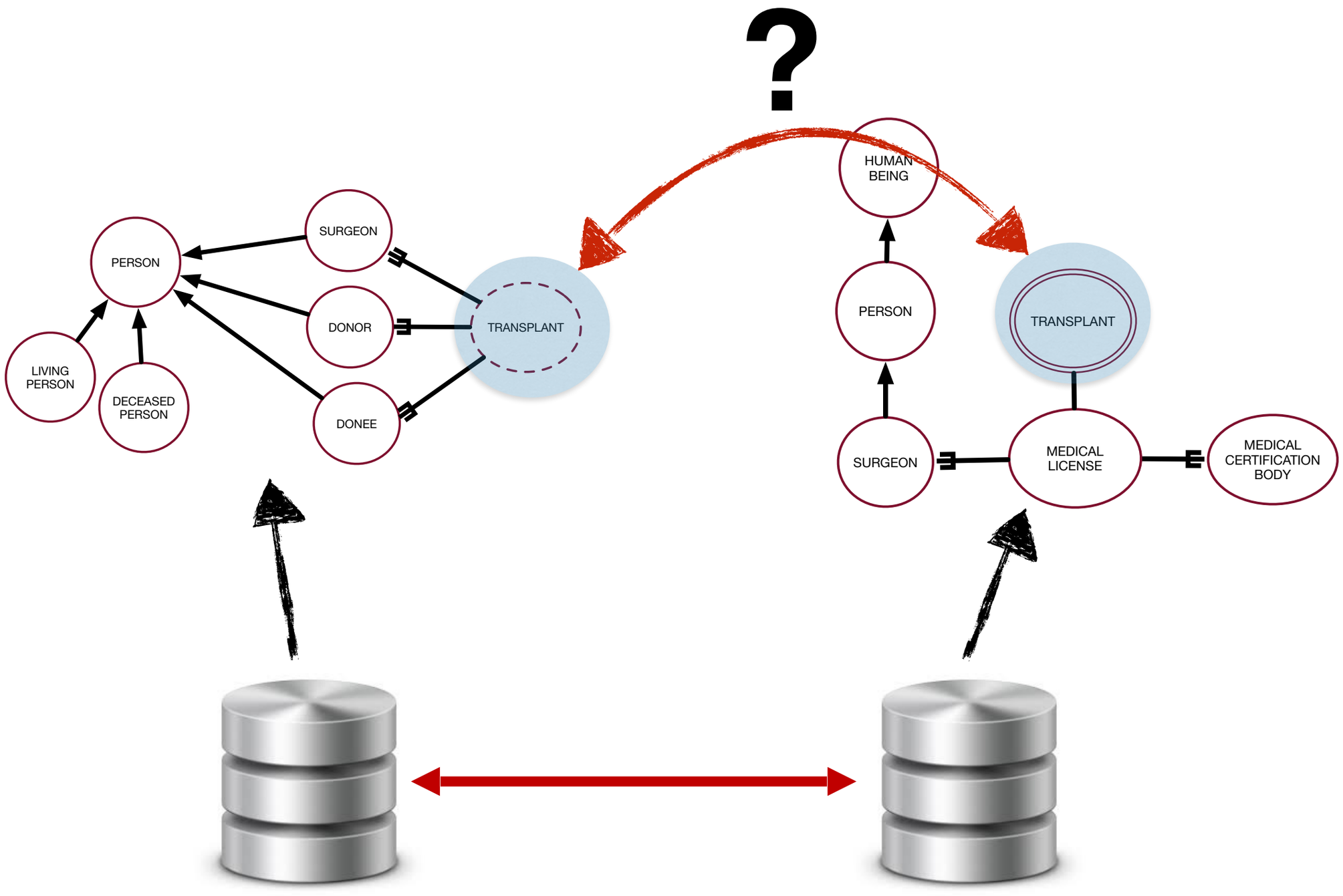
PERSON

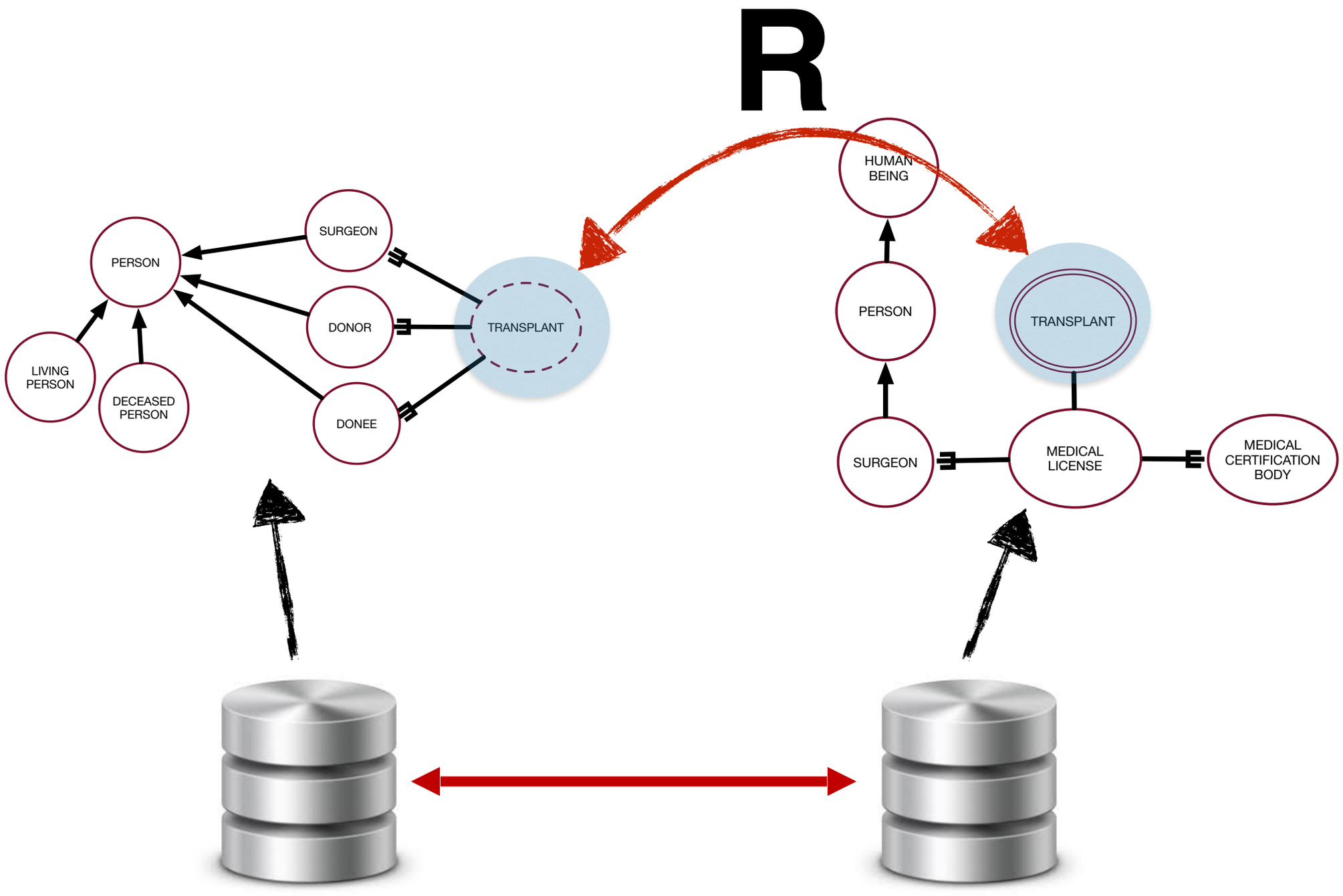
TRANSPLANT

SURGEON

MEDICAL LICENSE

MEDICAL CERTIFICATION BODY


?
HUMAN BEING
PERSON
SURGEON
DONOR
DONEE
TRANSPLANT
LIVING PERSON
DECEASED PERSON
PERSON
TRANSPLANT
SURGEON
MEDICAL LICENSE
MEDICAL CERTIFICATION BODY


R
HUMAN BEING
PERSON
SURGEON
DONOR
DONEE
LIVING PERSON
DECEASED PERSON
TRANSPLANT
PERSON
TRANSPLANT
SURGEON
MEDICAL LICENSE
MEDICAL CERTIFICATION BODY

Ontology ≈

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

“one of the main reasons that so many online market makers have foundered [is that] the transactions they had viewed as simple and routine actually involved **many subtle distinctions in terminology and meaning**”.

Harvard Business Review, 2001

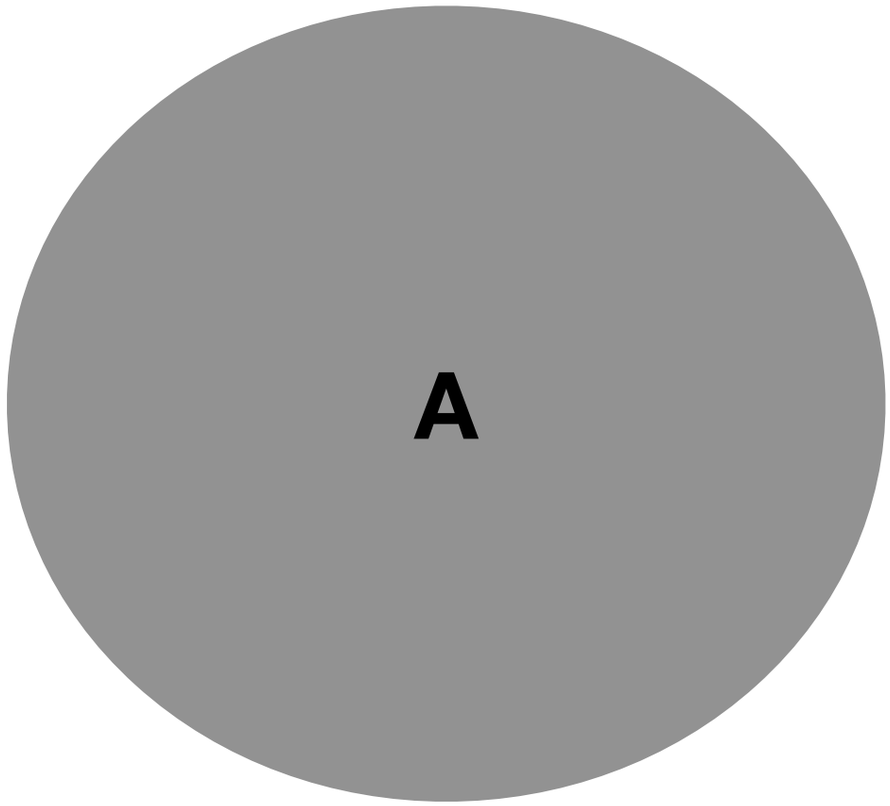
Software?

Software?

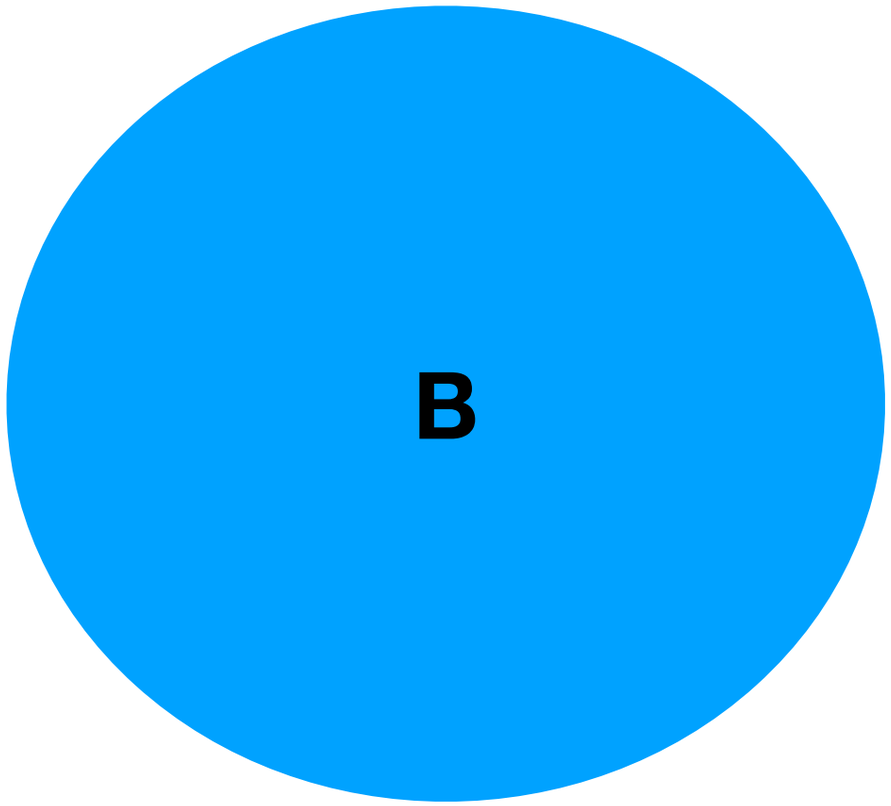
- Software Code?
- Software Program?
- Software System?
- Software Product?

Software?

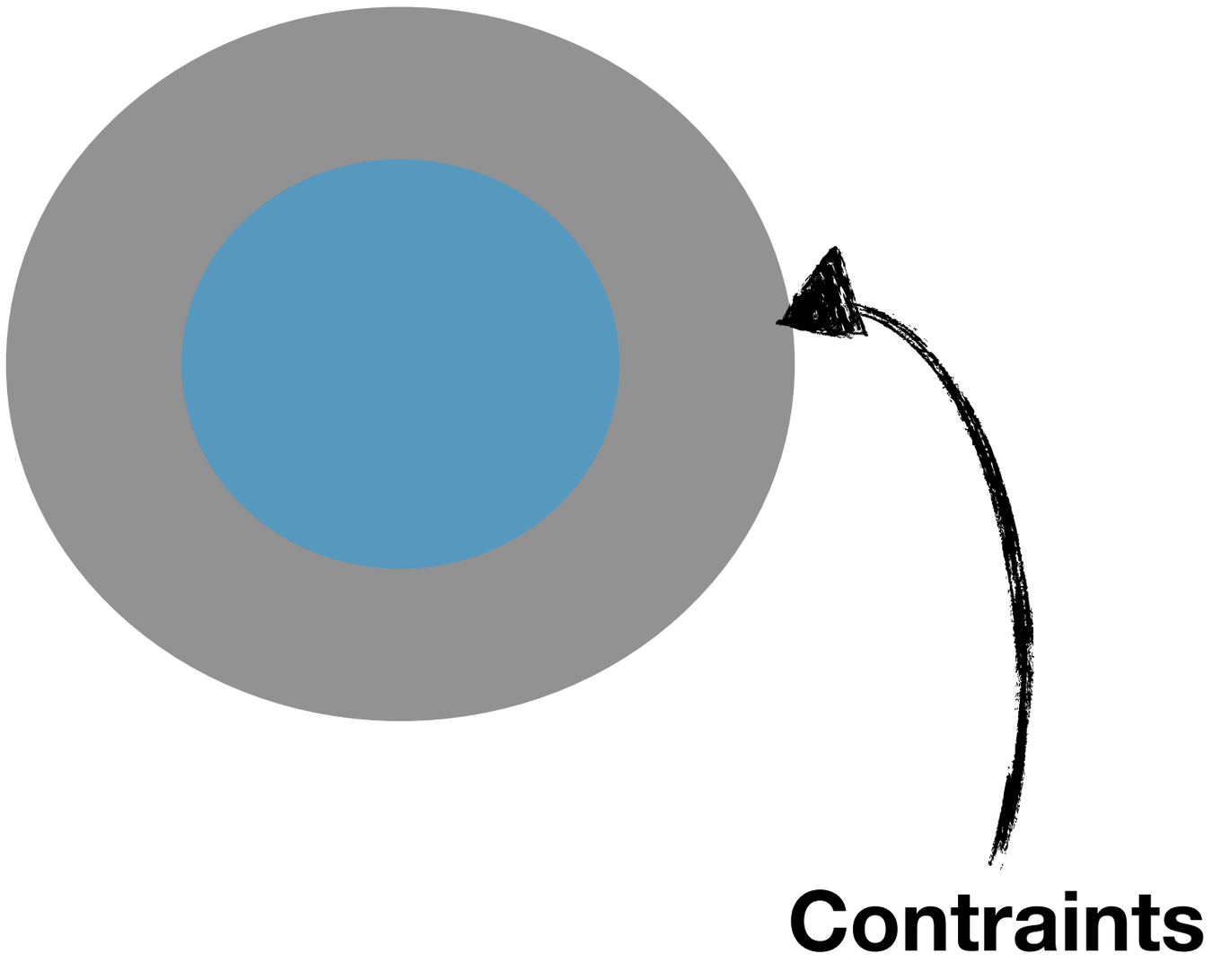
- Software Code? **IDENTITY = SYNTACTICAL FORM**
- Software Program? **IDENTITY = EXECUTION CLASS**
- Software System? **IDENTITY = REQUIREMENTS**
- Software Product? **IDENTITY = PRODUCT AGREEMENT**



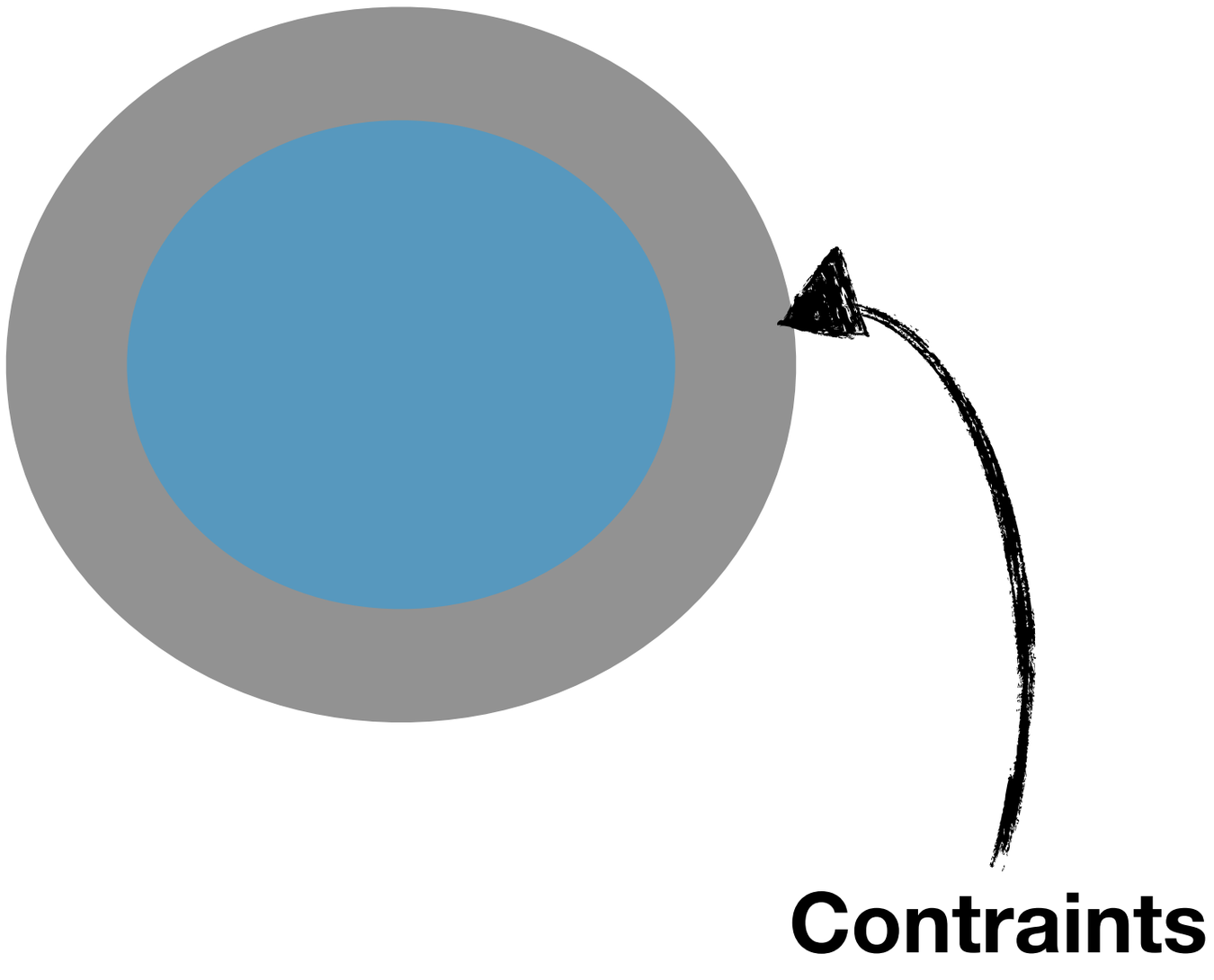
Possible Interpretations of a Model



Intended Interpretations of that Model



Contraints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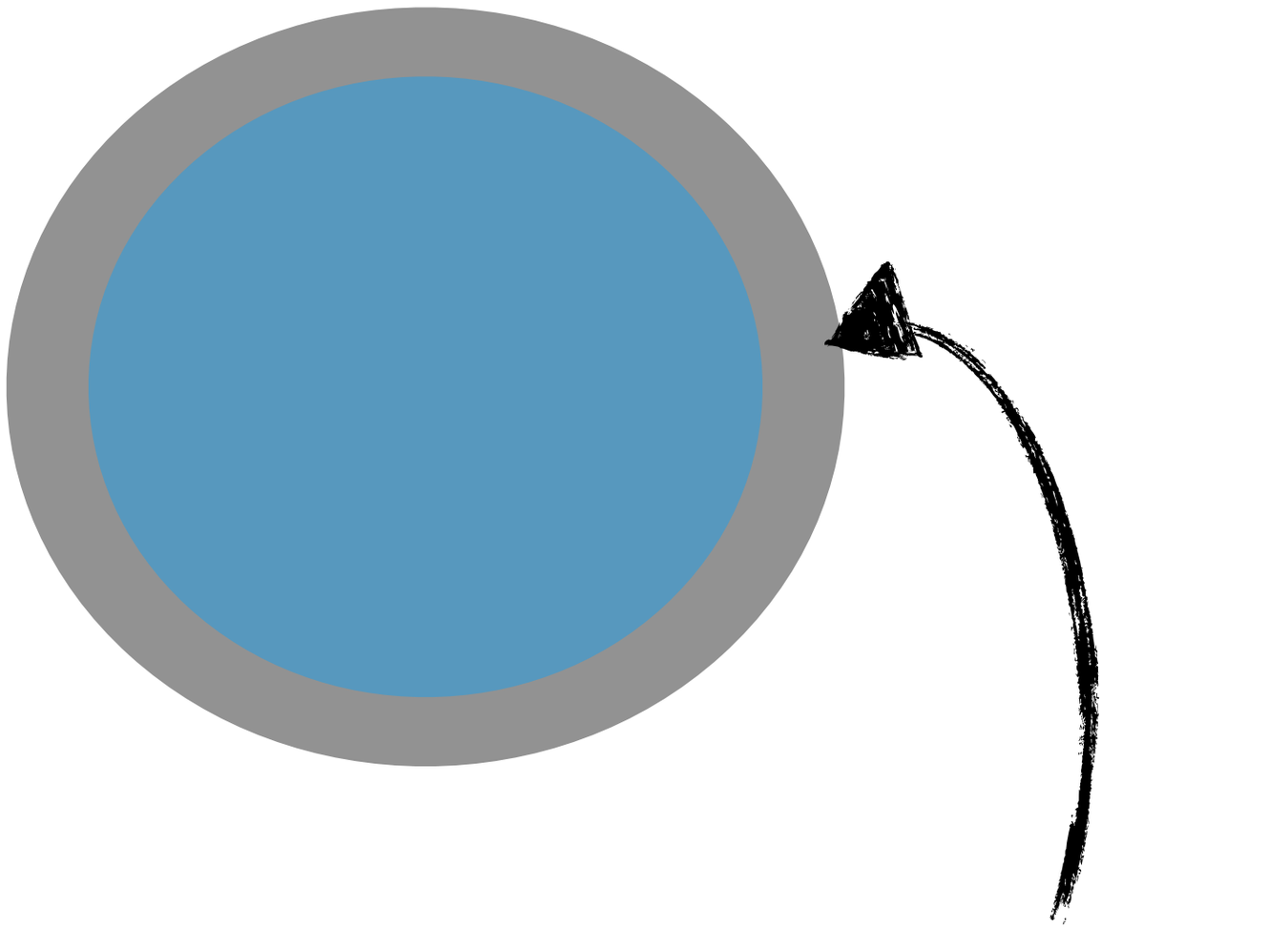

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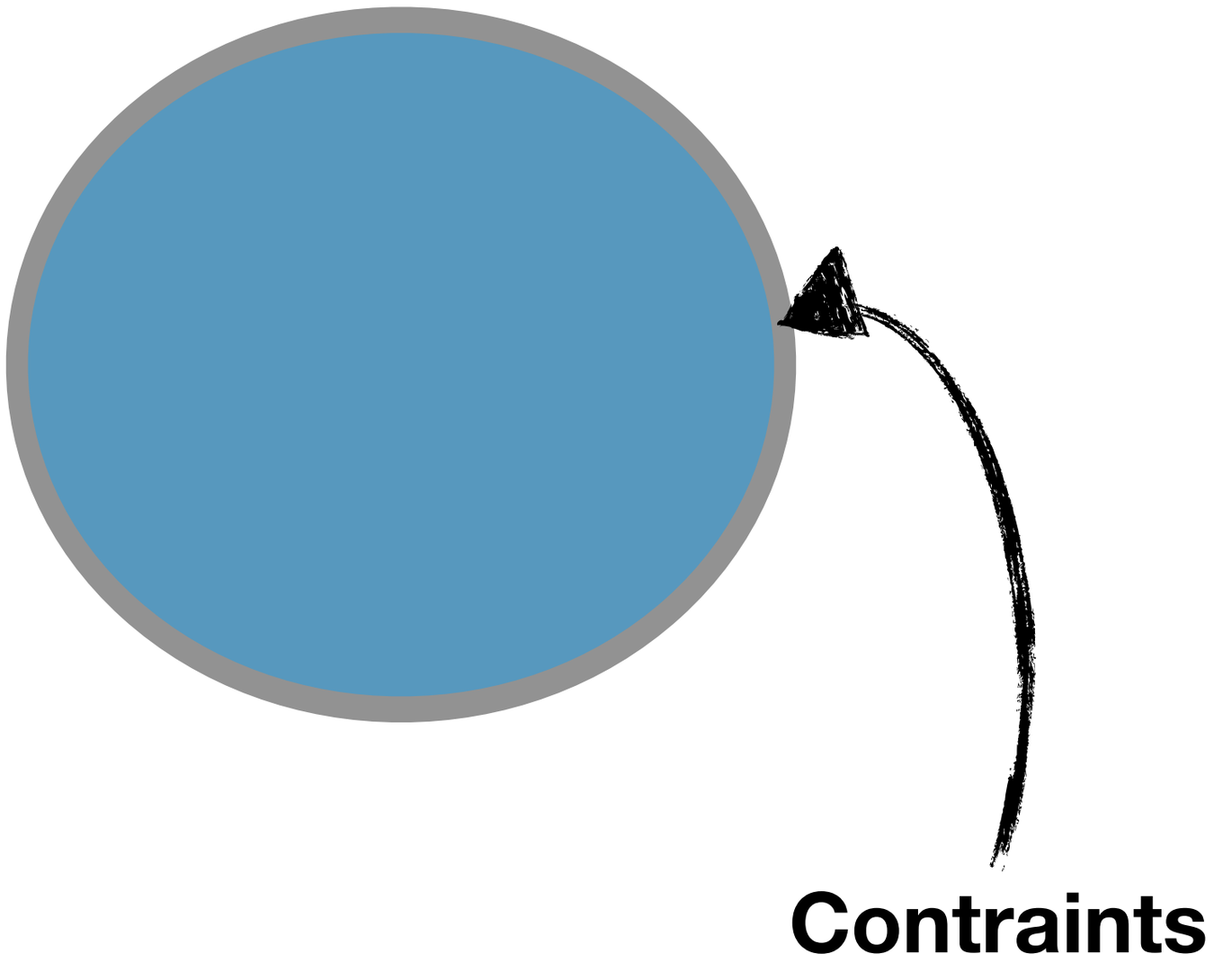
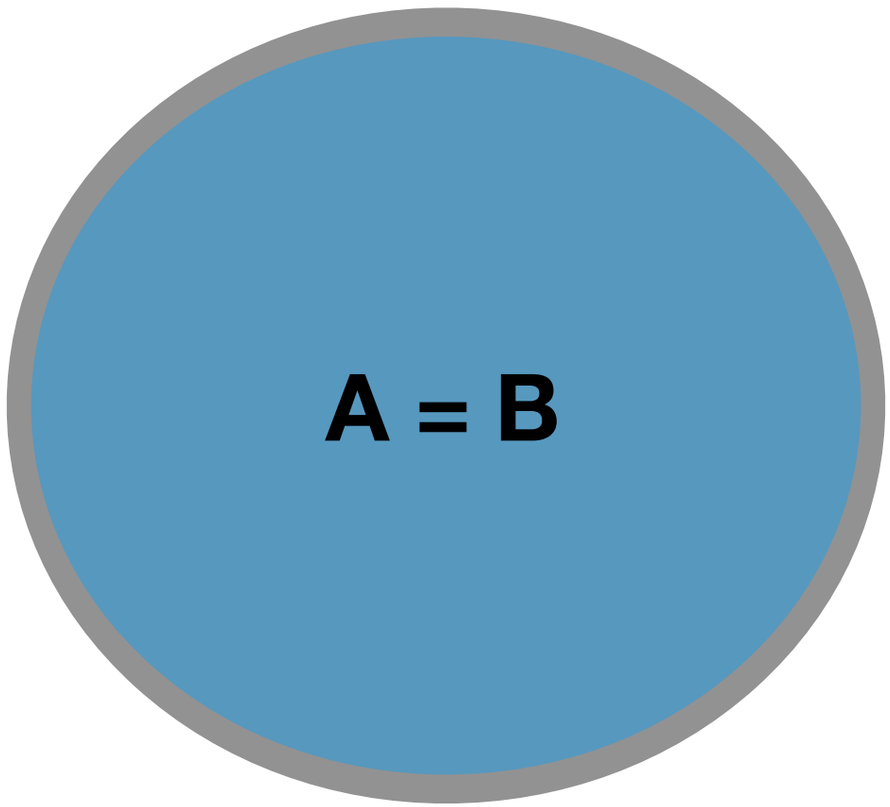
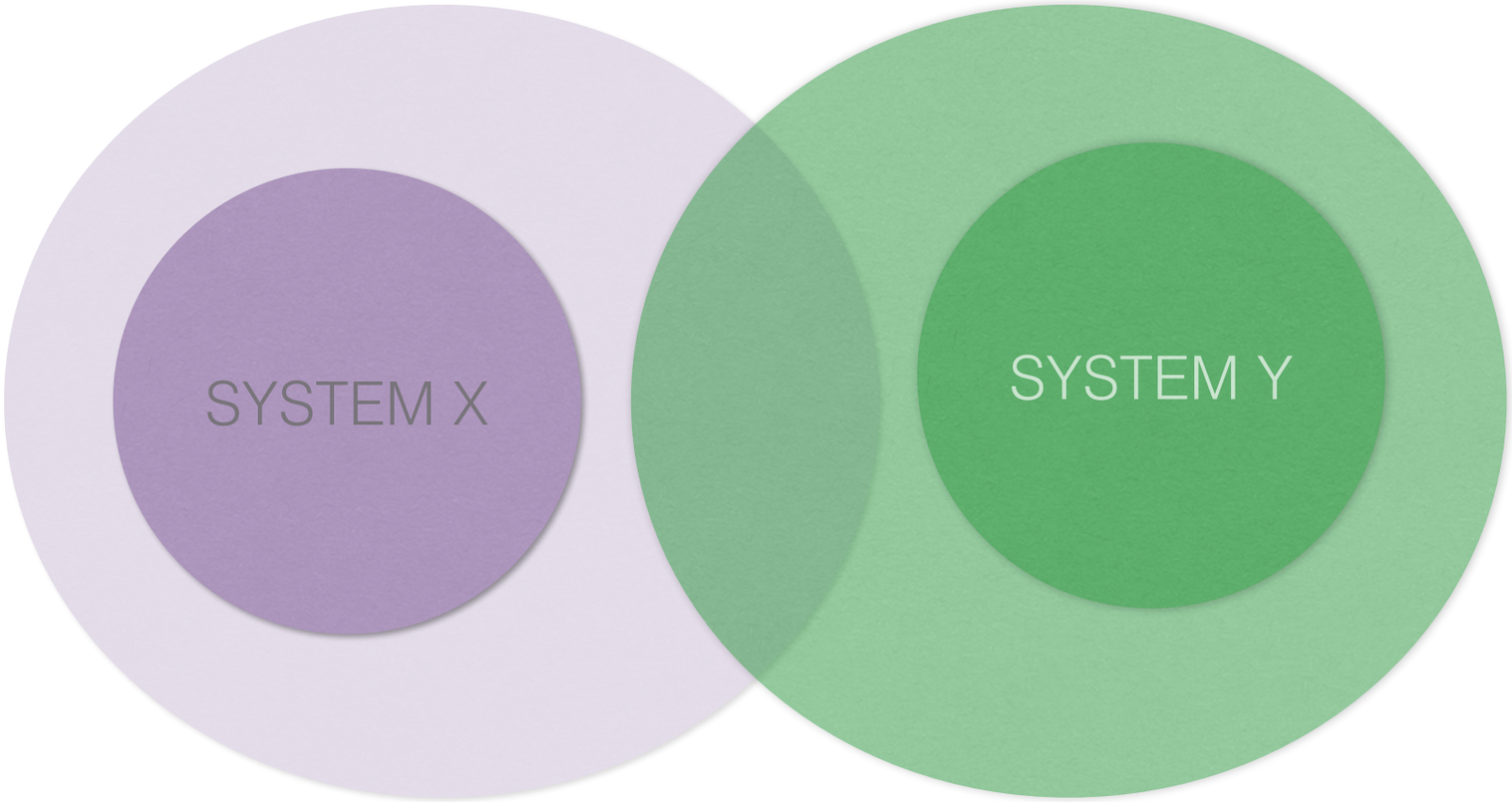
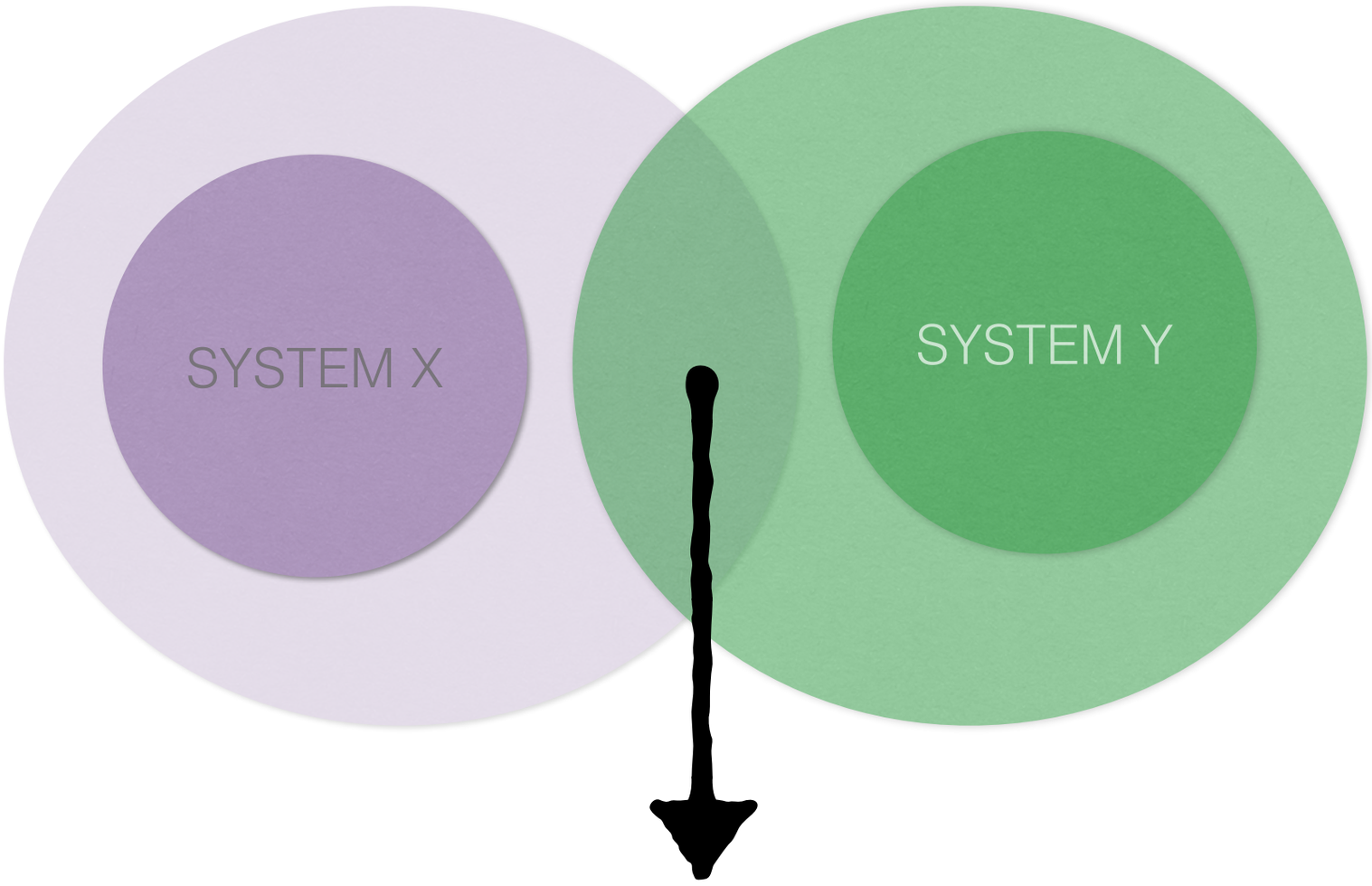


Contraints


A = B


SYSTEM X
SYSTEM Y



FALSE AGREEMENT

ontology ≈

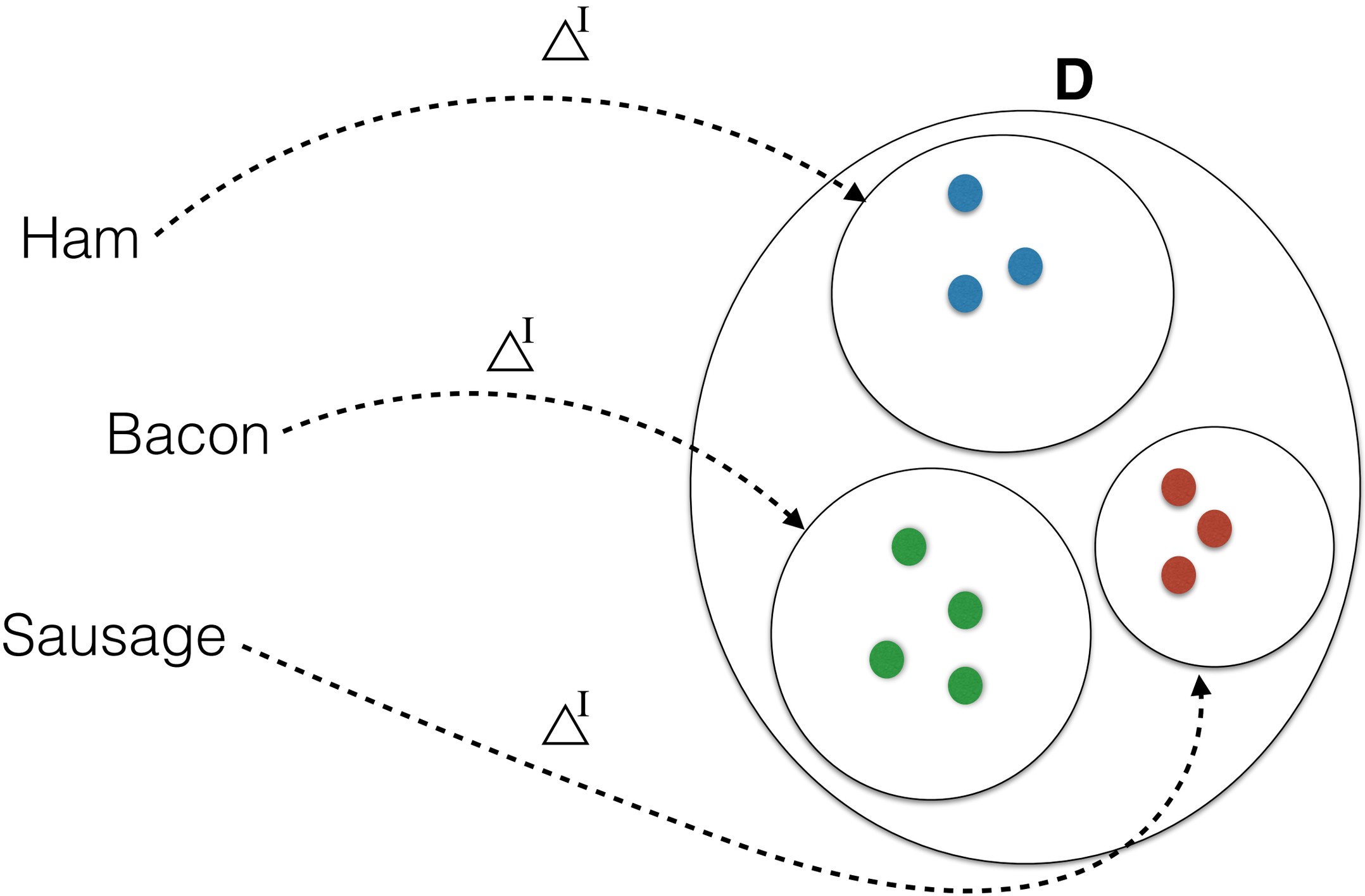
~~A theory about the kinds of entities and their ties that are assumed to exist by~~ **a given description of reality**

ontology ≈

~~A theory about the kinds of entities and their ties that are assumed to exist by~~ **a given logical description** ~~of reality~~

ontology ≈

~~A theory about the kinds of entities and their ties that are assumed to exist by~~ **a given logical description in OWL** ~~of reality~~

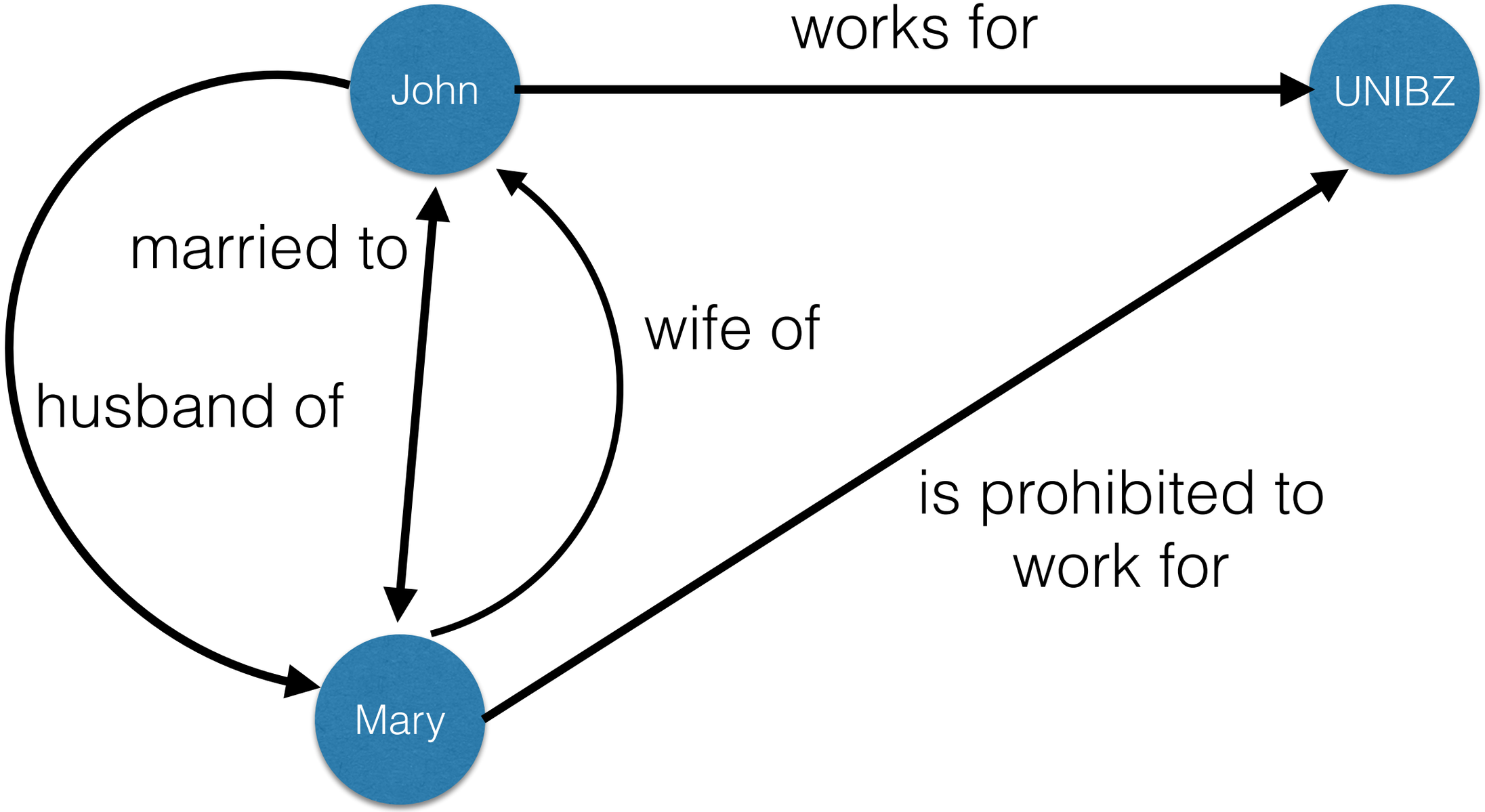

Ham
Bacon
Sausage
I
I
I
D

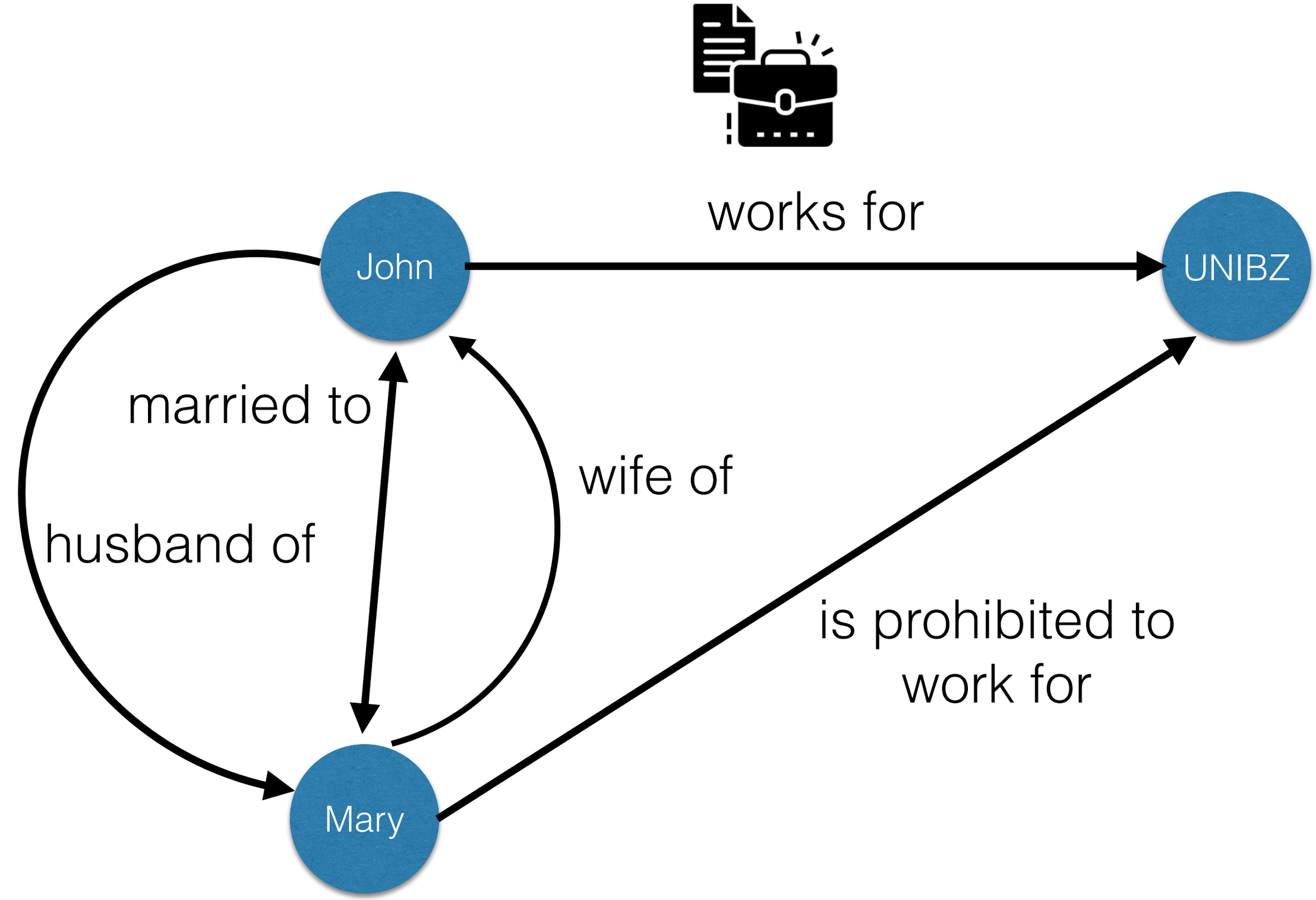
Descriptive

X

Explanatory

Descriptive
(**Truth-bearers**)
X
Explanatory
(**Truth-makers**)


works for
John
UNIBZ
married to
husband of
wife of
is prohibited to
work for
Mary


works for
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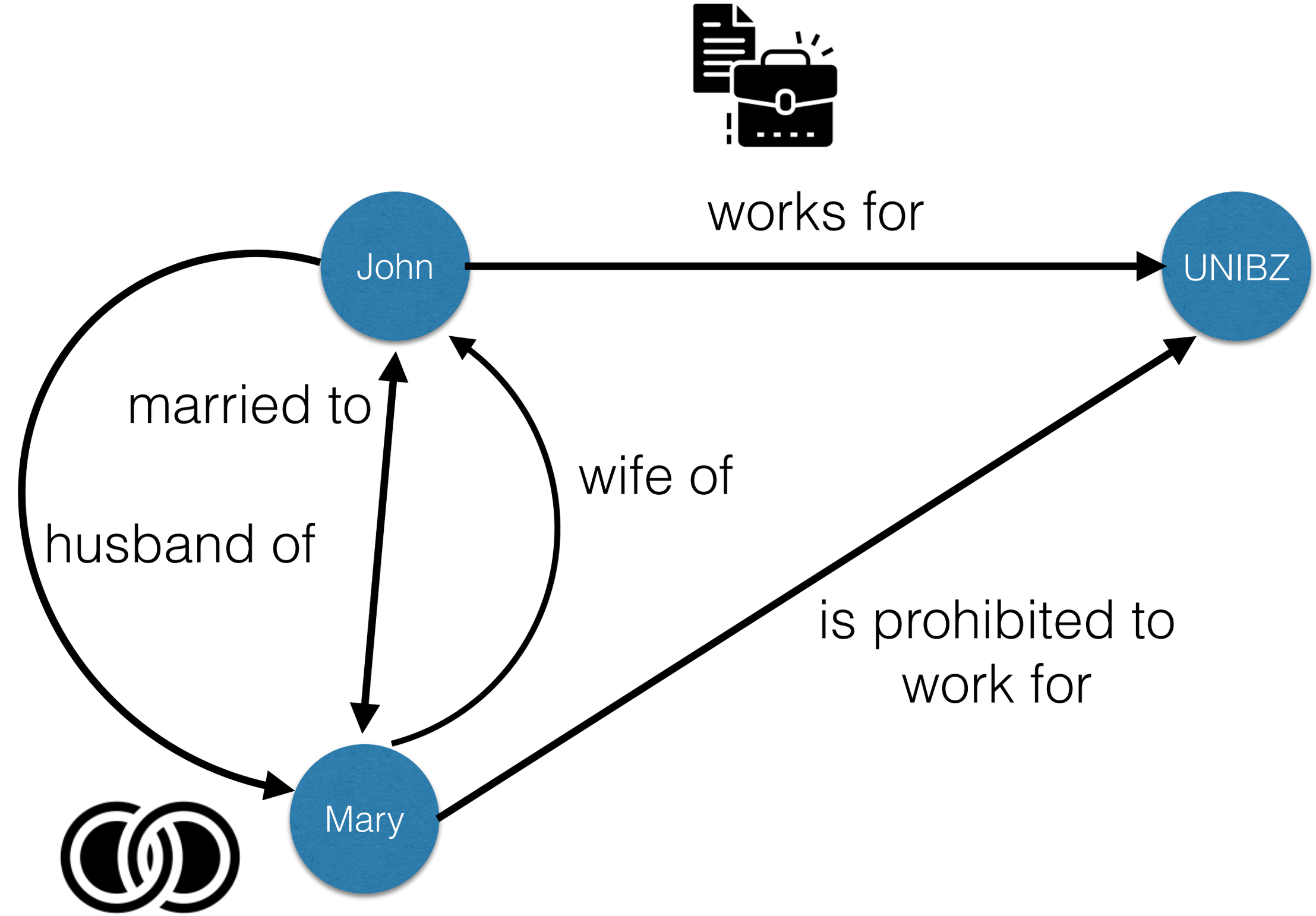
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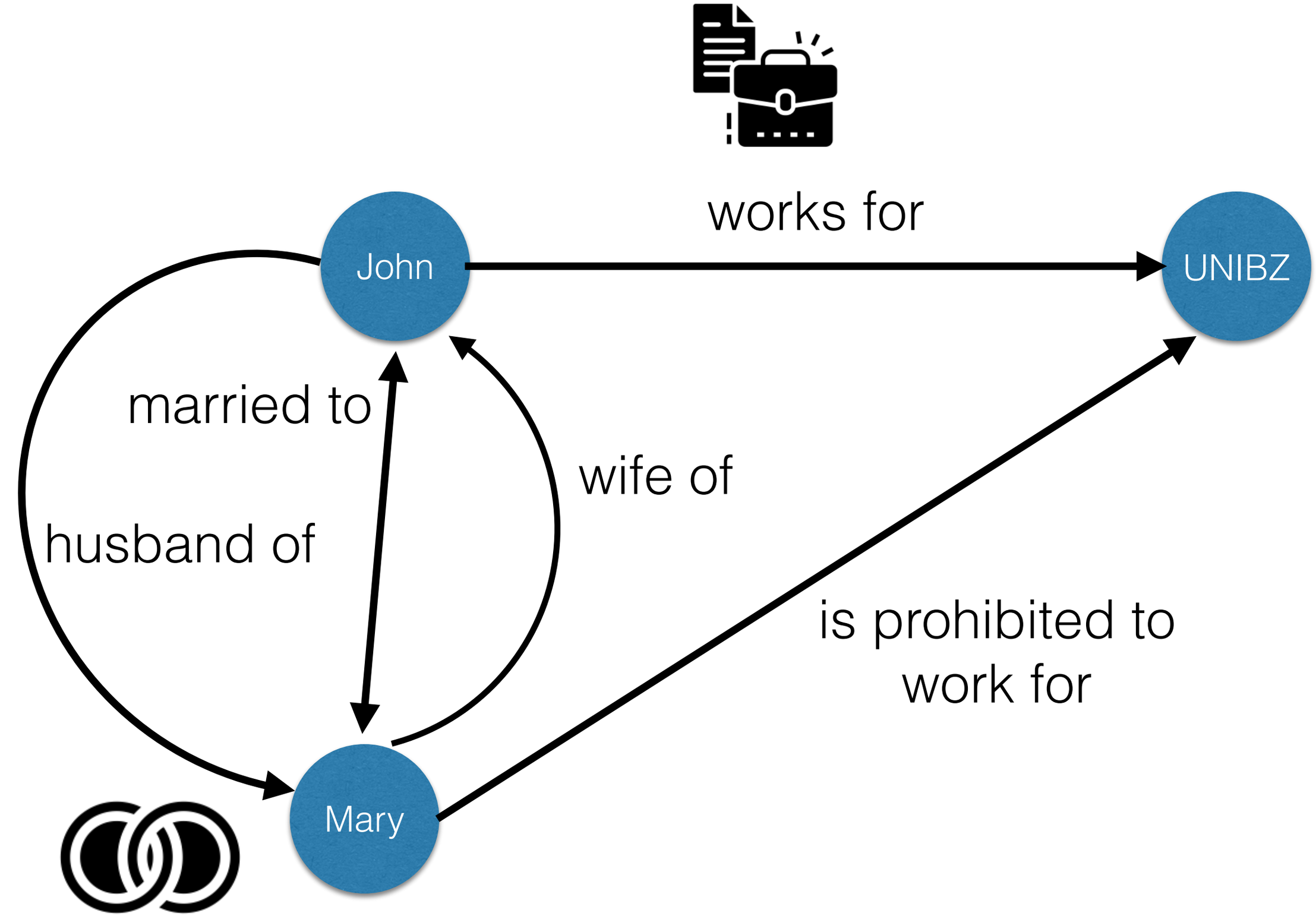
works for
John
UNIBZ
married to
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wife of
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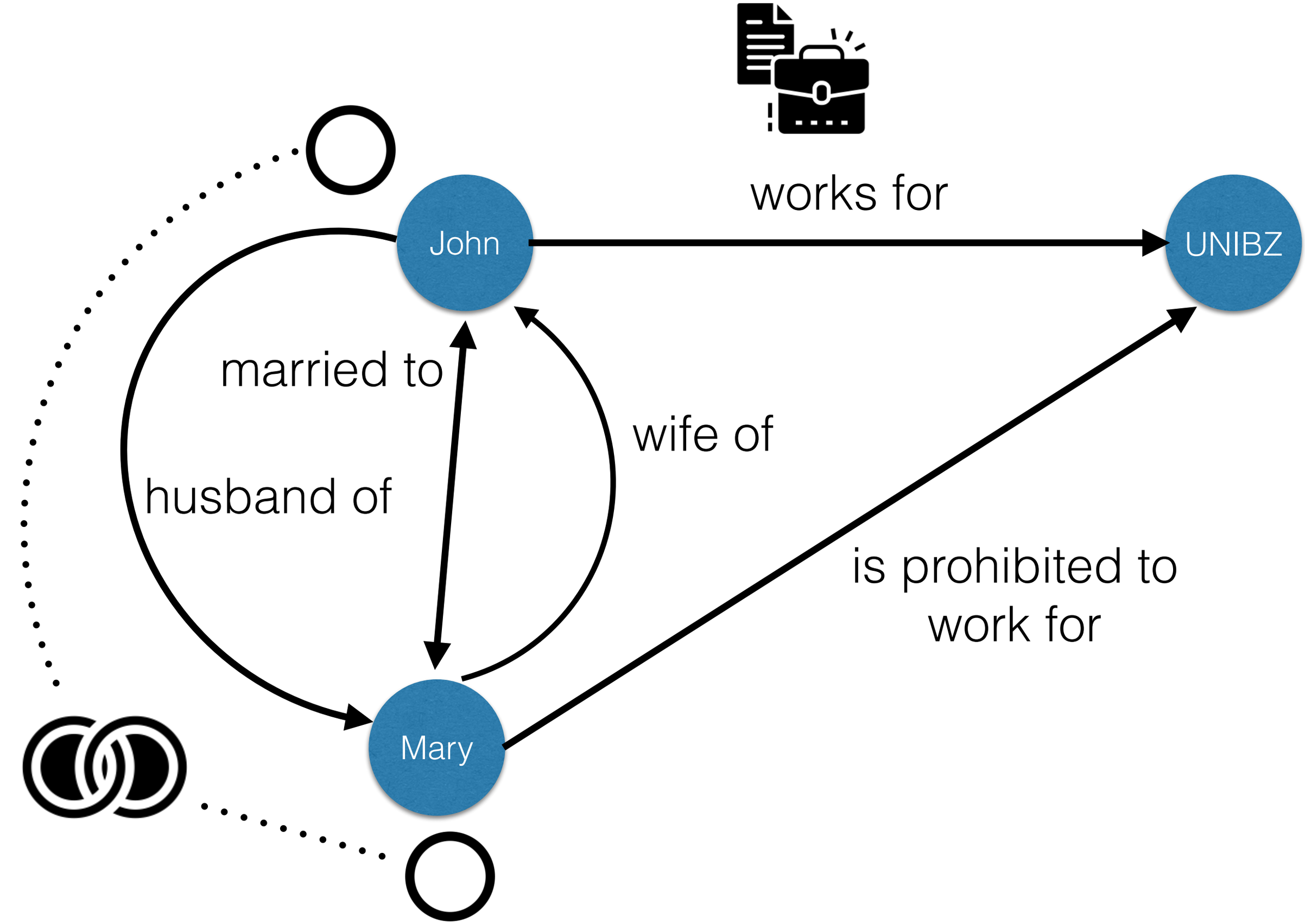
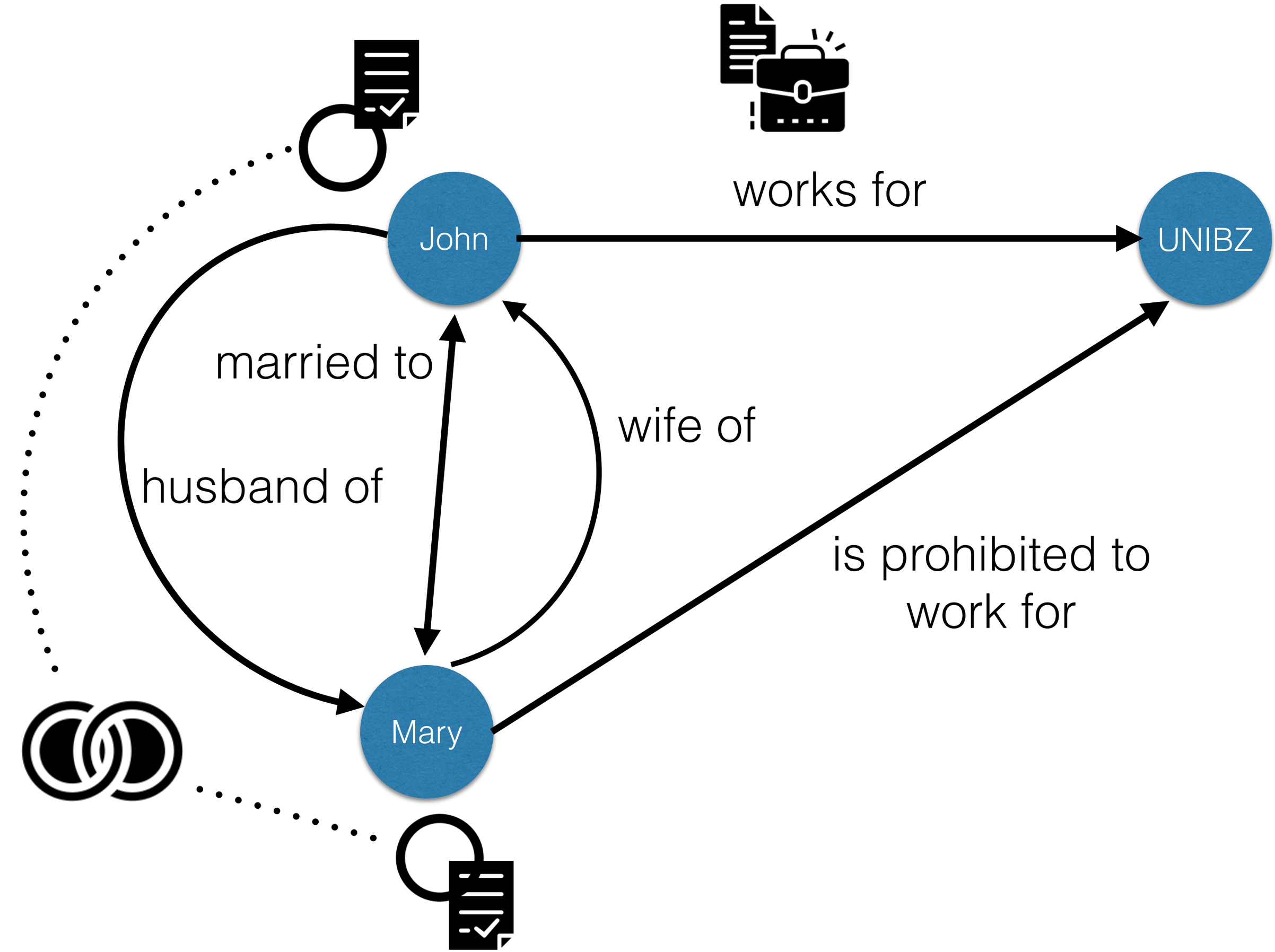
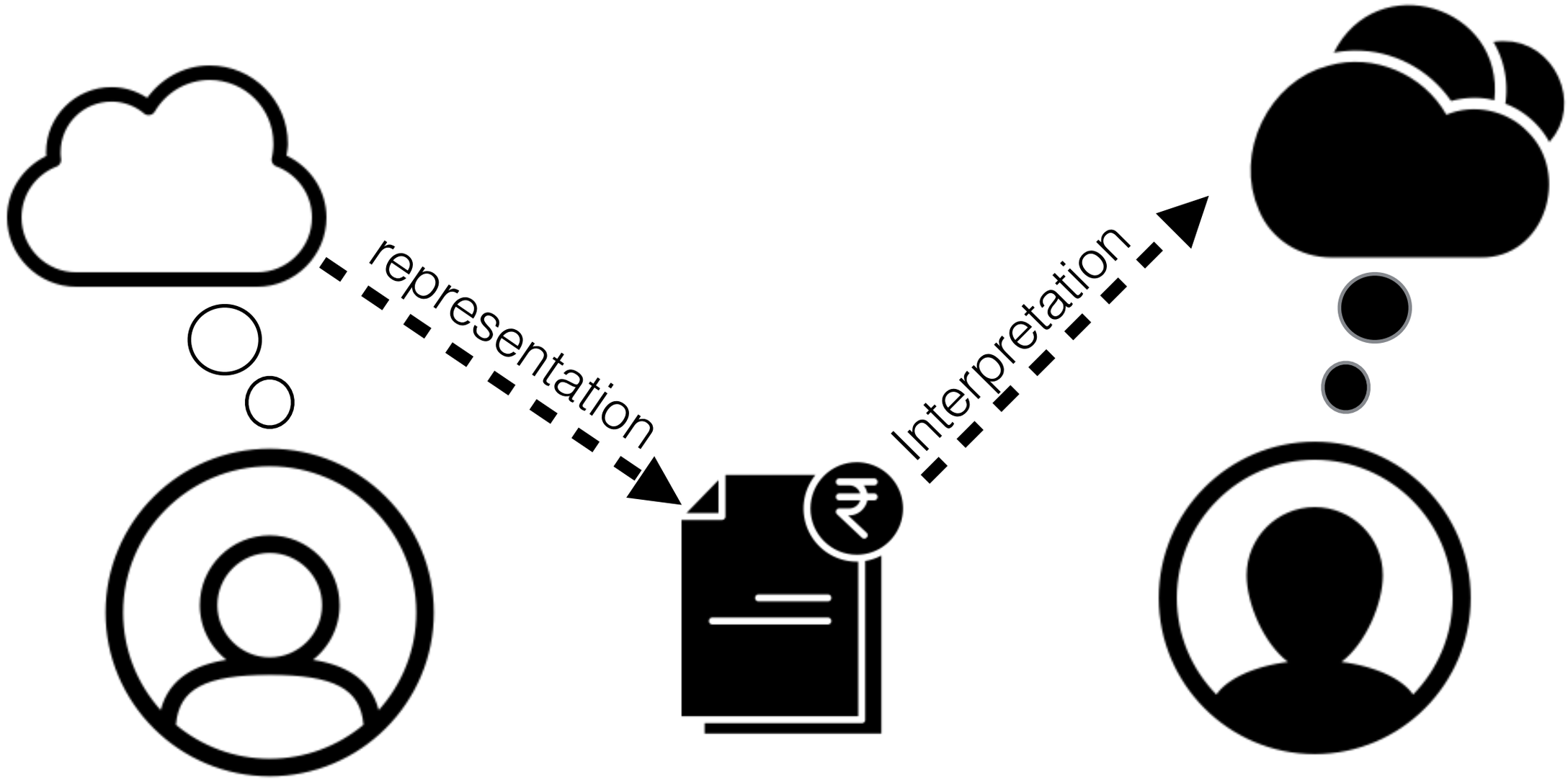
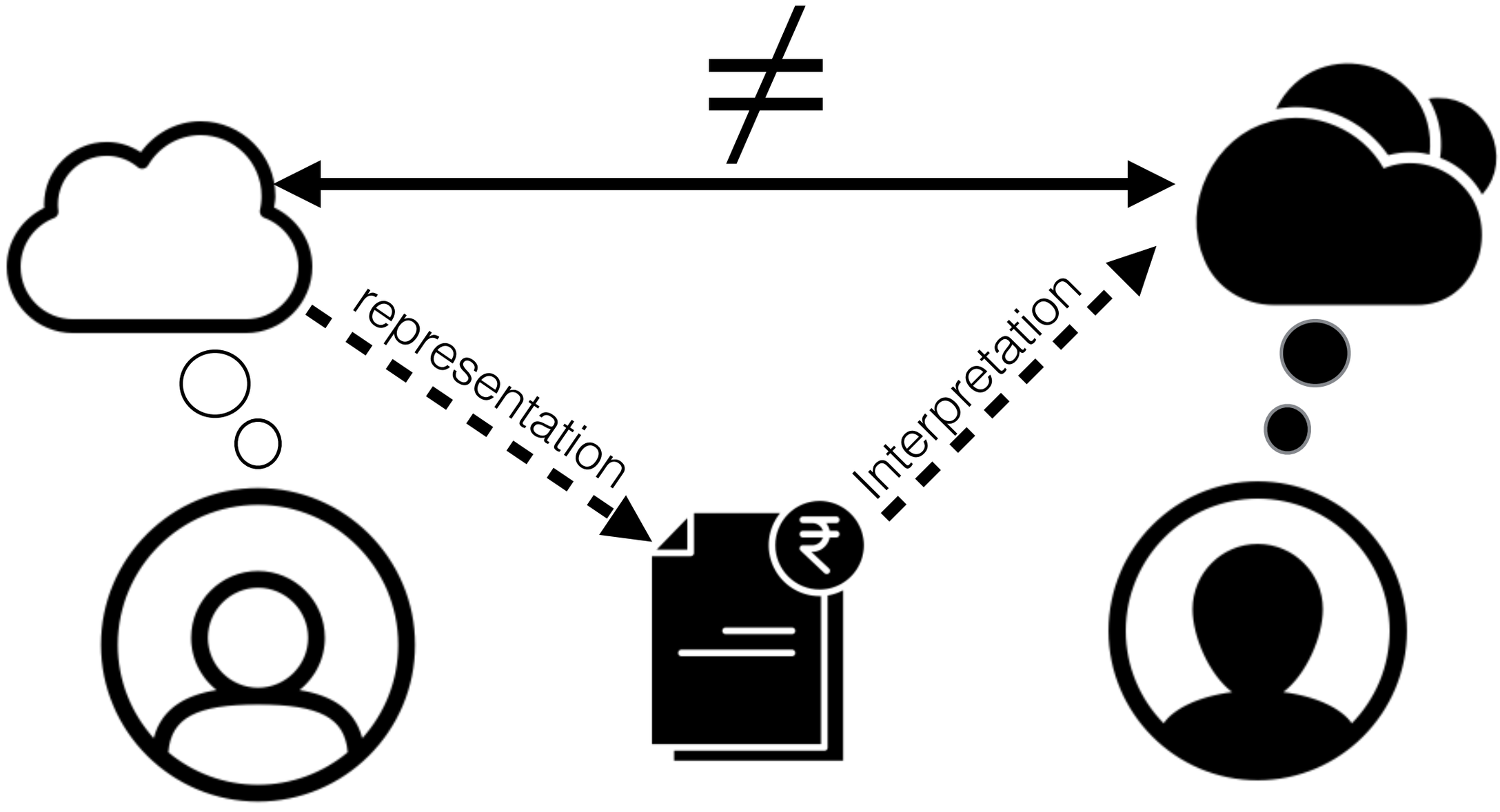
work for
Mary

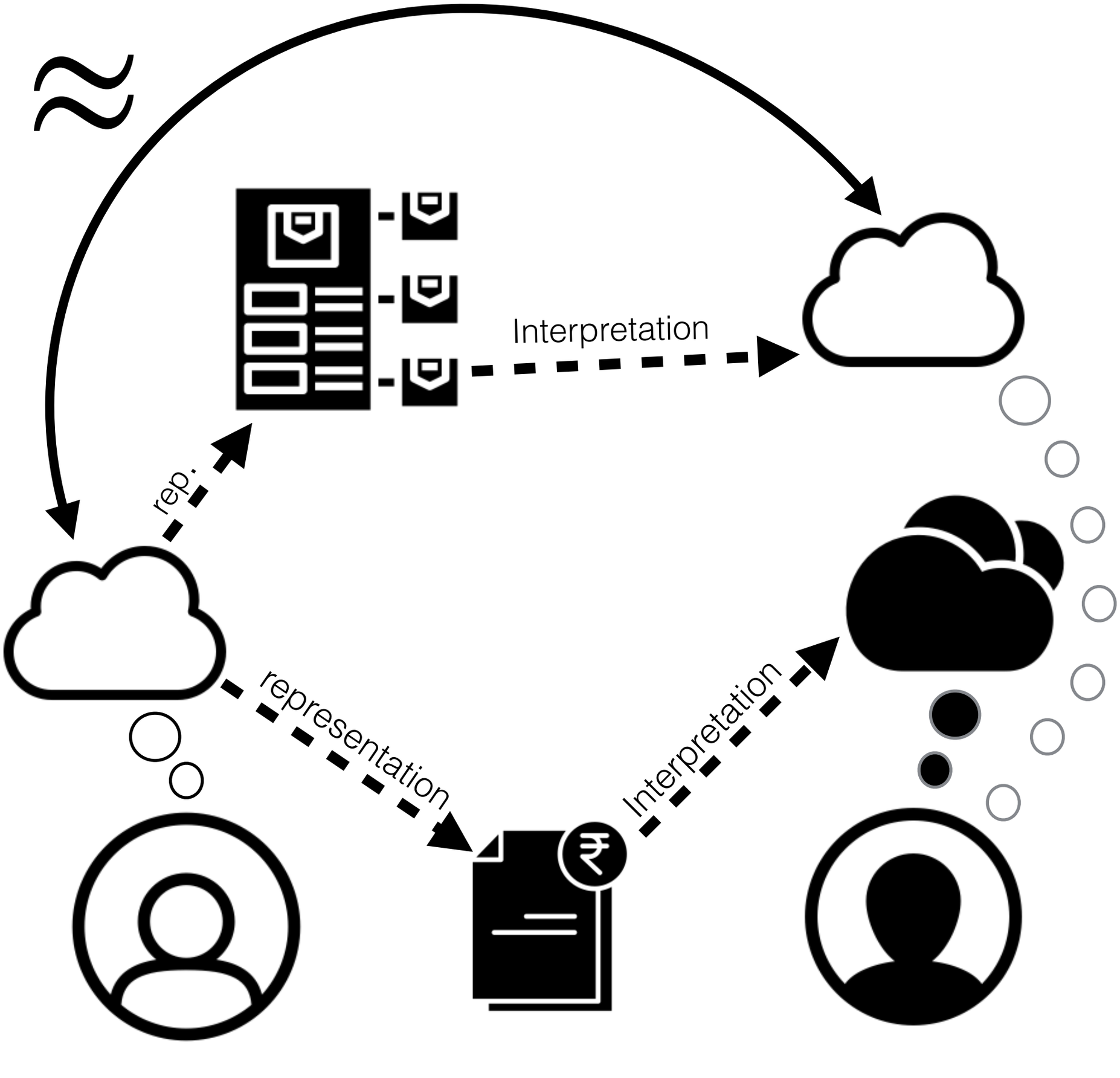

works for
John
UNIBZ
married to
husband of
wife of
is prohibited to
work for
Mary

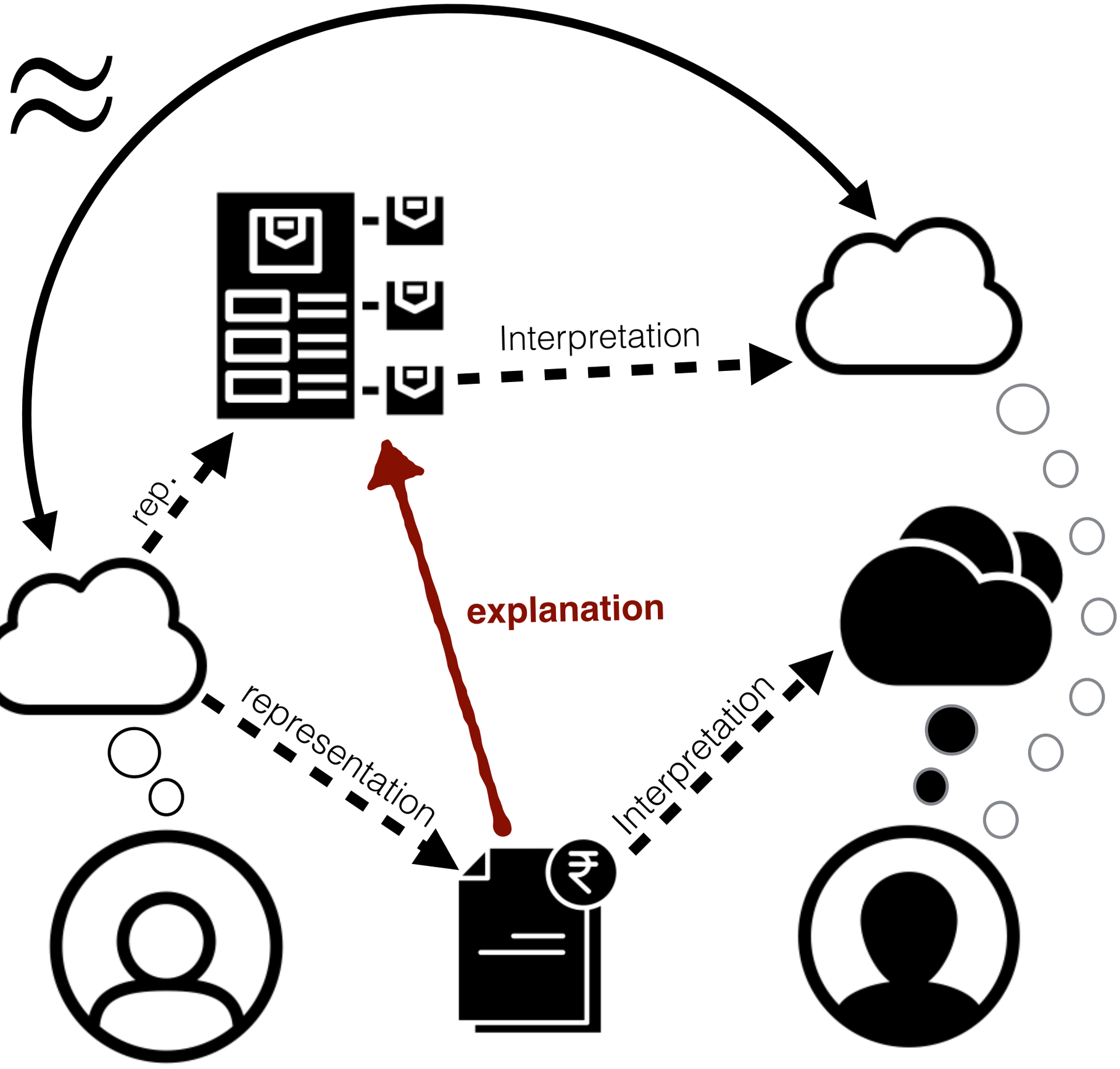

John
works for
UNIBZ
married to
husband of
wife of
is prohibited to
work for
Mary

Isn’t a **description** (just by being a symbolic artefact) already an **explanation**?


representation
Interpretation


≠
representation
Interpretation


Interpretation
rep.
representation
Interpretation


Interpretation
rep.
explanation
representation
Interpretation

“The **ontological** approach to **explanation**” by

T.Y. Cao(2004). Ontology and scientific explanation. Oxford University Press

“whenever we have something important but difficult to understand, we should focus our attention on finding what the primary entities are in the domain under investigation…”

“…Discovering these entities and their intrinsic and structural properties, rather than manipulating uninterpreted or ill-interpreted mathematical symbols, or speculating on free-floating universal laws and principles, is the real work of science…”

“Mathematical formalisms and universal laws and principles are relevant and important only when they have a firm ontological basis.”

RESEARCH ARTICLE

Semantic Interoperability: Ontological Unpacking of a Viral Conceptual Model

Anna Bernasconi[1,4*], Giancarlo Guizzardi[2,3], Oscar Pastor[4] and Veda C. Storey[5]

*Correspondence:
anna.bernasconi@polimi.it
[1]Department of Electronics, Information and Bioengineering, Politecnico di Milano, Milan, Italy
[4]PROS Research Center & VRAIN Research Institute, Universidad Politècnica de València, Valencia, Spain
Full list of author information is available at the end of the article

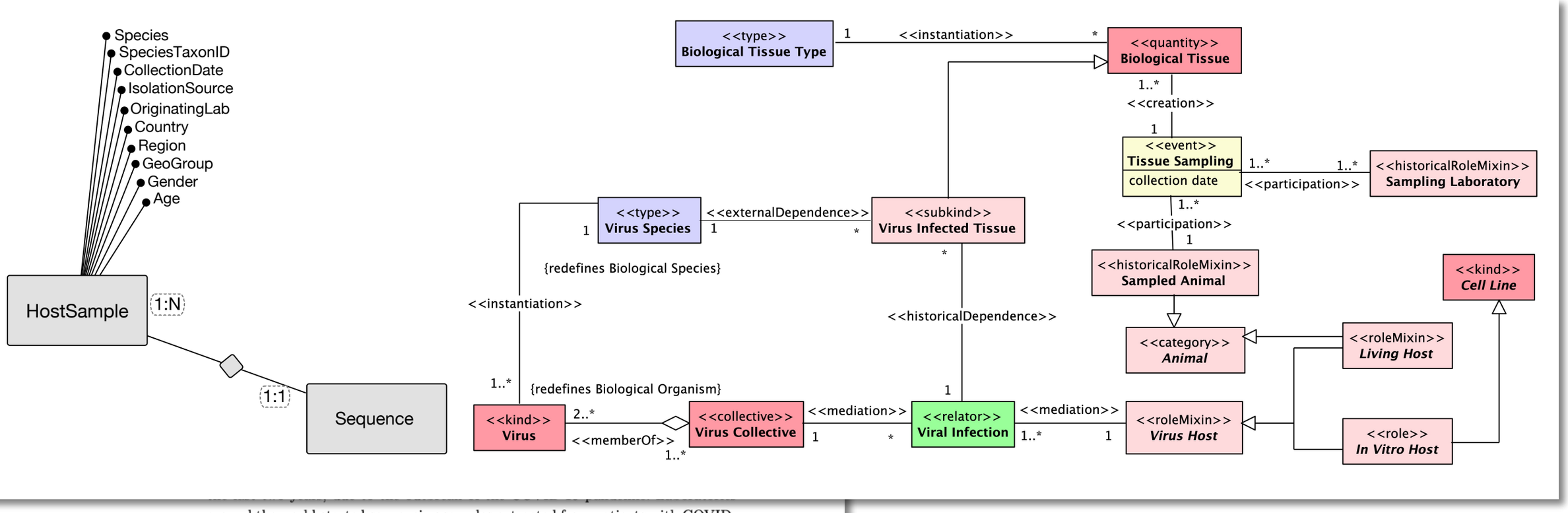
Abstract

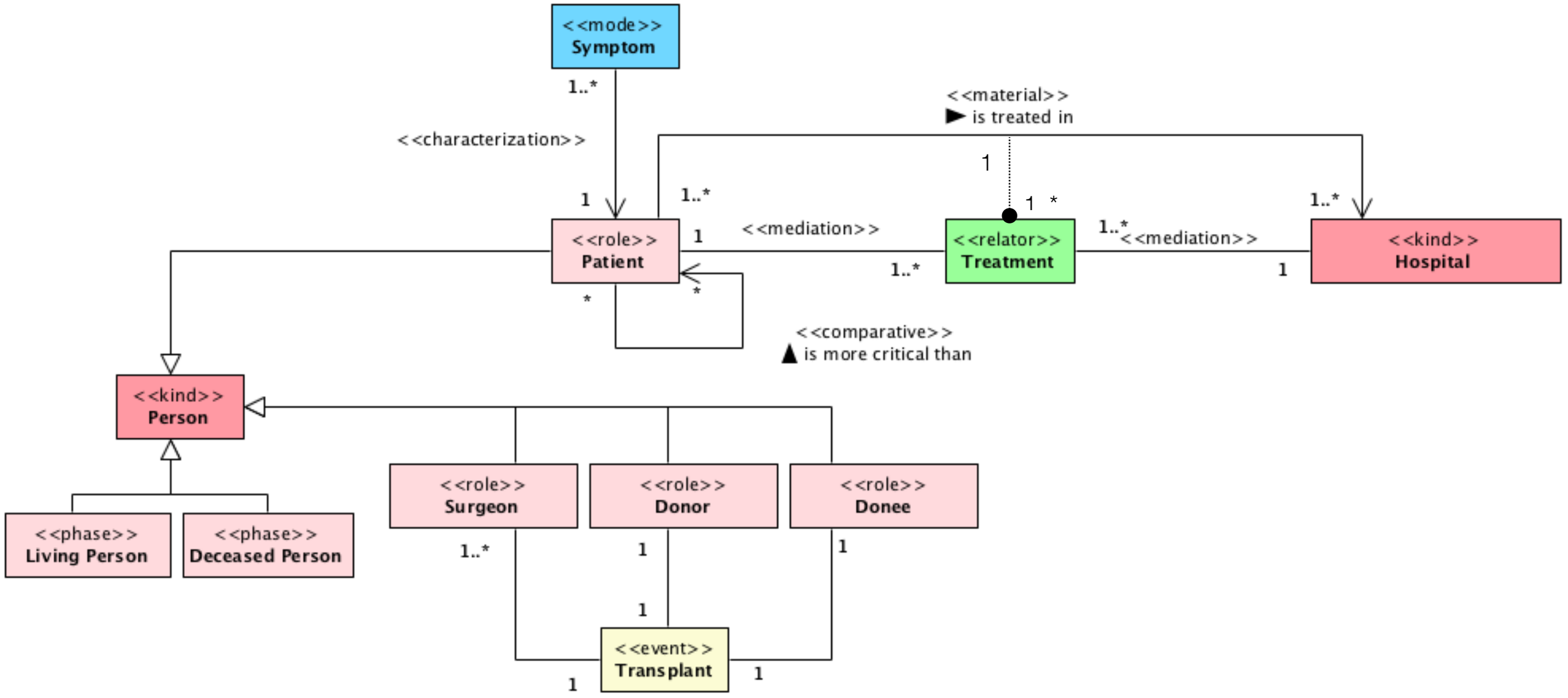
Background: Genomics and virology are unquestionably important, but complex, domains being investigated by a large number of scientists. The need to facilitate and support work within these domains requires sharing of databases, although it is often difficult to do so because of the different ways in which data is represented across the databases. To foster semantic interoperability, models are needed that provide a deep understanding and interpretation of the concepts in a domain, so that the data can be consistently interpreted among researchers.

Results: In this research, we propose the use of conceptual models to support semantic interoperability among databases and assess their ontological clarity to support their effective use. This modeling effort is illustrated by its application to the Viral Conceptual Model (VCM) that captures and represents the sequencing of viruses, inspired by the need to understand the genomic aspects of the virus

around the world started sequencing samples extracted from patients with COVID-

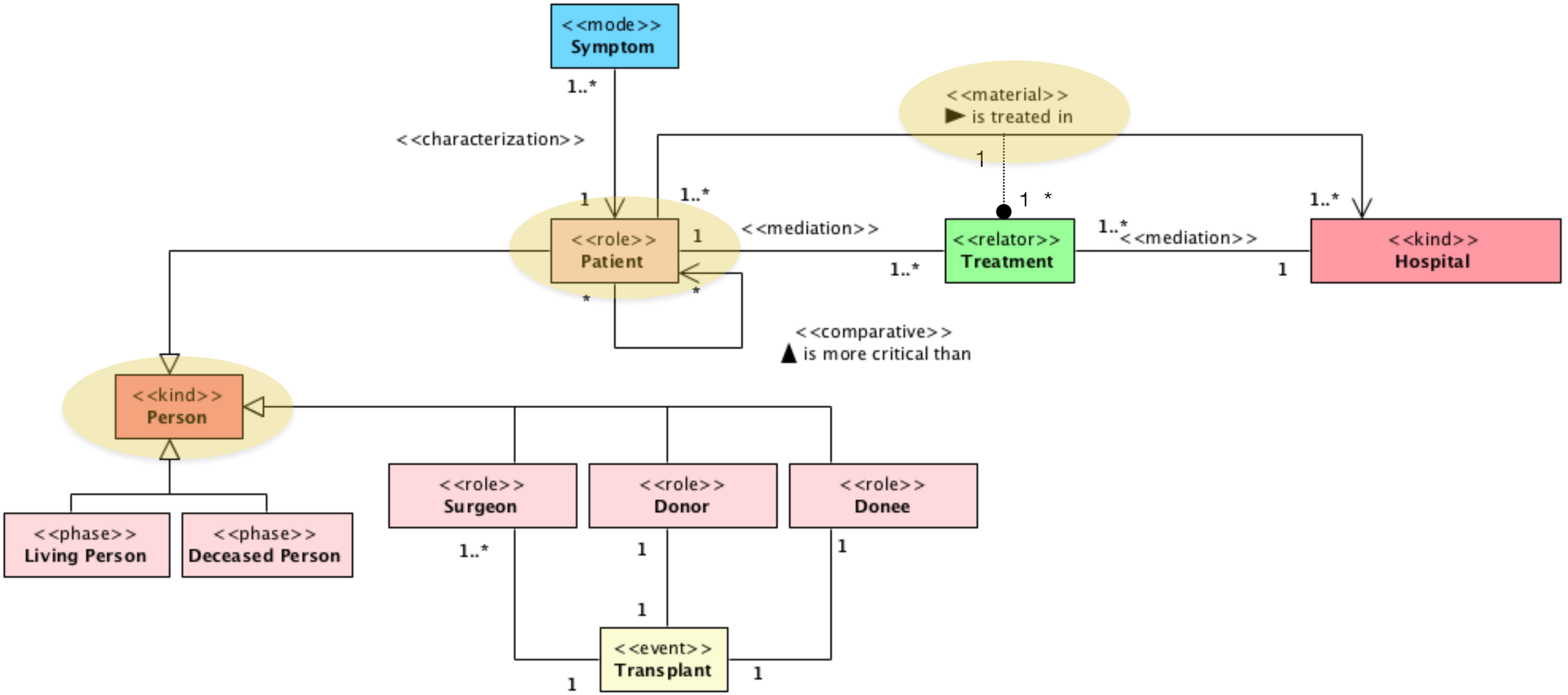
Ontological Unpacking





Unified Foundational Ontology

ONTOUML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Symptom
1..*
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1..*
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Treatment
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Living Person
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Transplant
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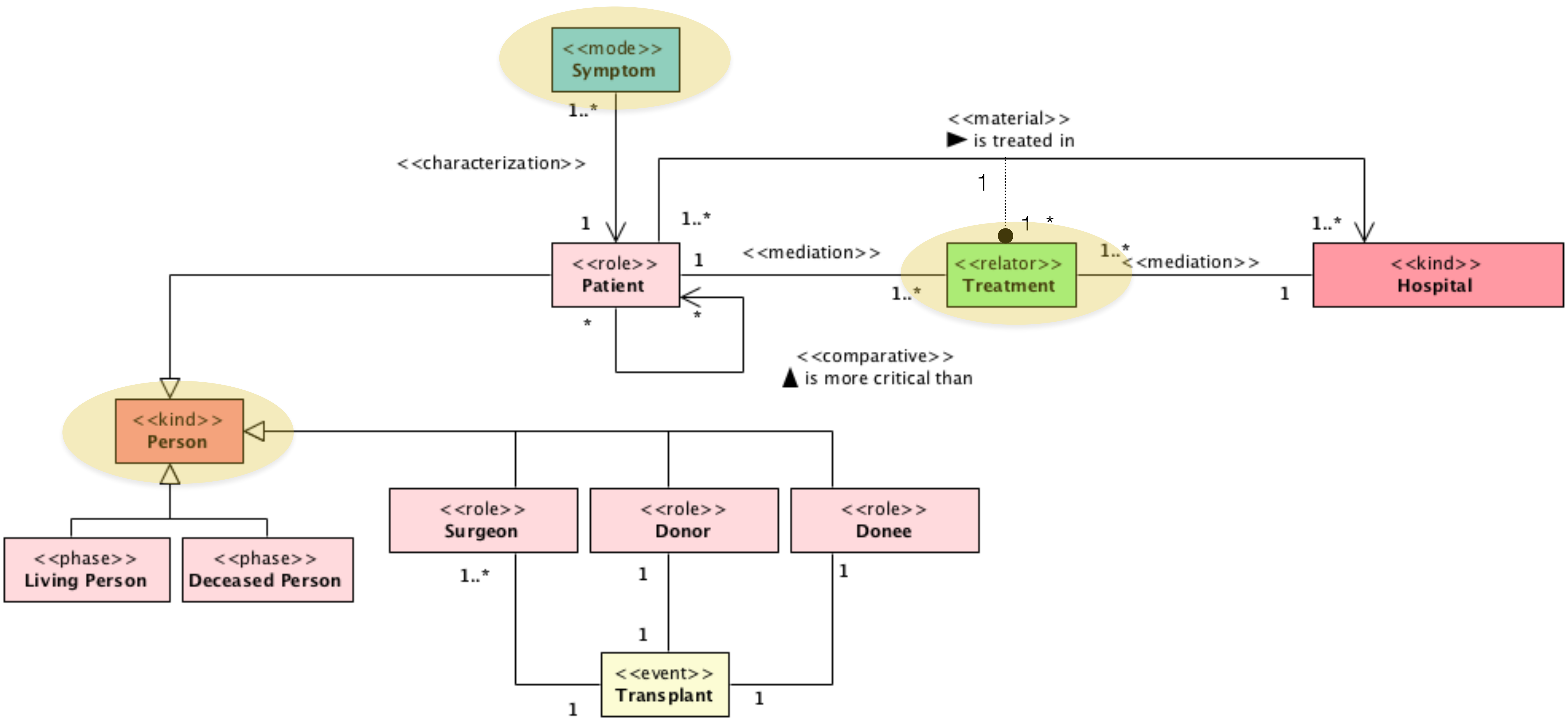

<<mode>>
Symptom
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▶ is treated in
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Patient
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Treatment
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Hospital
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<<comparative>>
▲ is more critical than
<<kind>>
Person
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Surgeon
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Donor
<<role>>
Donee
<<phase>>
Living Person
<<phase>>
Deceased Person
1..*
1
1
1
<<event>>
Transplant
1
1

ontology≈

the representation resulting from a proper **Ontological Unpacking**

2

What’s in a Relation?

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**

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

WHAT'S IN A LINK:

Foundations for Semantic Networks

W. A. Woods

November 1975

Sponsored by
Advanced Research Projects Agency
ARPA Order No. 2904

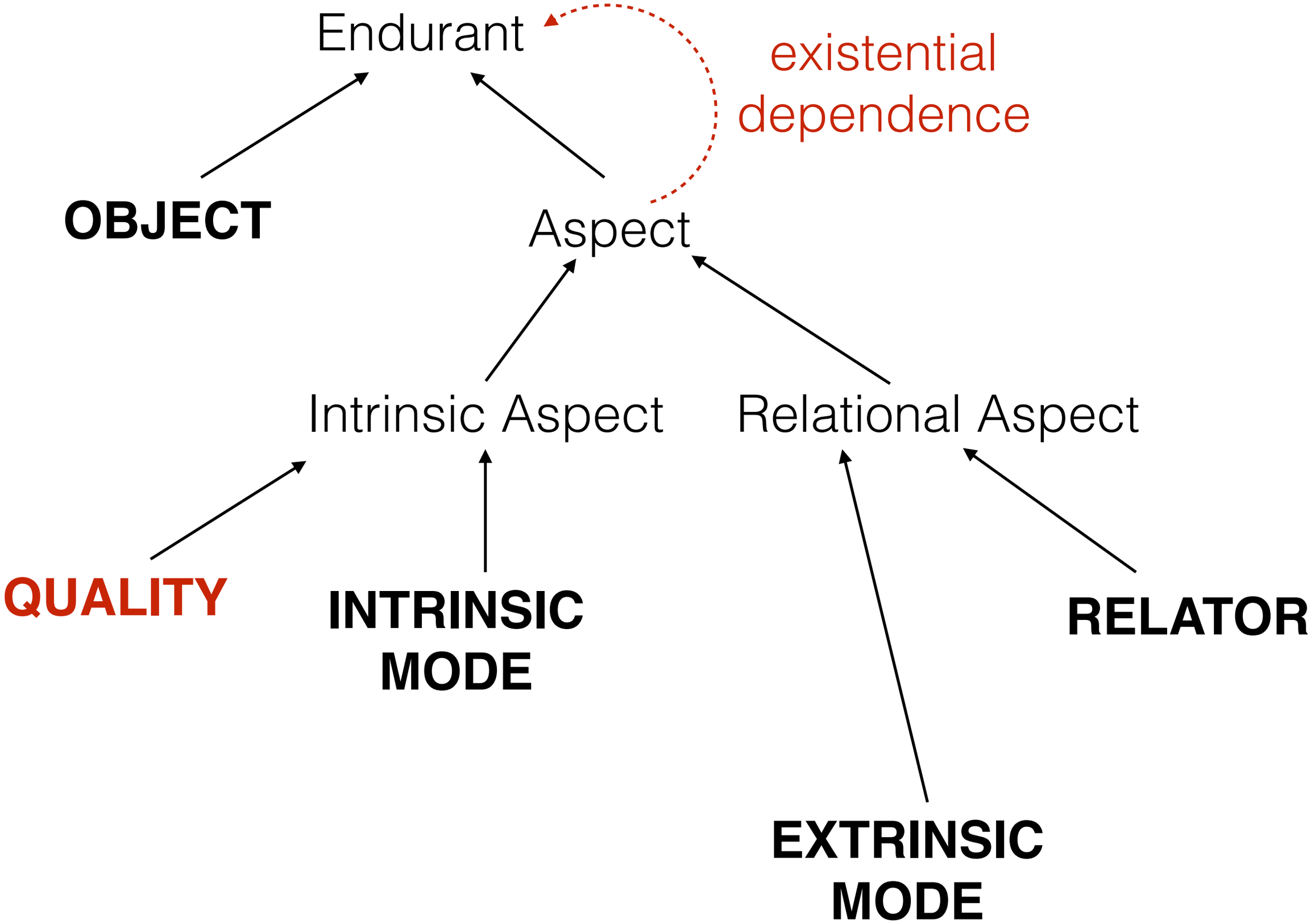
of today's semantic networks. Facts about an object can frequently be stored on a "property list" of the object by specifying such attribute-value pairs as HEIGHT : 6 FEET, HAIRCOLOR : BROWN, OCCUPATION : SCIENTIST, etc. (Such lists are provided, for example, for all atoms in the LISP programming language.) 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:

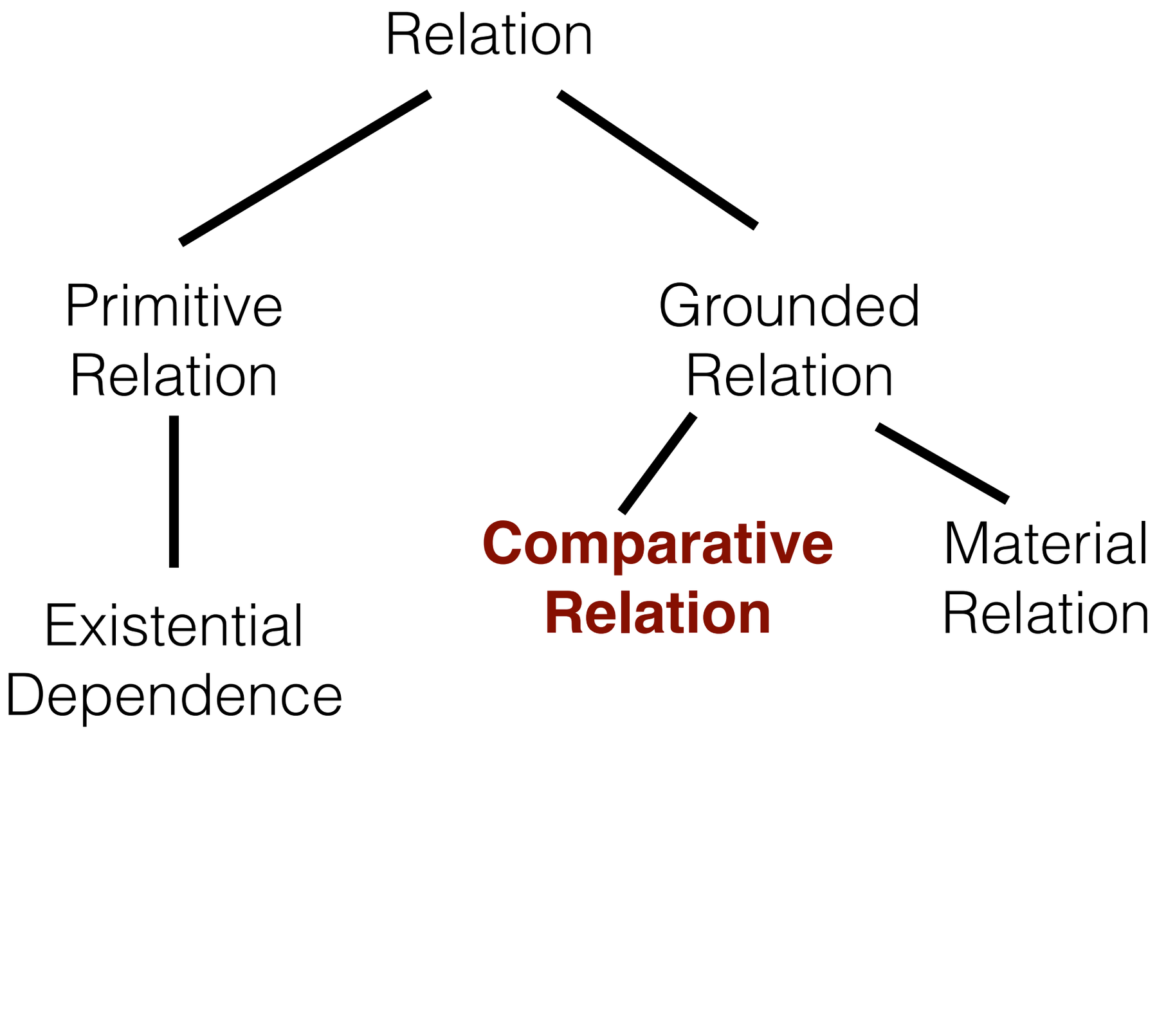
```
          JOHN

               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

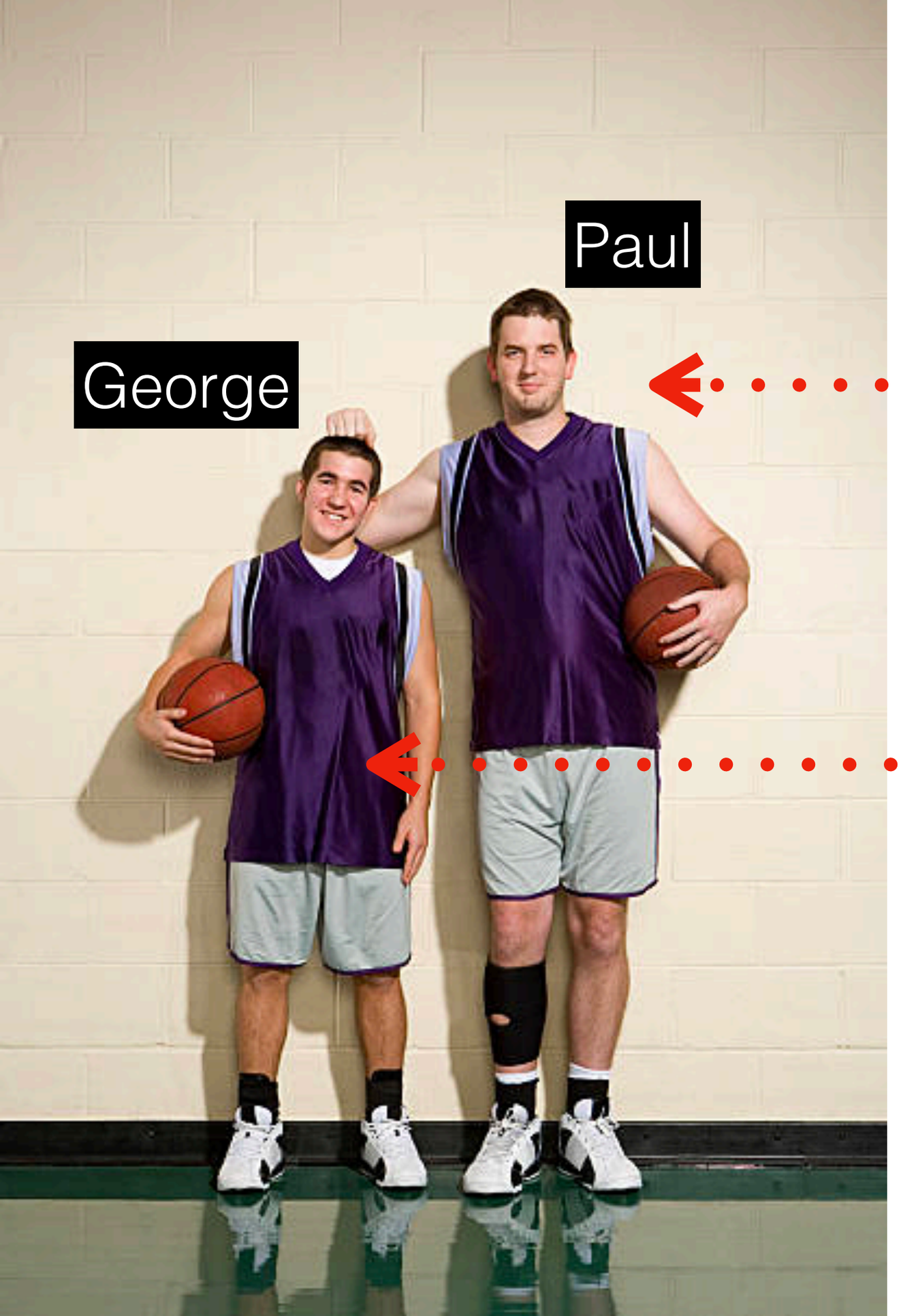
but that is departing completely from the notion of attribute-value links. There is another possible interpretation of the thing at the end of the HEIGHT link which would be capable of dealing with this type of situation. That is, the HEIGHT link can point from JOHN to a node which represents the intensional 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,


Endurant
existential dependence
OBJECT
Aspect
Intrinsic Aspect
Relational Aspect
QUALITY
INTRINSIC MODE
EXTRINSIC MODE
RELATOR


Relation
Primitive Relation
Grounded Relation
Existential Dependence
Comparative Relation
Material Relation


Paul
George

taller-than (Paul,George)?

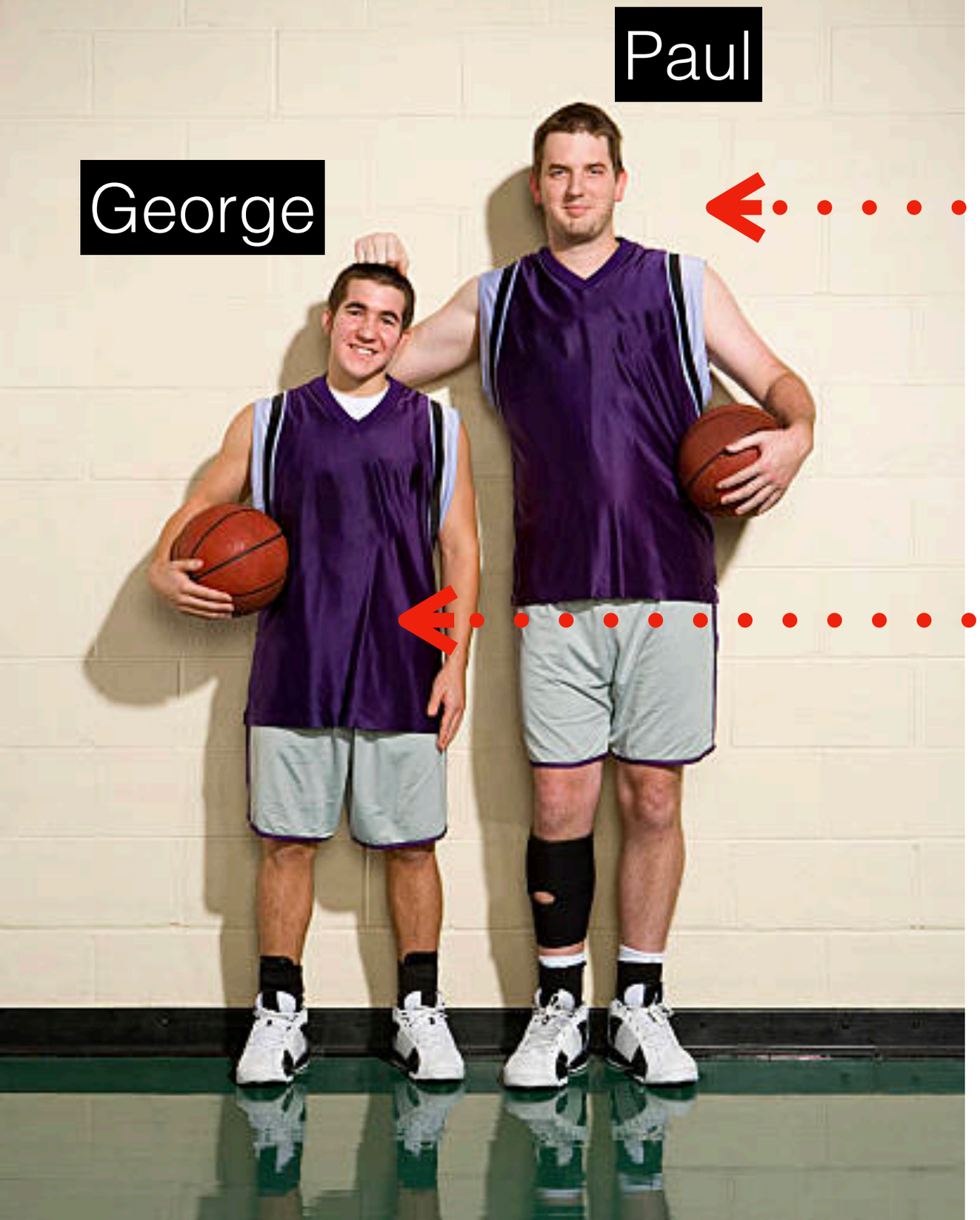


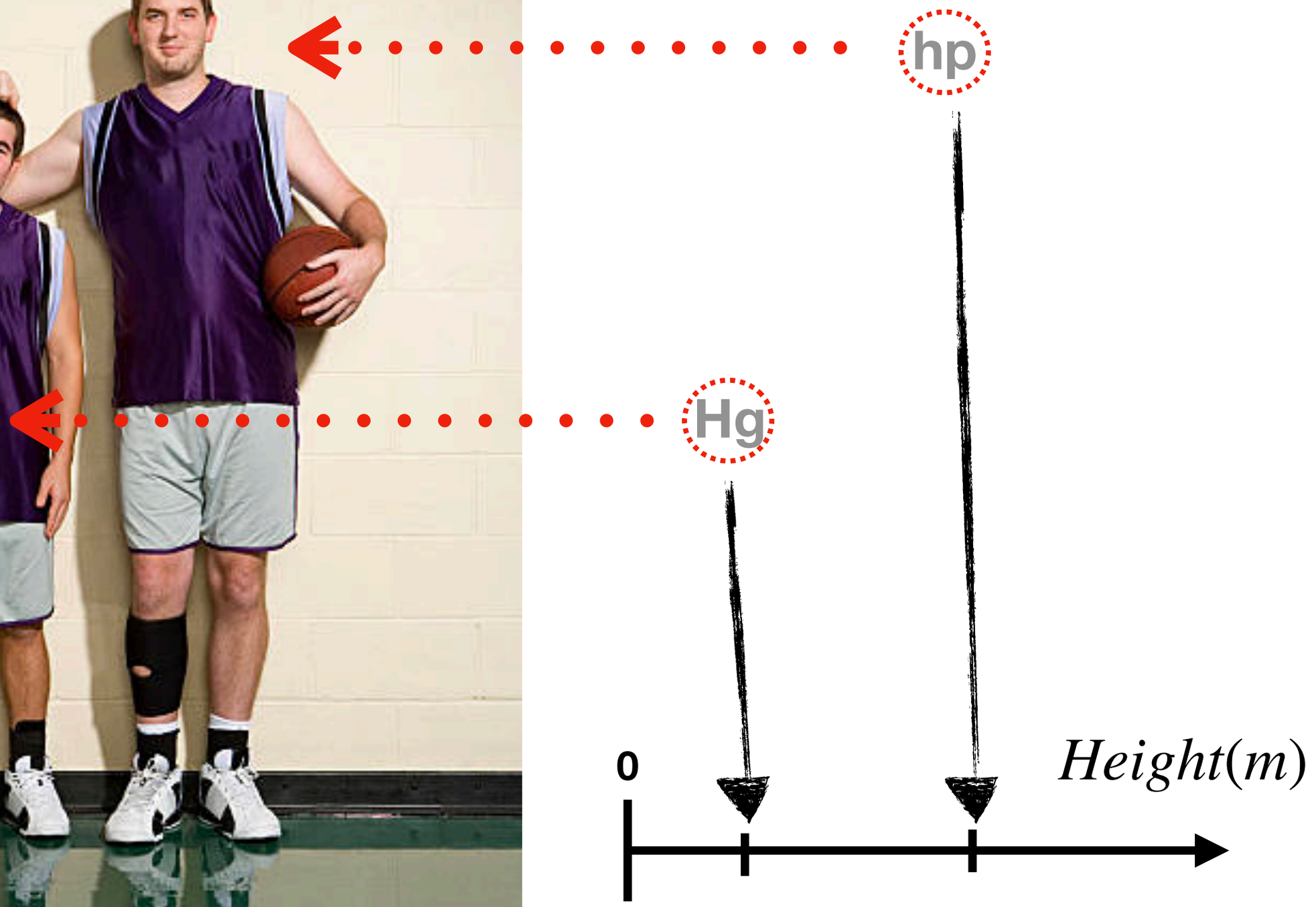
taller-than (Paul,George)?

hp

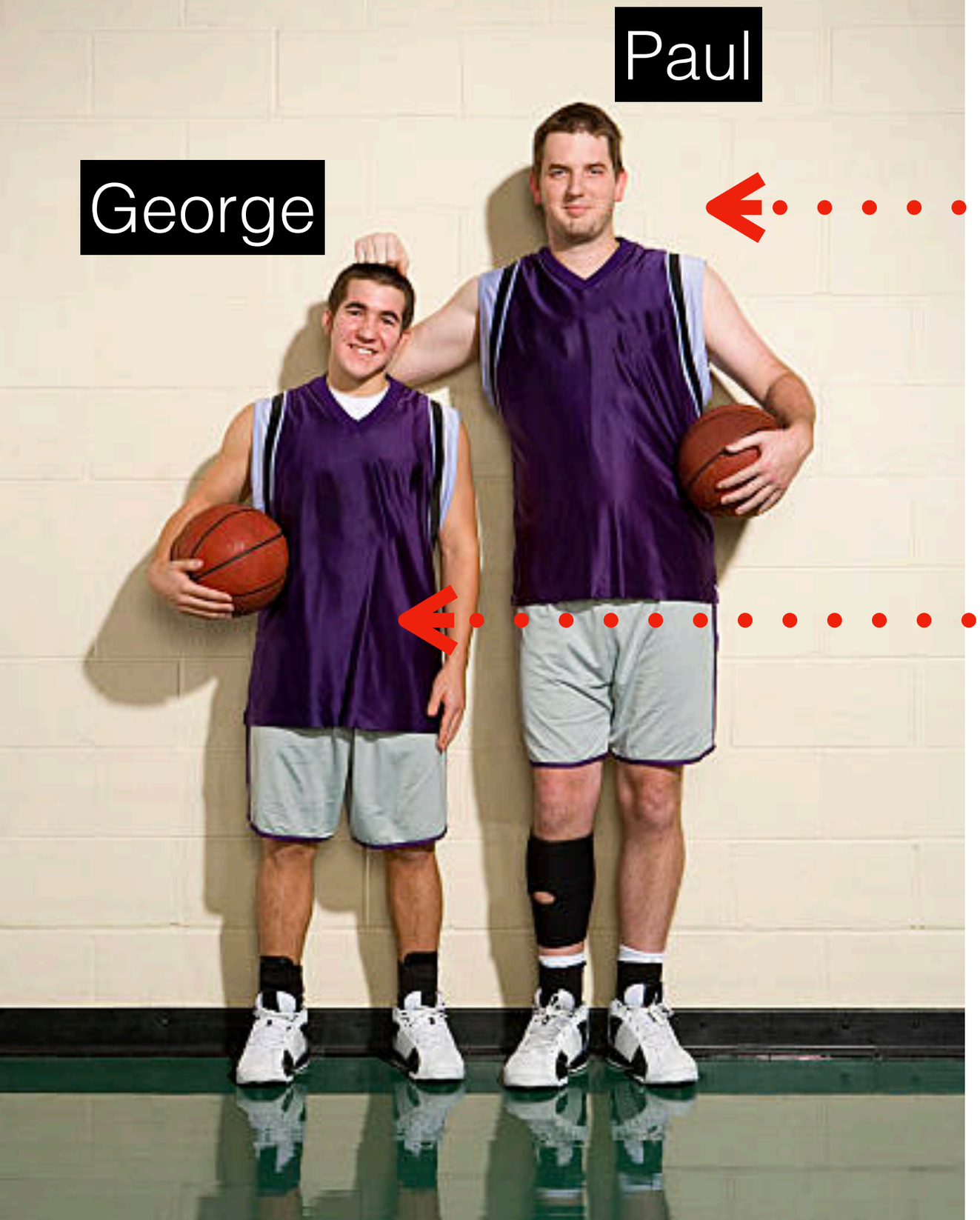
Hg

taller-than (Paul,George)?





taller-than (Paul,George)?



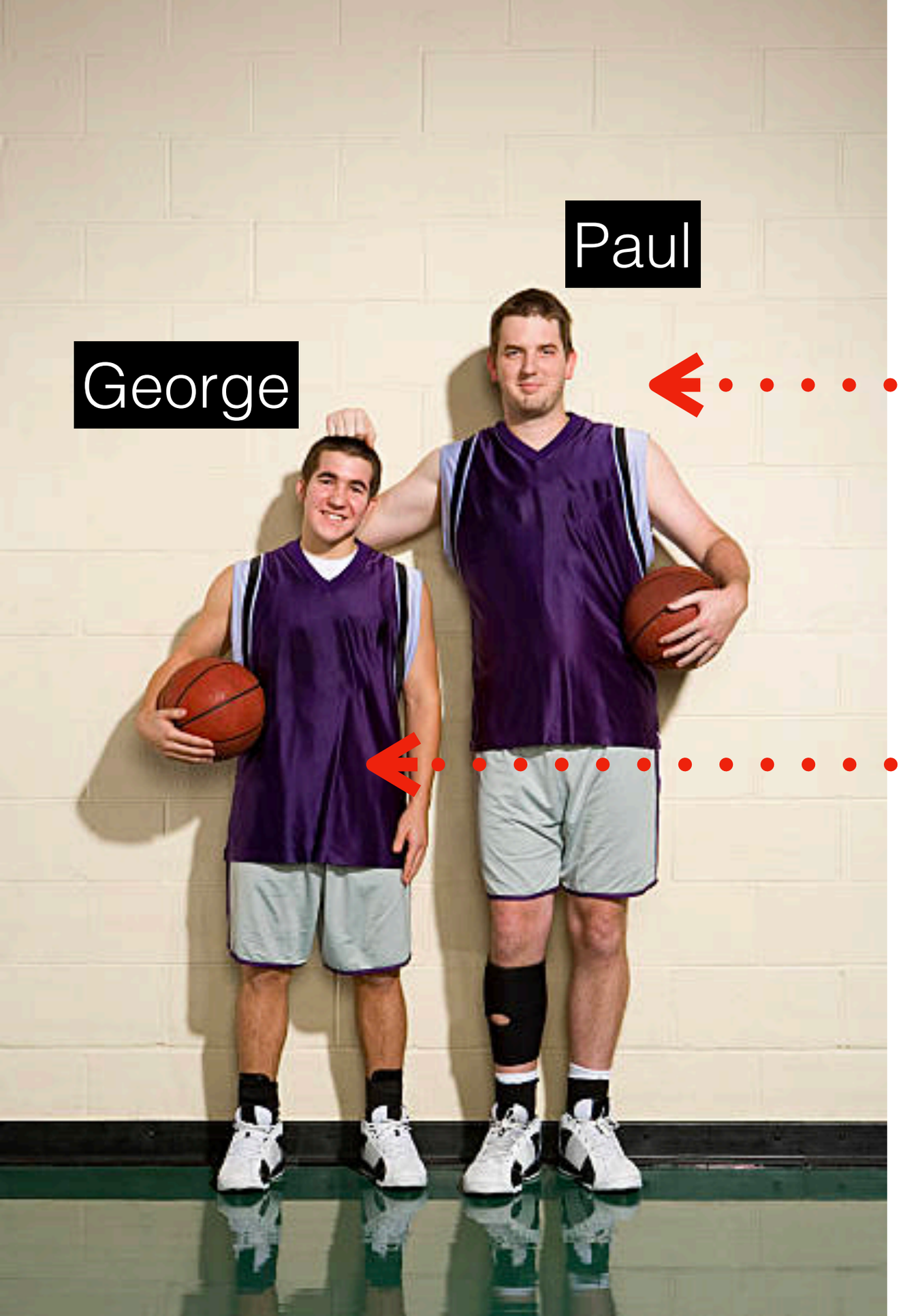
hp

Hg

0

Height(m)

vhg < vhp ?



taller-than (Paul,George)?

Totally Ordered
(Non-reflexive
Asymmetric
Transitive
Total)

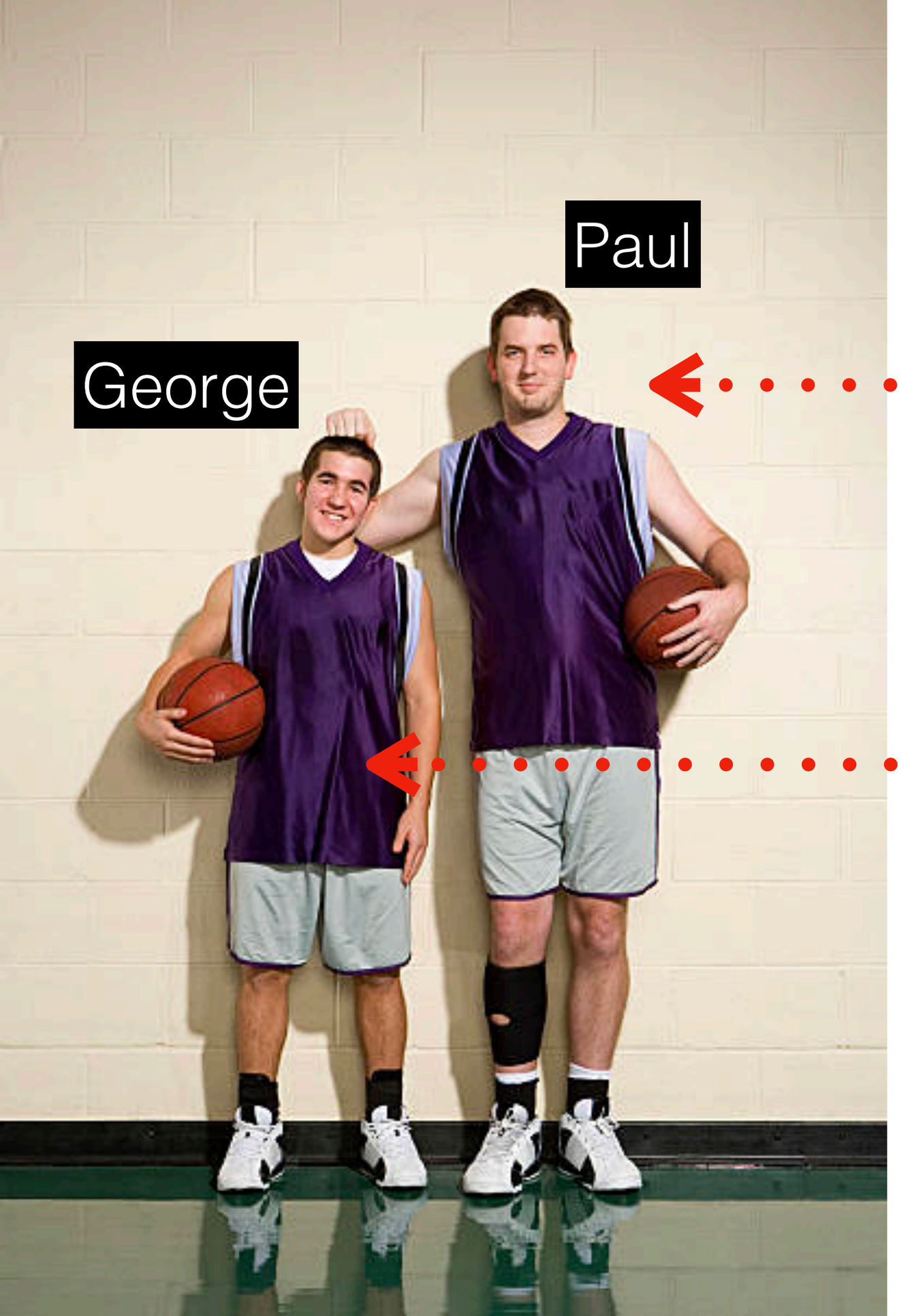
hp

Hg

0

Height(m)

vhg < vhp ?



taller-than (Paul,George)?

hp

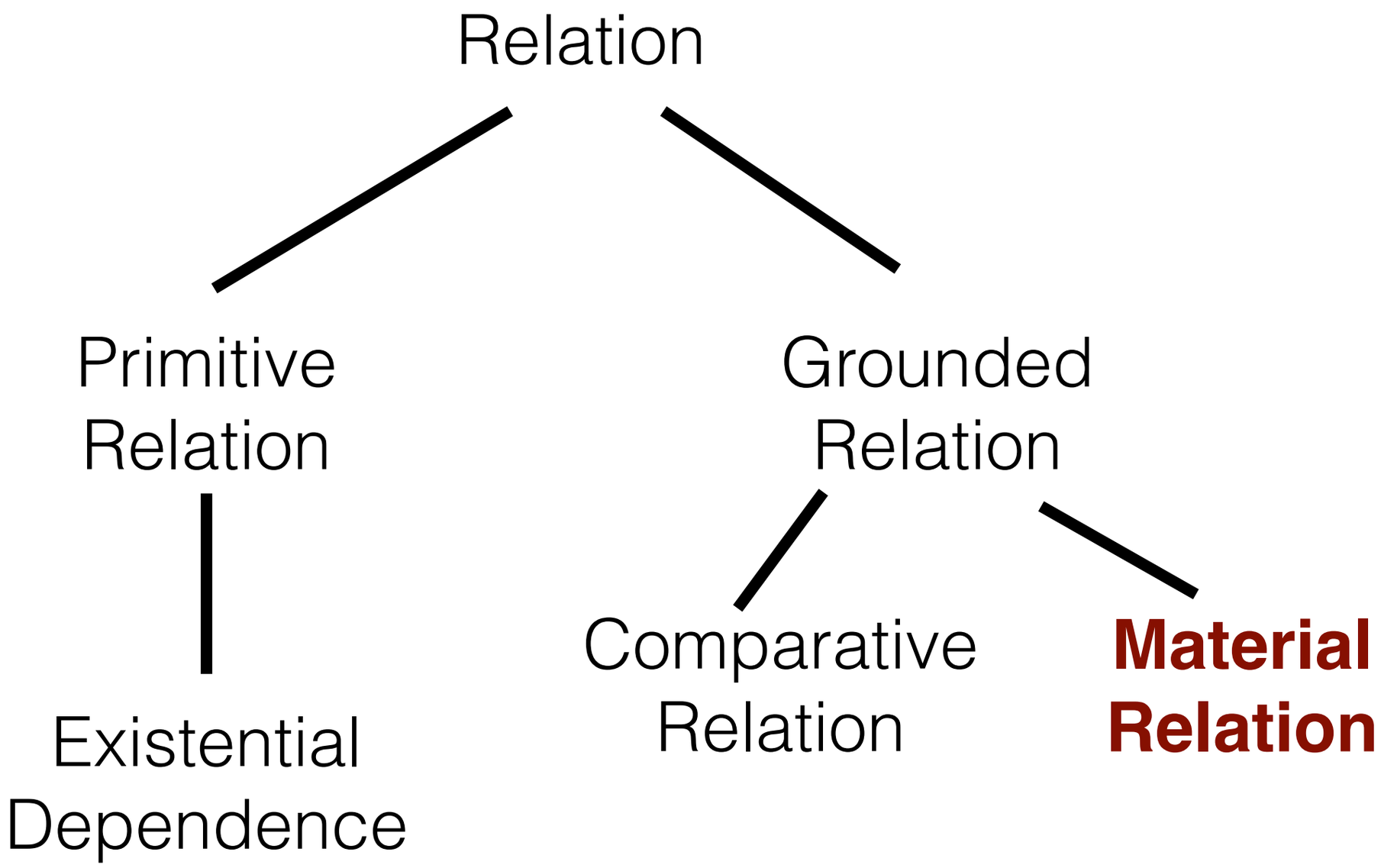
Hg

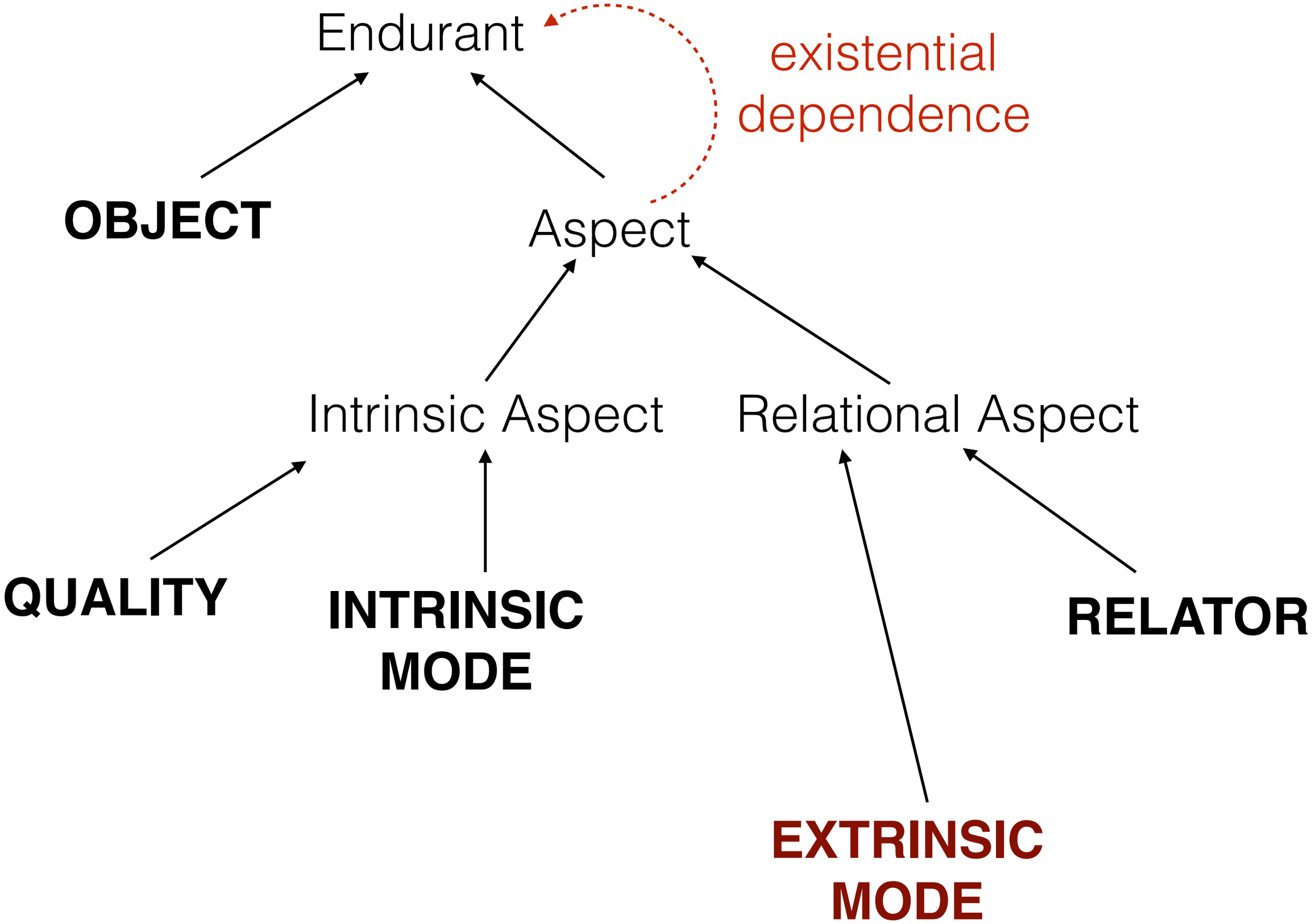
Totally Ordered (Non-reflexive Asymmetric Transitive Total)

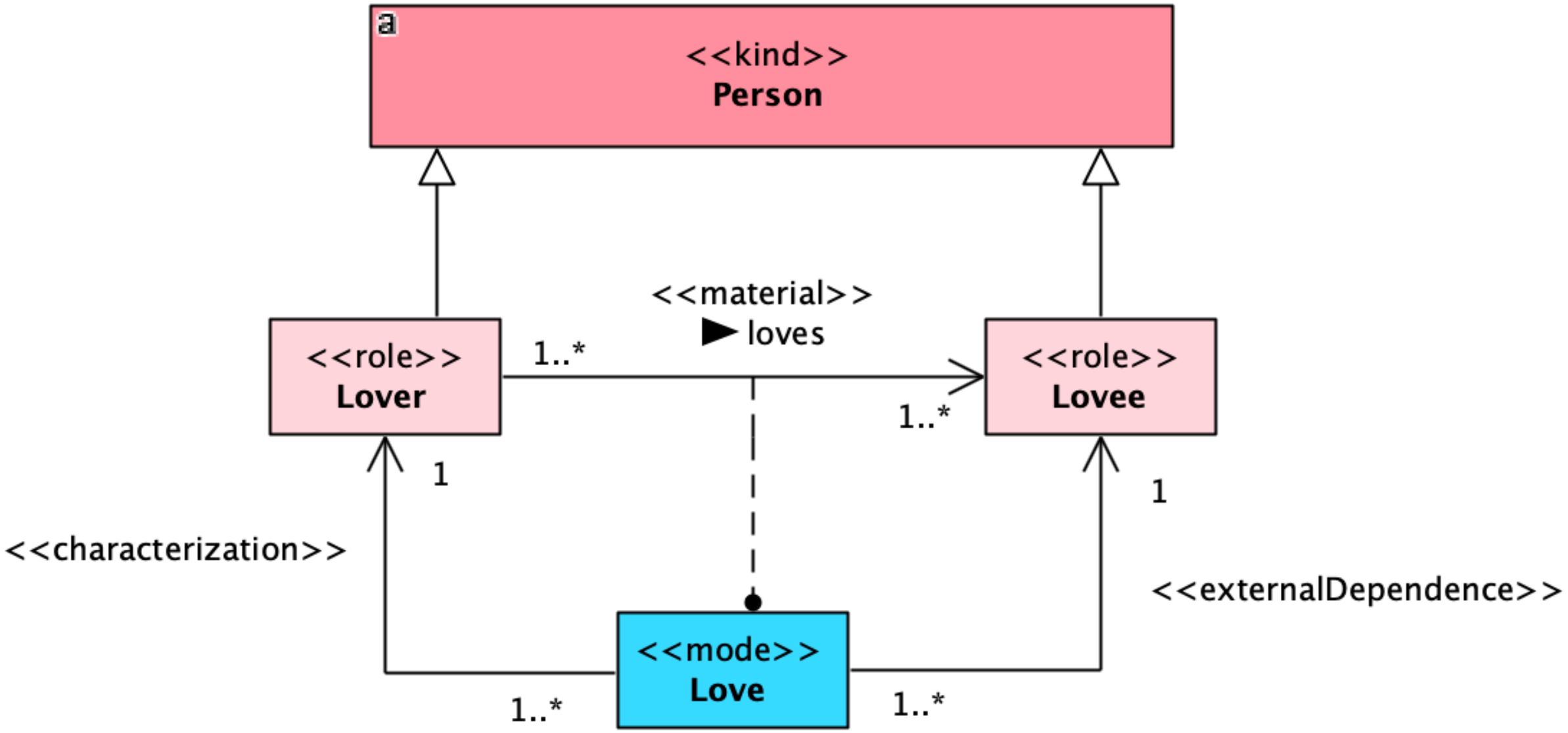
0

Height(m)

vhg < vhp ?


Relation
Primitive Relation
Grounded Relation
Existential Dependence
Comparative Relation
Material Relation


Endurant
existential dependence
OBJECT
Aspect
Intrinsic Aspect
Relational Aspect
QUALITY
INTRINSIC MODE
EXTRINSIC MODE
RELATOR


a
<<kind>>
Person
<<material>>
loves
<<role>>
Lover
1..*
1..*
<<role>>
Lovee
1
1
<<characterization>>
<<externalDependence>>
<<mode>>
Love
1..*
1..*

a

<<kind>>
Person

<<material>>
loves

<<role>>
Lover

1..*

1..*

<<role>>
Lovee

1

1

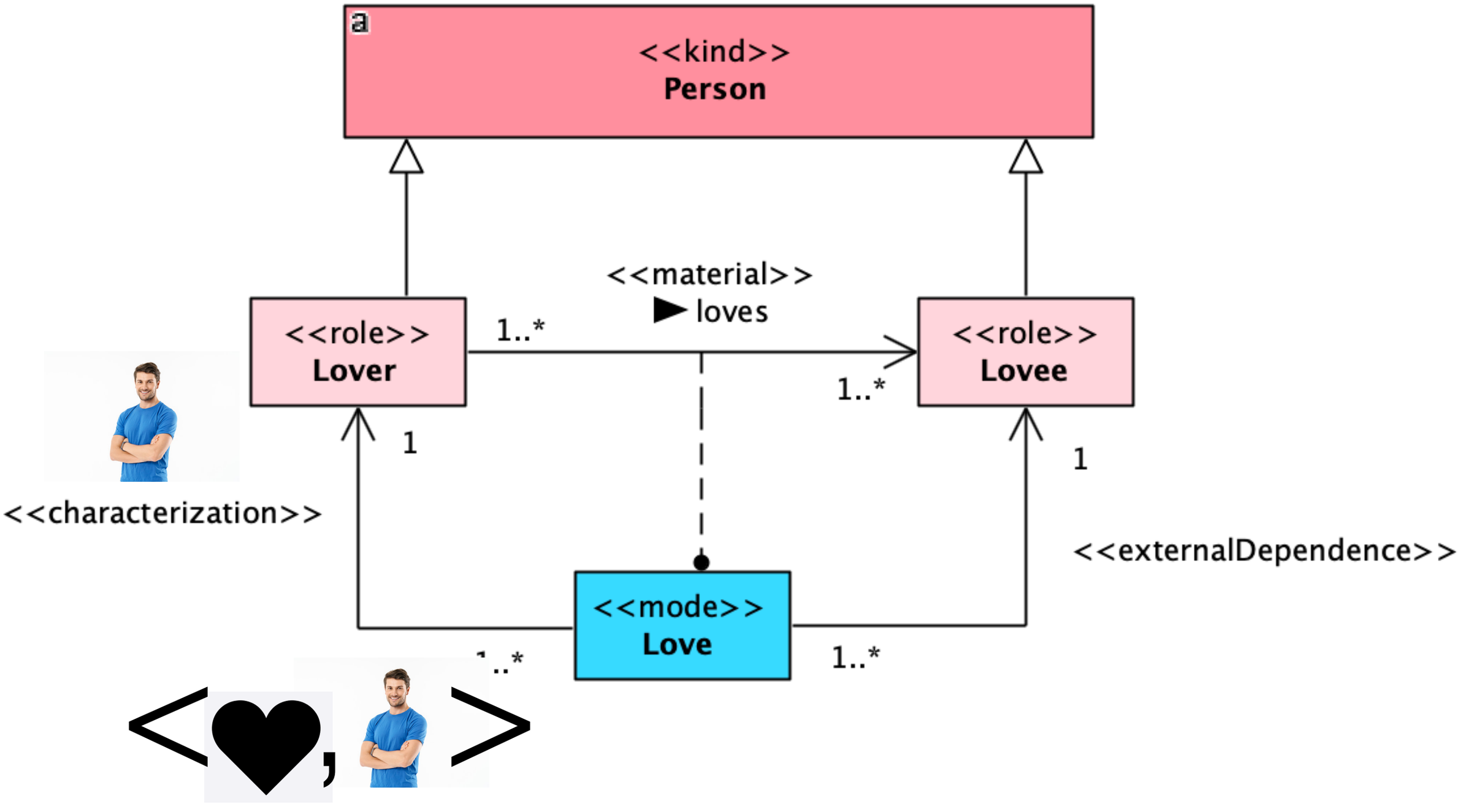
<<characterization>>

<<externalDependence>>

<<mode>>
Love

1..*

1..*


<<kind>>
Person
<<material>>
loves
<<role>>
Lover
1..*
<<role>>
Lovee
1..*
1
1
<<characterization>>
<<externalDependence>>
<<mode>>
Love
1..*
1..*

a

<<kind>>
Person

<<material>>
loves

<<role>>
Lover

1..*

<<role>>
Lovee

1..*

1

1

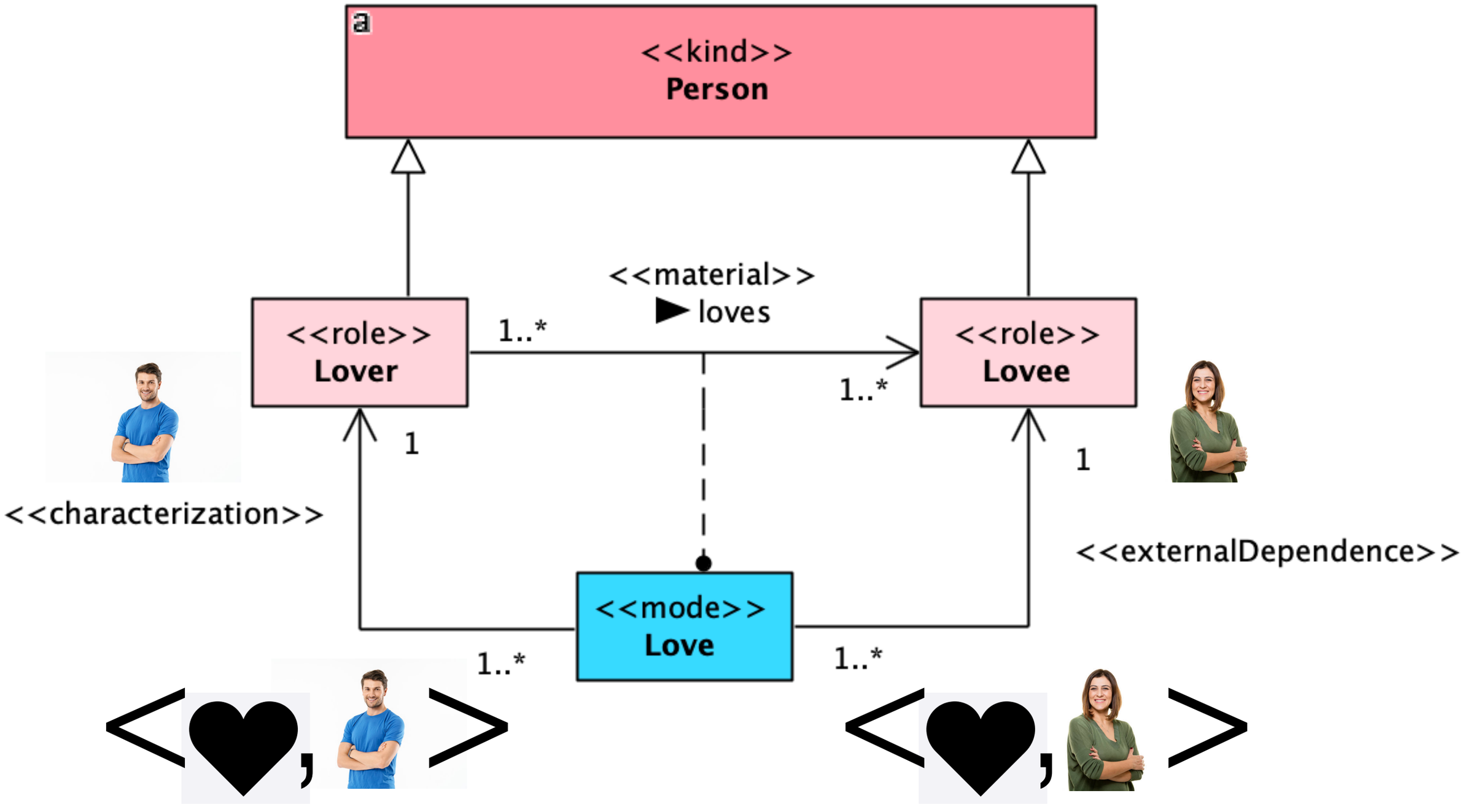
<<characterization>>

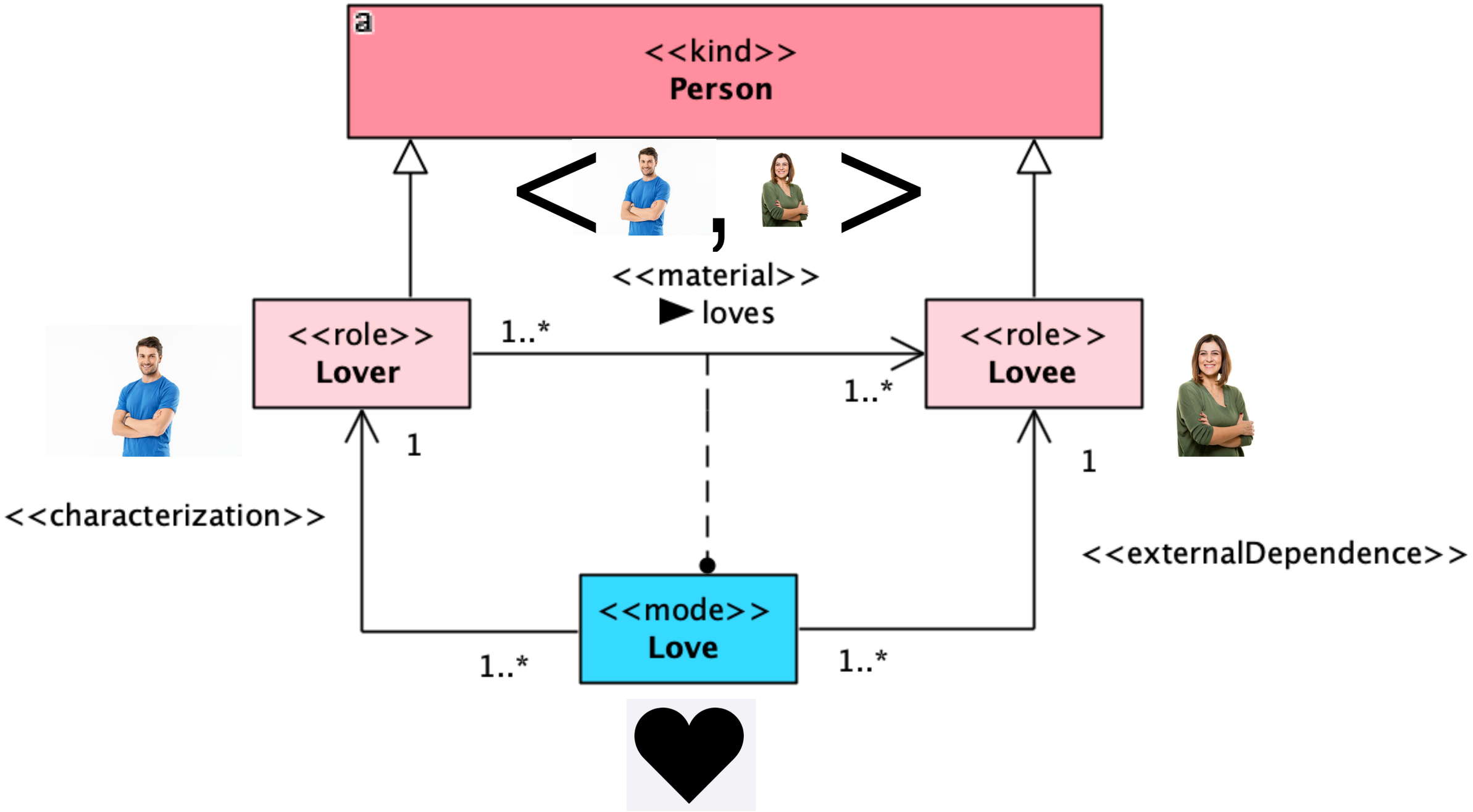
<<externalDependence>>

<<mode>>
Love

1..*

1..*


a
<<kind>>
Person
<<material>>
loves
<<role>>
Lover
1..*
<<role>>
Lovee
1..*
1
1
<<characterization>>
<<externalDependence>>
<<mode>>
Love
1..*
1..*


a
<<kind>>
Person
<<material>>
loves
<<role>>
Lover
1..*
1..*
<<role>>
Lovee
1
1
<<characterization>>
<<externalDependence>>
<<mode>>
Love
1..*
1..*

<<category>>
Entity

<<category>>
Agent

<<roleMixin>>
Value Beholder

<<roleMixin>>
Value Entity

<<roleMixin>>
Prefered Entity

<<roleMixin>>
Deprecated Entity

<<externalDependence>>

1

1

1

1

<<mode>>
Preference

<<characterization>>

2

1..*

<<mode>>
Value

*

*

*

higher than
<<comparative>>

<<characterization>>

1..*

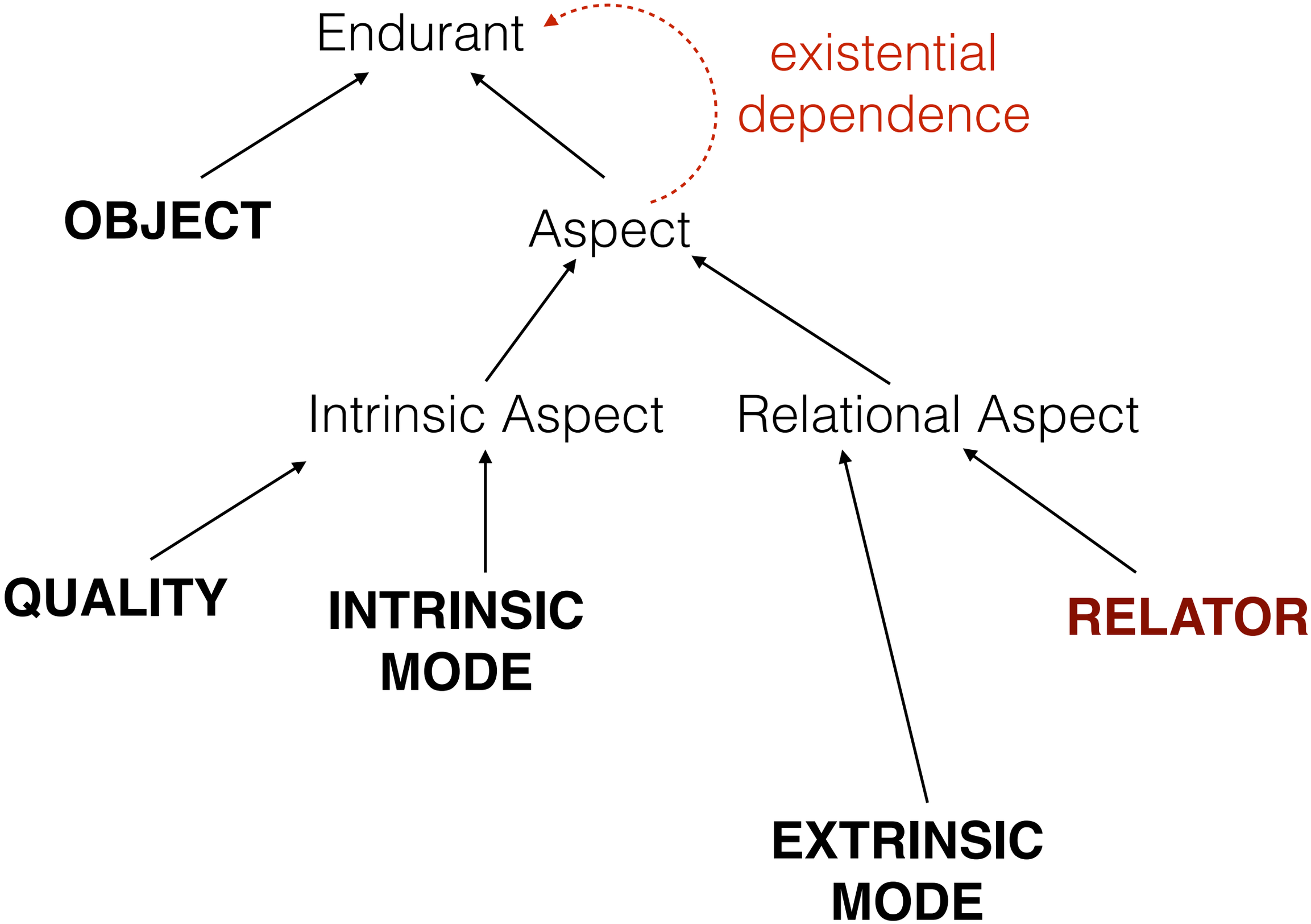
*

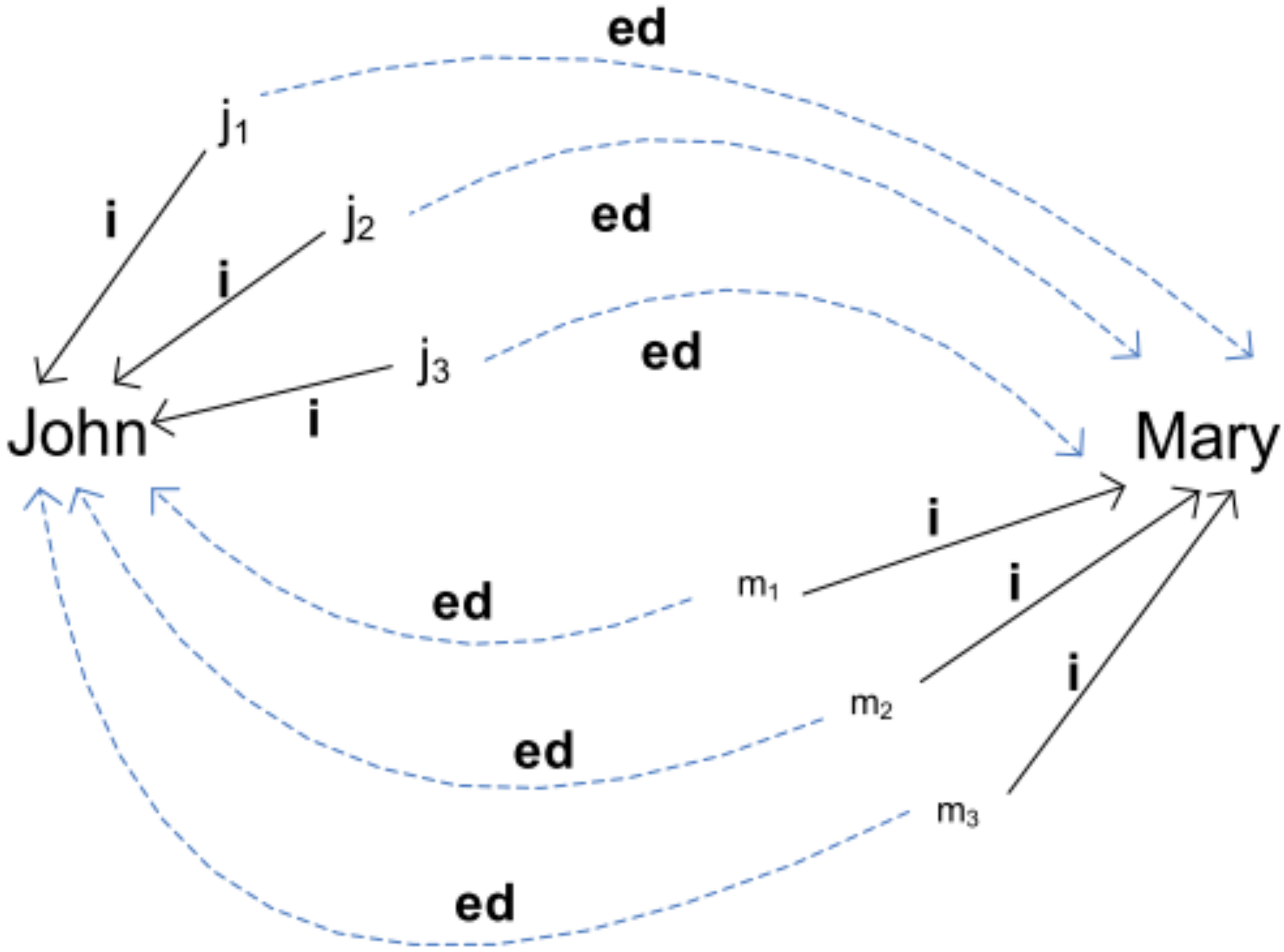
*

greater than

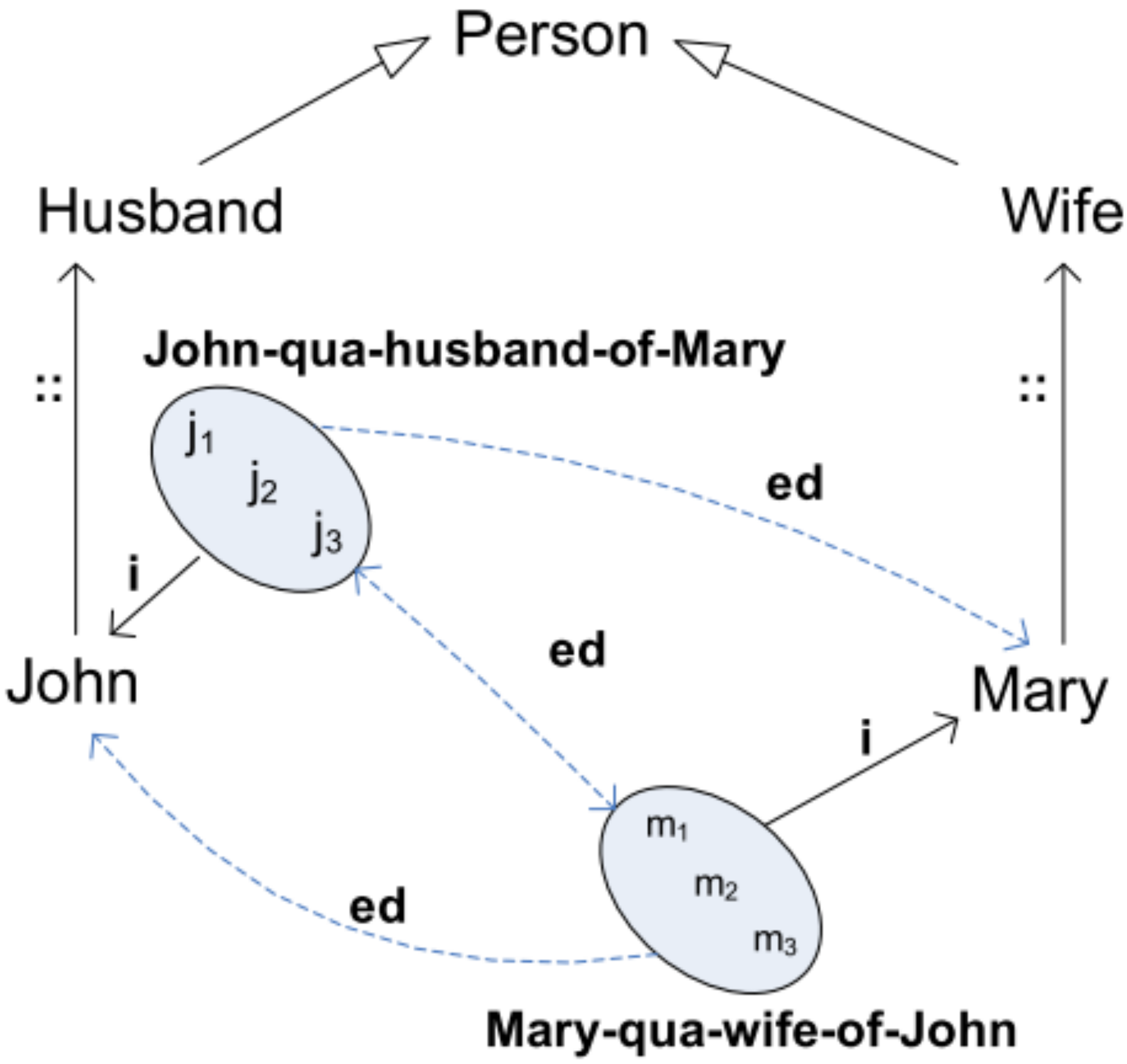
<<datatype>>
Value Magnitude Space

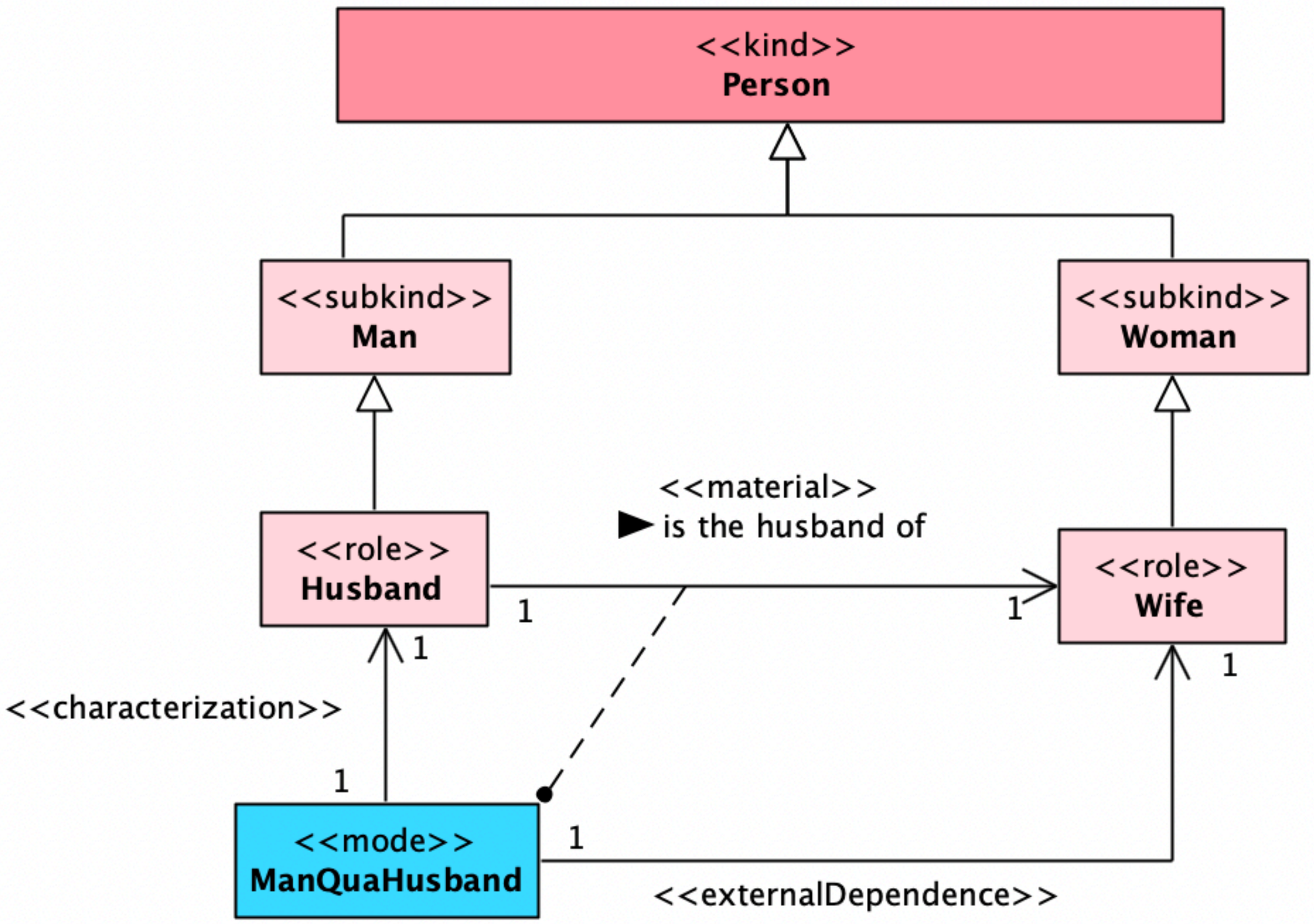
1

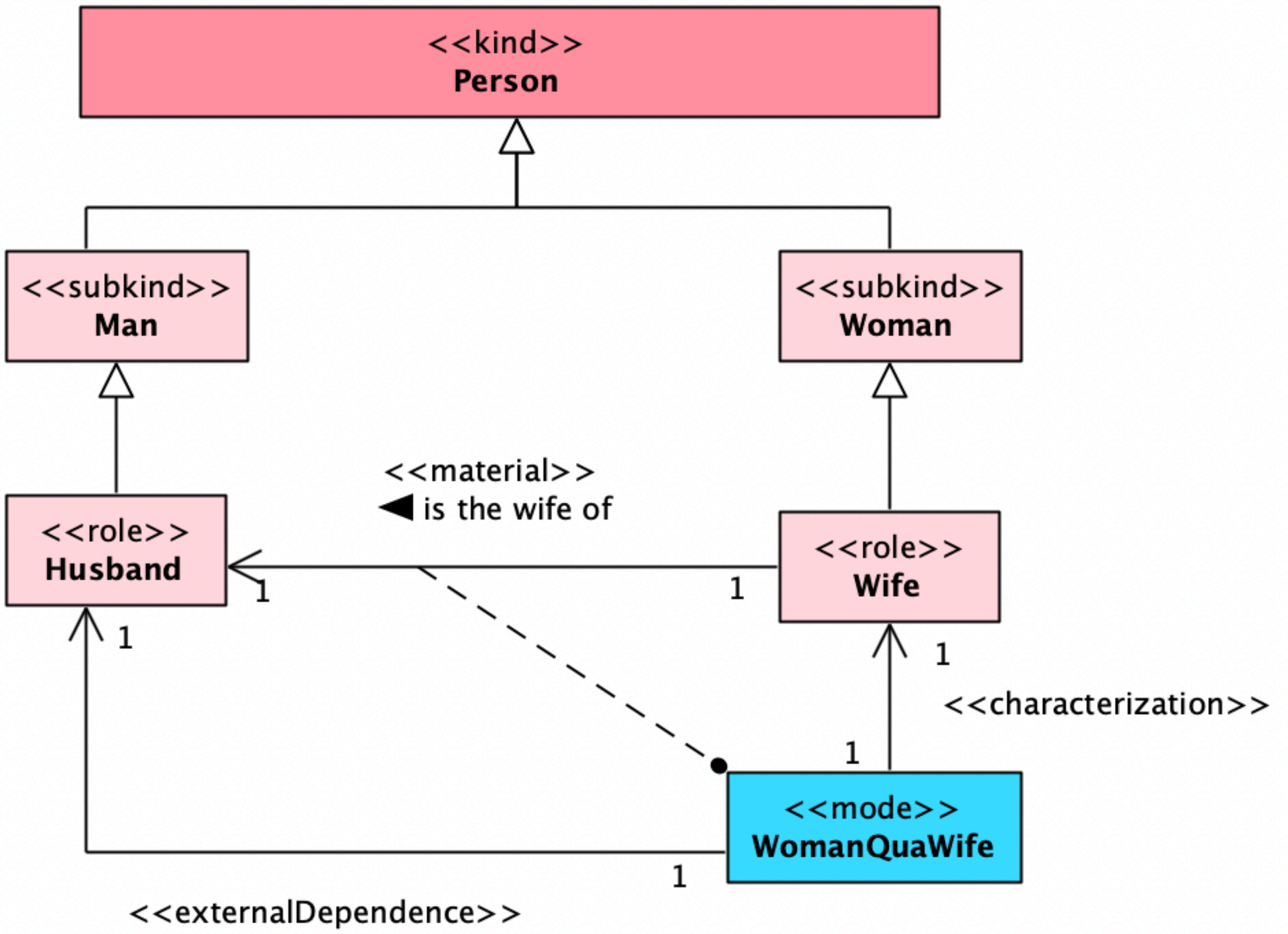

Endurant
existential dependence
OBJECT
Aspect
Intrinsic Aspect
Relational Aspect
QUALITY
INTRINSIC MODE
EXTRINSIC MODE
RELATOR

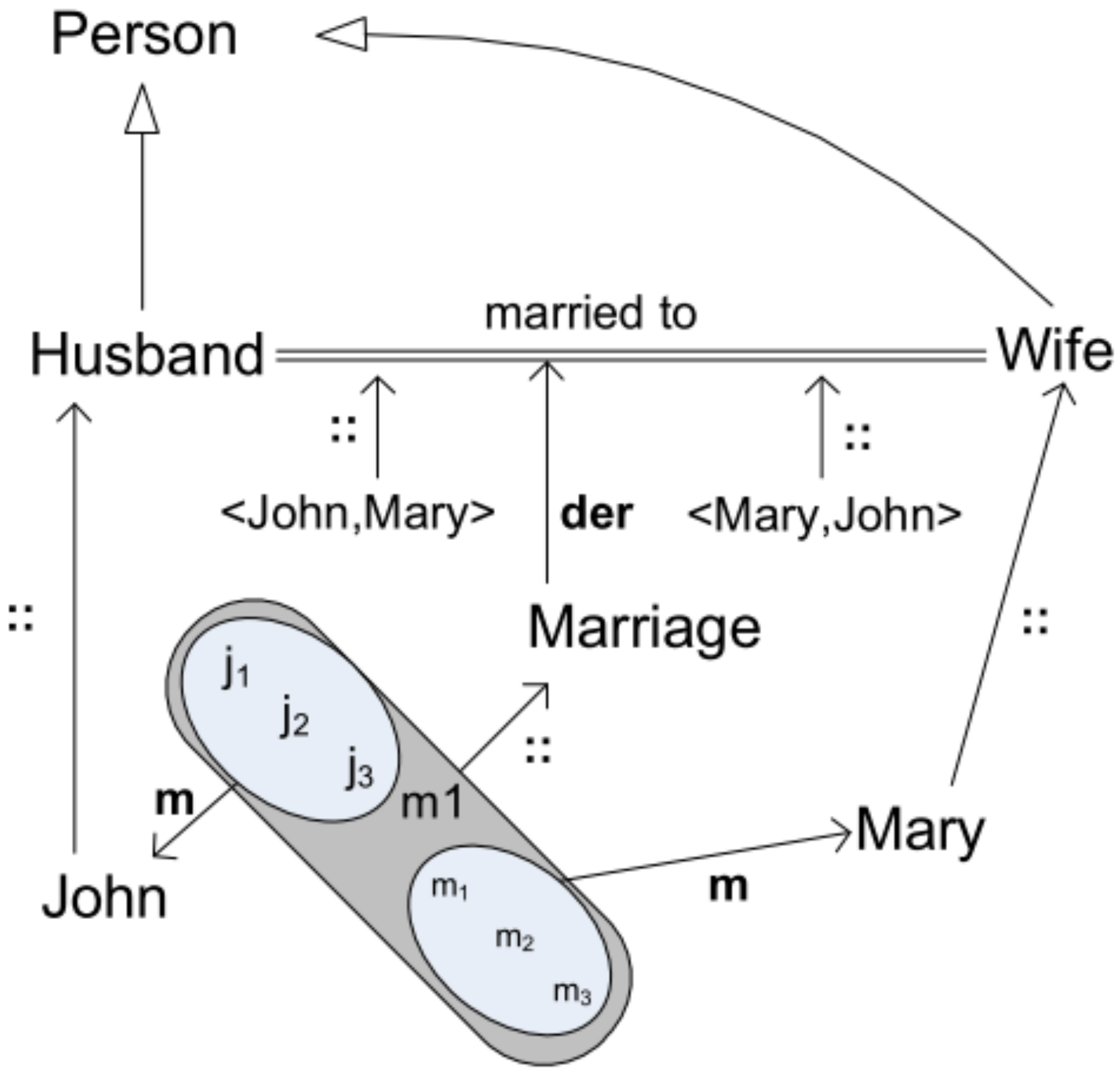


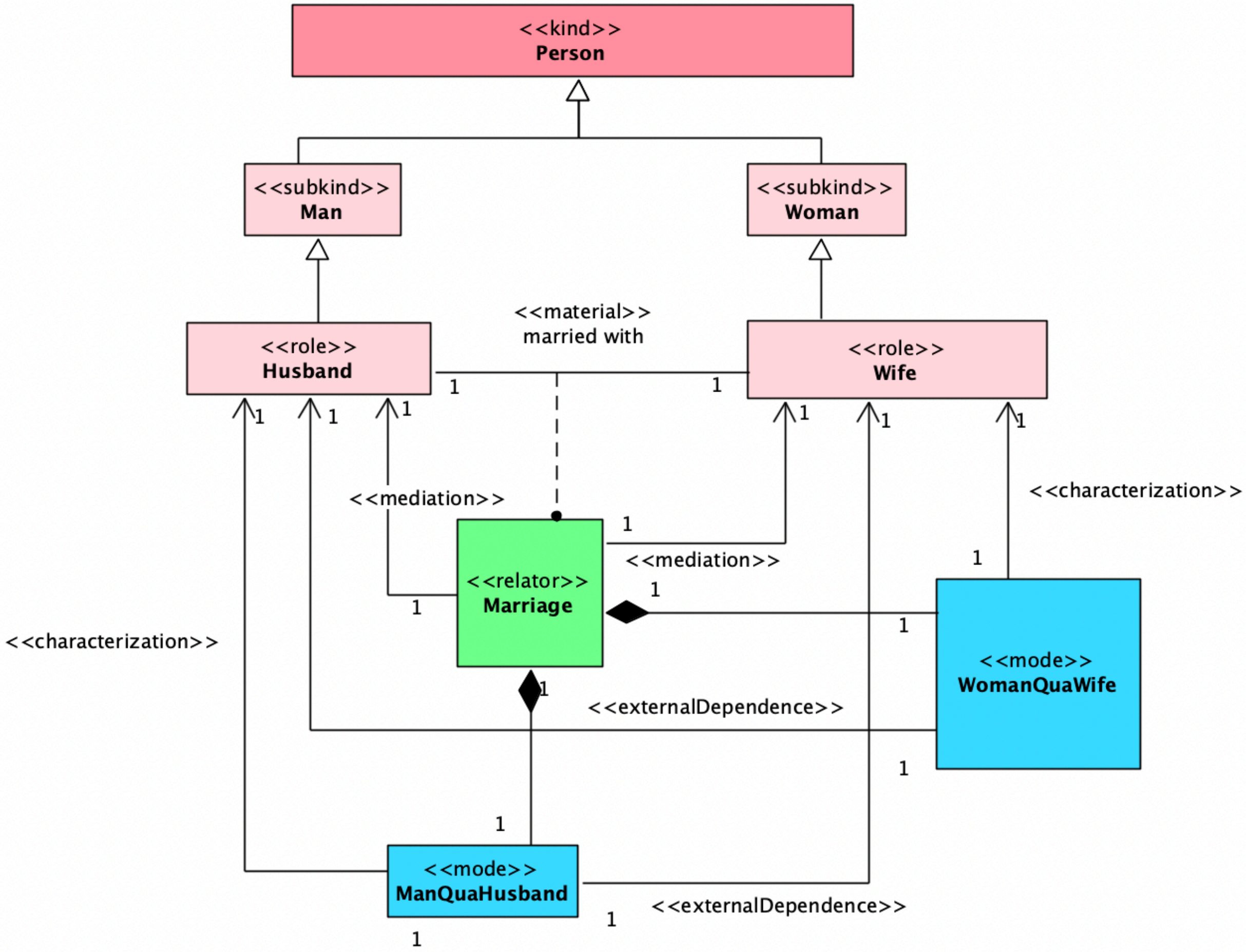
Suppose John marries Mary

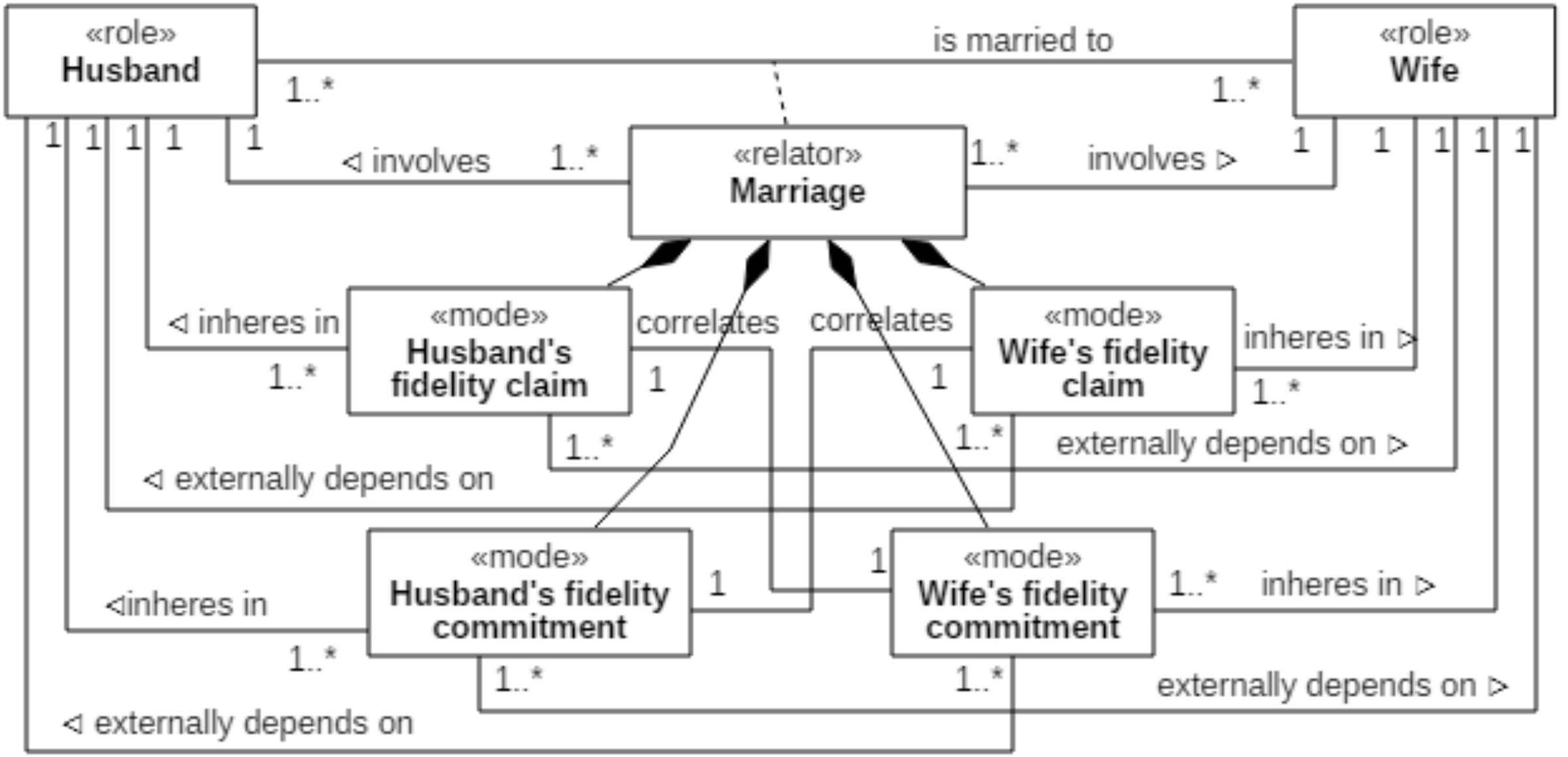

Person
Husband
Wife
::
::
John-qua-husband-of-Mary
j1
j2
j3
ed
i
ed
John
Mary
i
m1
m2
m3
ed
Mary-qua-wife-of-John


<<kind>>
Person
<<subkind>>
Man
<<subkind>>
Woman
<<material>>
is the husband of
<<role>>
Husband
<<role>>
Wife
1
1
1
1
1
<<characterization>>
1
<<mode>>
ManQuaHusband
1
<<externalDependence>>


<<kind>>
Person
<<subkind>>
Man
<<subkind>>
Woman
<<material>>
is the wife of
<<role>>
Husband
<<role>>
Wife
1
1
1
1
1
1
<<characterization>>
<<mode>>
WomanQuaWife
<<externalDependence>>


Person
Husband
married to
Wife
::
::
<John,Mary>
der
<Mary,John>
::
::
Marriage
j1
j2
j3
m1
::
m
m1
m2
m3
John
m
Mary


<<kind>>
Person
<<subkind>>
Man
<<subkind>>
Woman
<<role>>
Husband
<<material>>
married with
<<role>>
Wife
1
1
1
1
1
1
1
1
1
<<mediation>>
<<mediation>>
1
1
1
<<relator>>
Marriage
1
1
1
<<characterization>>
<<mode>>
WomanQuaWife
1
<<externalDependence>>
1
1
<<mode>>
ManQuaHusband
1
<<externalDependence>>
1
1
<<characterization>>



Cristine Griffo, João Paulo A. Almeida, Giancarlo Guizzardi: Conceptual Modeling of Legal Relations. ER 2018: 169-183

3

What does that buy us?

What does that buy us?

1. Truthmaking

2. Makes justice to the complexity of the relational phenomena (**Precision**)

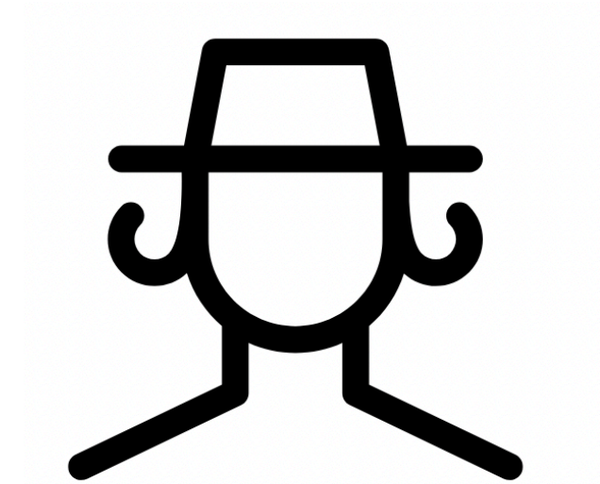
3. Helps to elicit tacit knowledge that would otherwise remain tacit (**Completeness**)

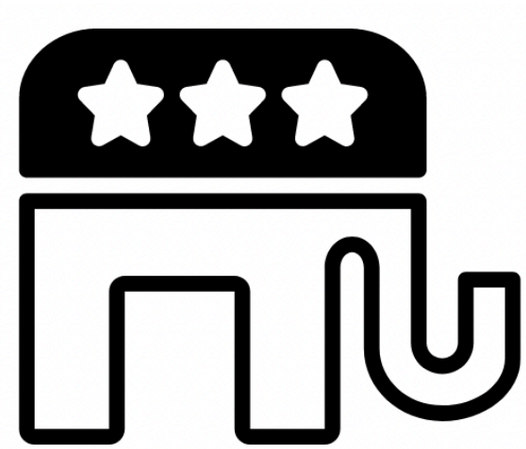
4. Disambiguation (**Semantic Clarity**)

What does that buy us?

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

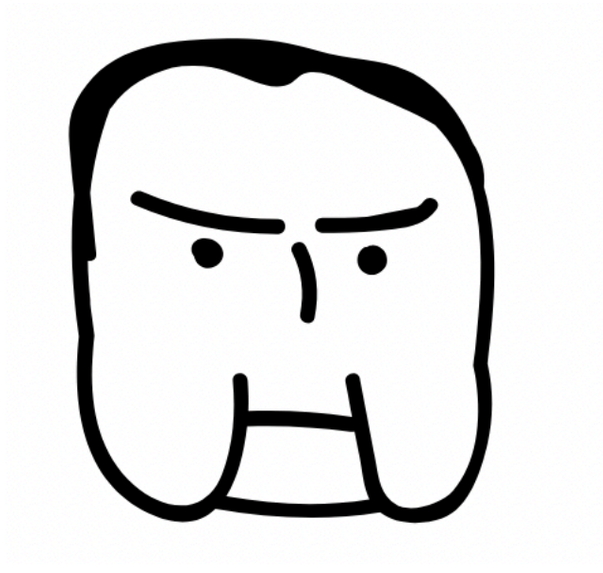
Incompatible Predication

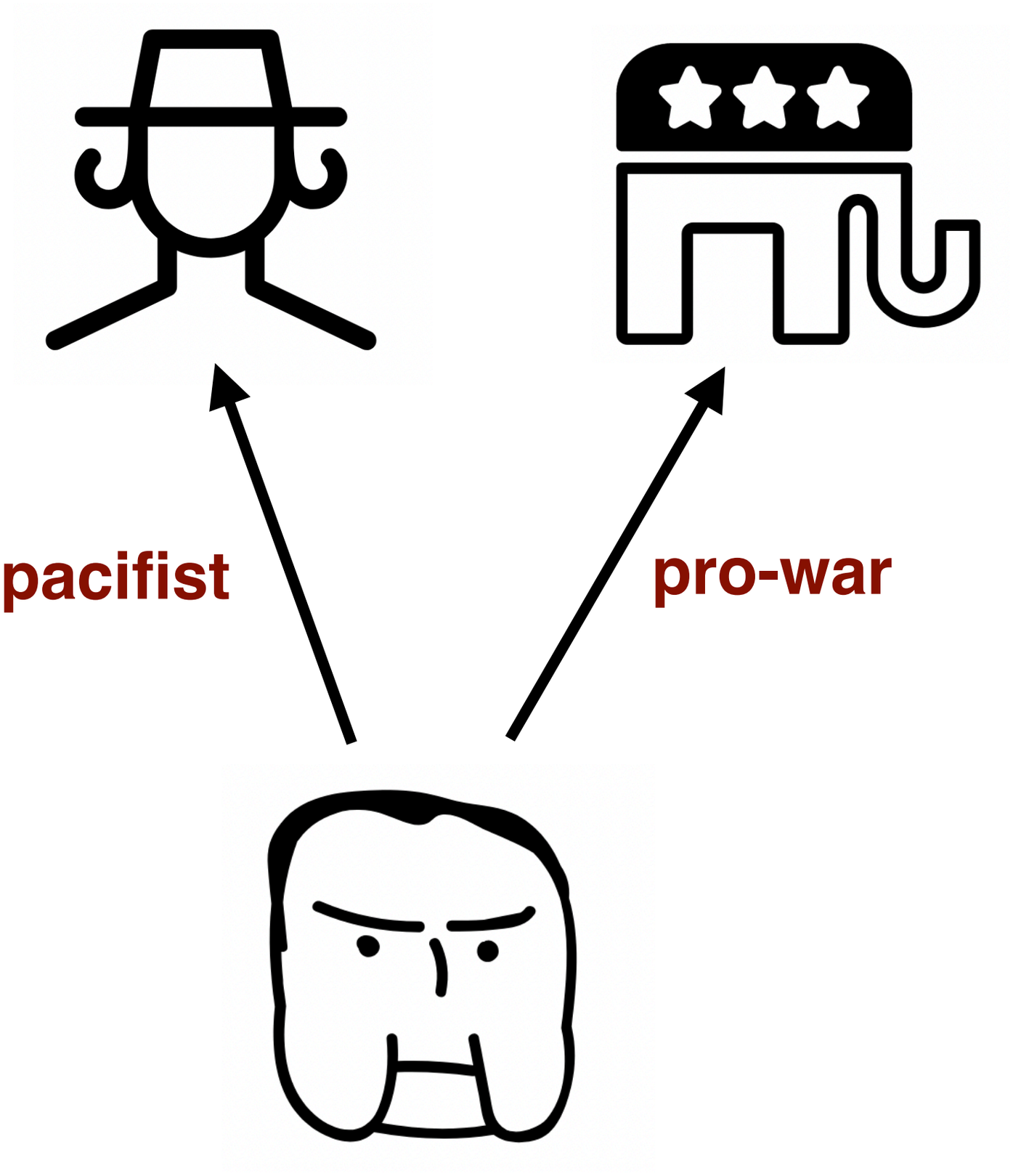




pacifist

pro-war

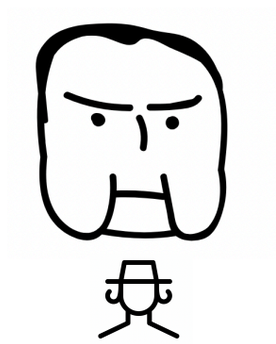


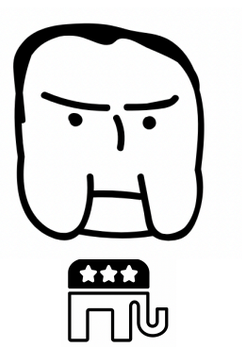


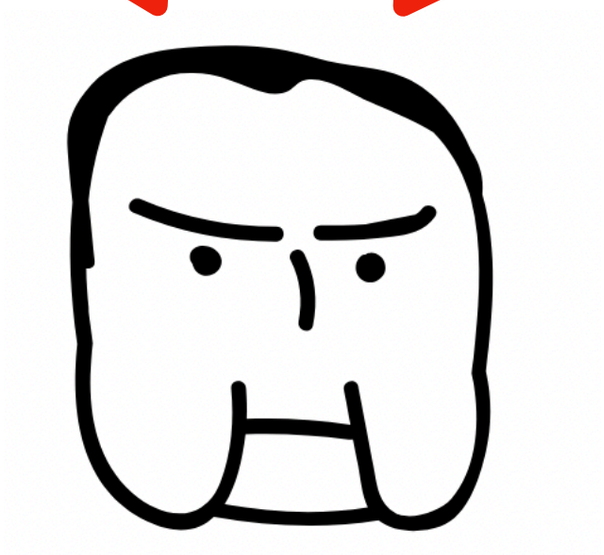
$$pacifist(Nixon) \wedge proWar(Nixon) \wedge (\neg \exists x\,.\,pacifist(x) \wedge proWar(x))$$

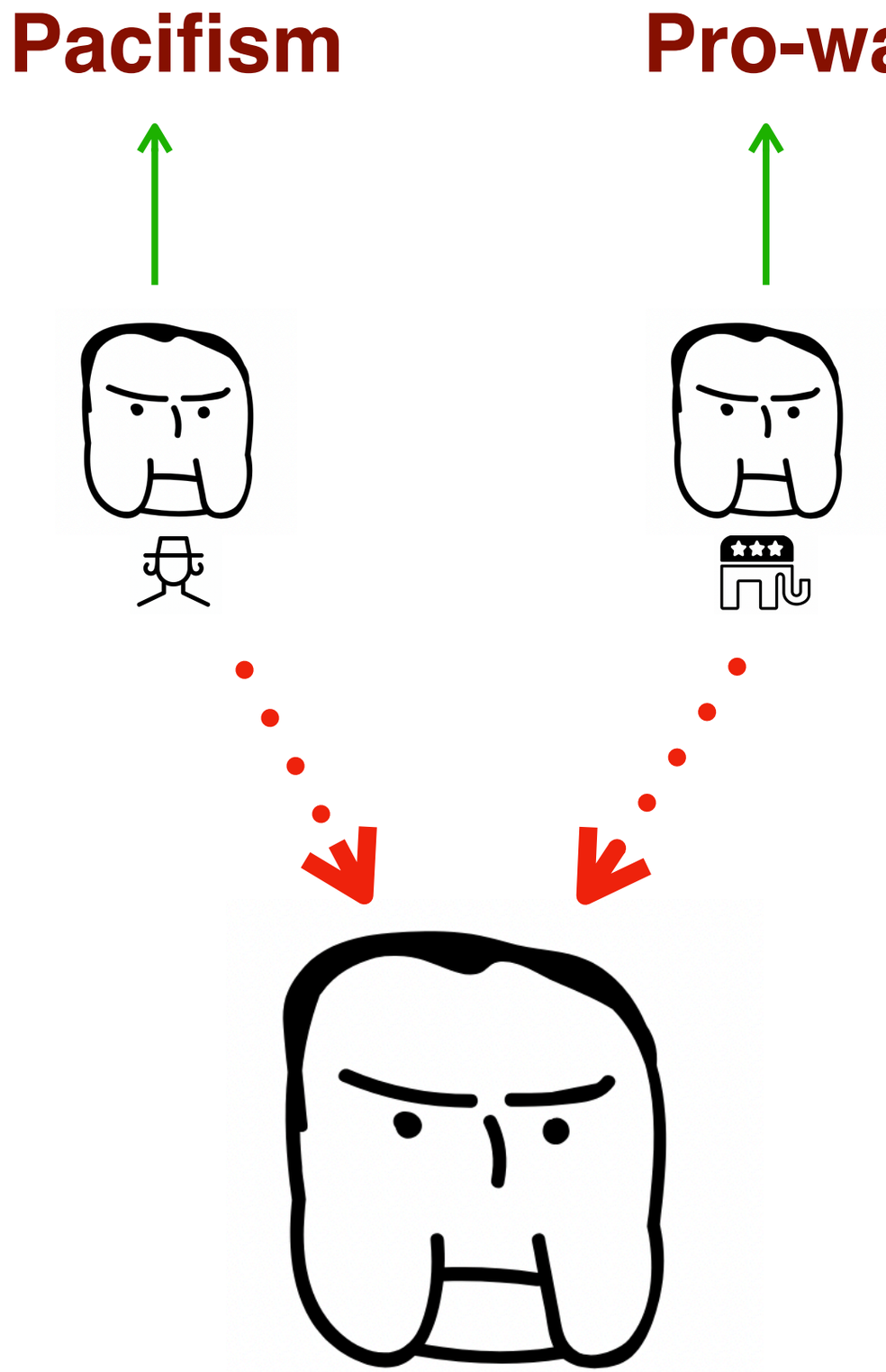
Pacifism

Pro-war









$$pacifist(Nixon - qua - Quaker) \wedge proWar(Nixon - qua - Republican)$$
$$\wedge inheres(Nixon - qua - quaker, Nixon) \wedge inheres(Nixon - qua - Republican, Nixon)$$
$$\wedge (\neg \exists x \,.\, pacifist(x) \wedge proWar(x))$$

The Counting Problem

The Counting Problem

- KLM flew 2000 passengers in 2021
- Every passenger is a person
- ERGO, KLM flew 2000 People in 2021

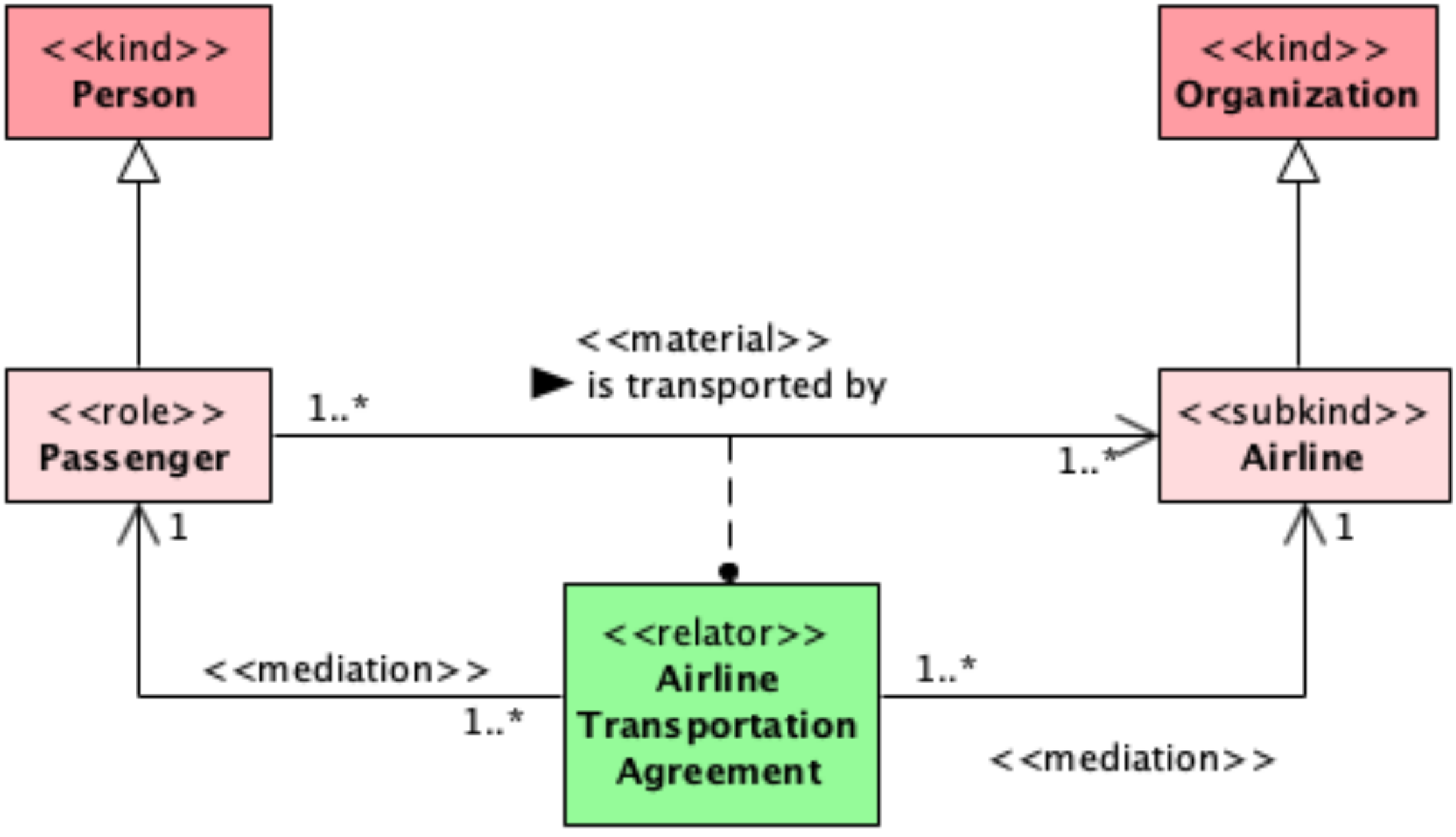
The Counting Problem

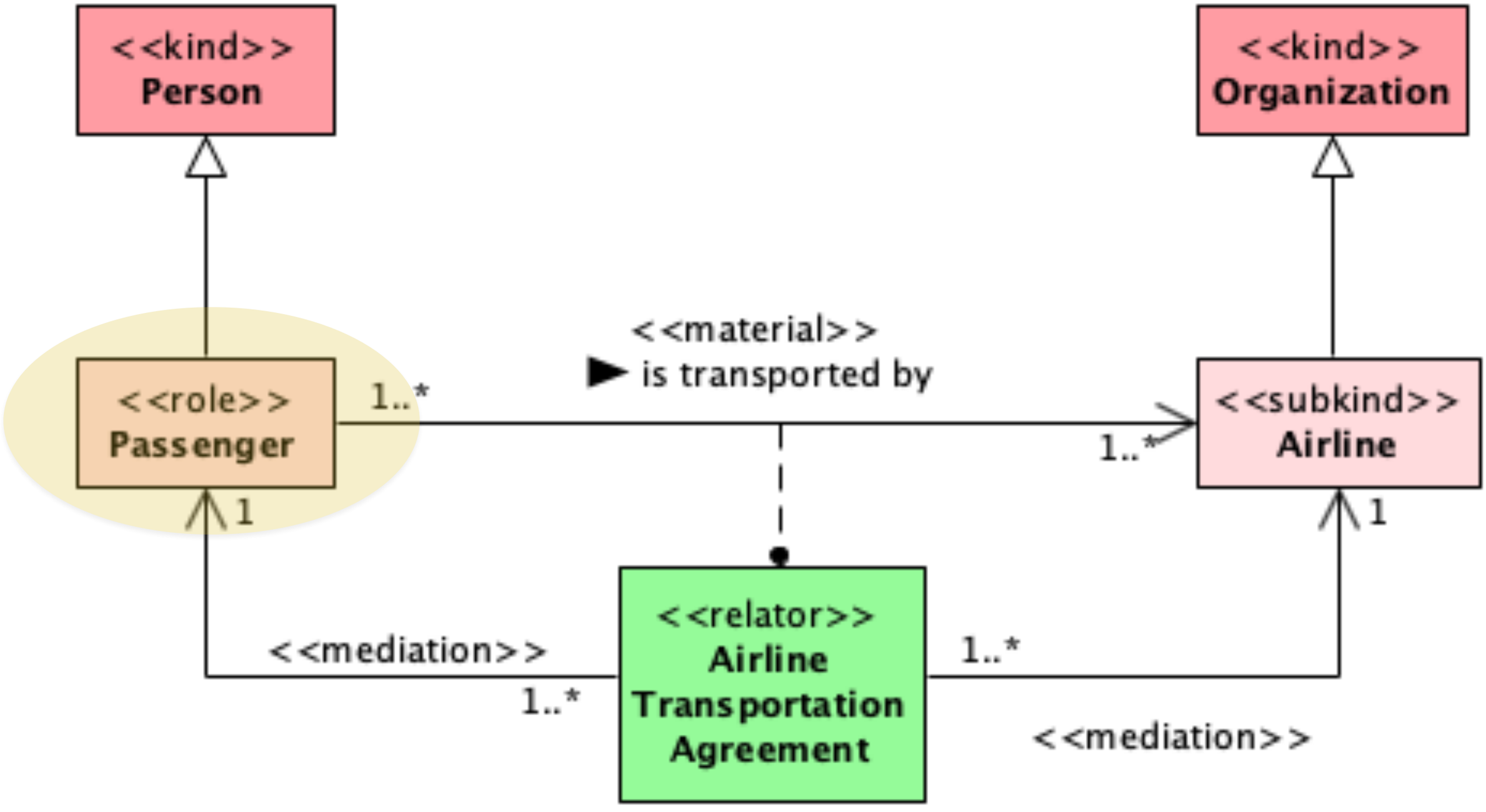
- KLM flew 2000 passengers in 2021
- Every passenger **is** a person
- ERGO, KLM flew 2000 People in 2021

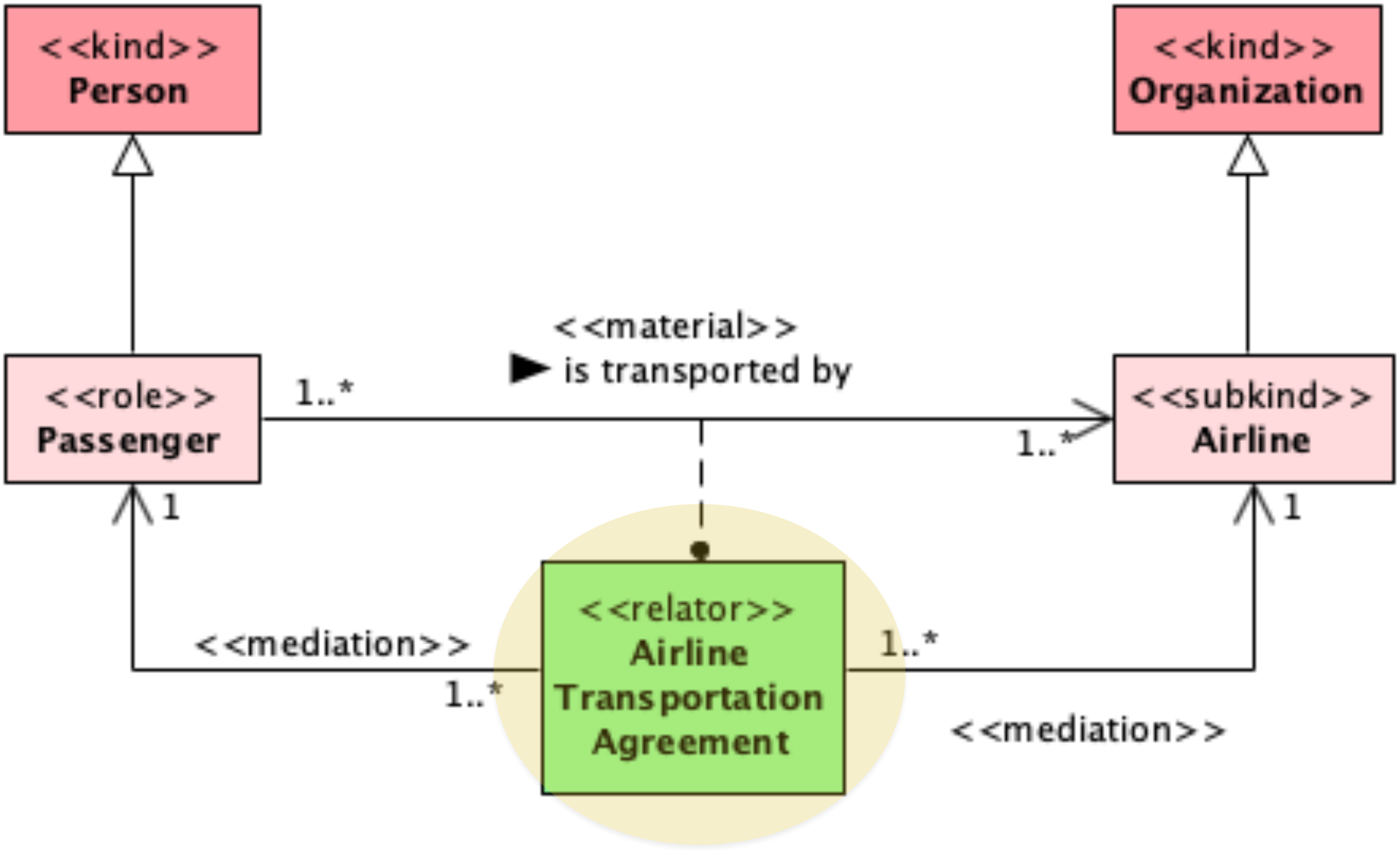
The Counting Problem

Existential Dependent

- KLM flew 2000 passengers in 2021
- Every passenger **is** a person
- ERGO, KLM flew 2000 People in 2021


<<kind>>
Person
<<kind>>
Organization
<<material>>
is transported by
1..*
<<role>>
Passenger
1..*
<<subkind>>
Airline
1
1
<<mediation>>
1..*
<<relator>>
Airline
Transportation
Agreement
1..*
<<mediation>>


<<kind>>
Person
<<kind>>
Organization
<<material>>
is transported by
<<role>>
Passenger
1..*
1..*
<<subkind>>
Airline
1
1
<<mediation>>
1..*
<<relator>>
Airline
Transportation
Agreement
1..*
<<mediation>>


<<kind>>
Person
<<kind>>
Organization
<<material>>
is transported by
<<role>>
Passenger
1..*
1..*
<<subkind>>
Airline
1
1
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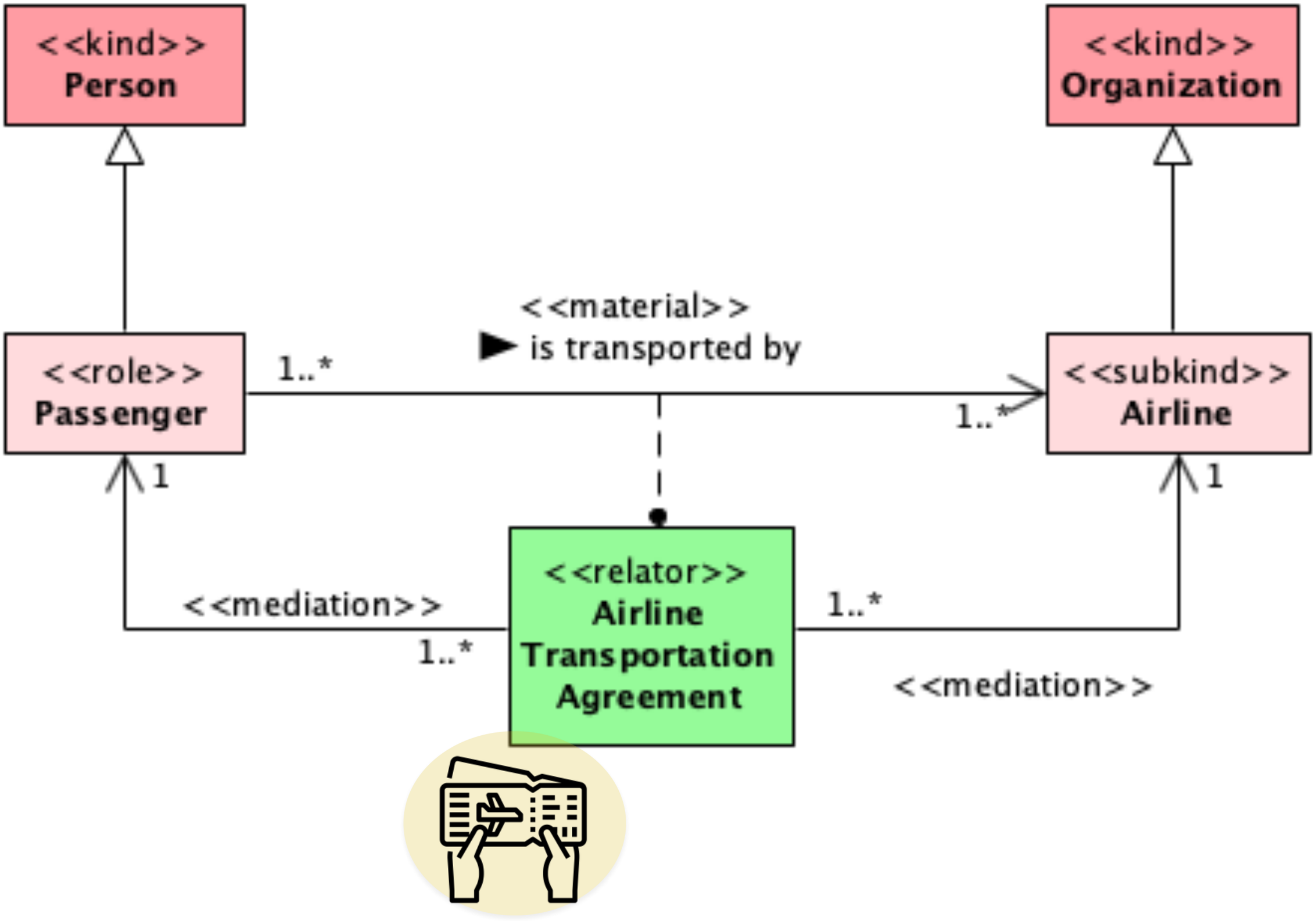
Airline
Transportation
Agreement
<<mediation>>
1..*
1..*
<<mediation>>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Person
<<kind>>
Organization
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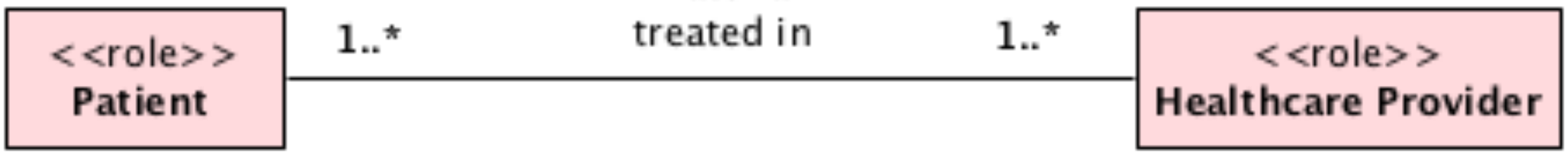
is transported by
<<role>>
Passenger
1..*
1..*
<<subkind>>
Airline
1
1
<<relator>>
Airline
Transportation
Agreement
<<mediation>>
1..*
1..*
<<mediation>>

The Collapse of Cardinality Constraints


<<material>>
treated in
1..*
1..*
<<role>>
Patient
<<role>>
Healthcare Provider

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..* ?

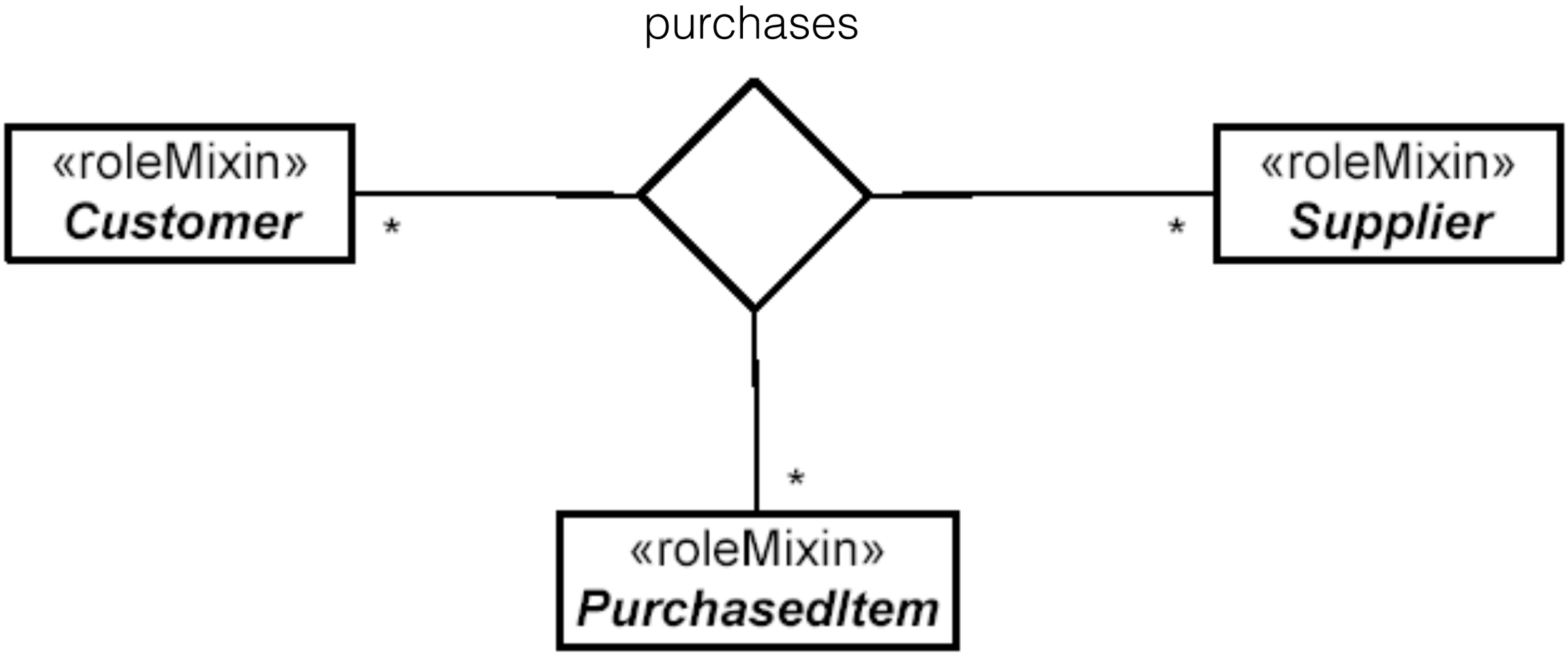
- Given a treatment, there is **exactly one patient**, **exactly one healthcare provider** but **both** patient and healthcare provider **can participate in many treatments**
- Given a treatment, there are **possibly many patients**, **exactly one healthcare provider** but **both** patient and healthcare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

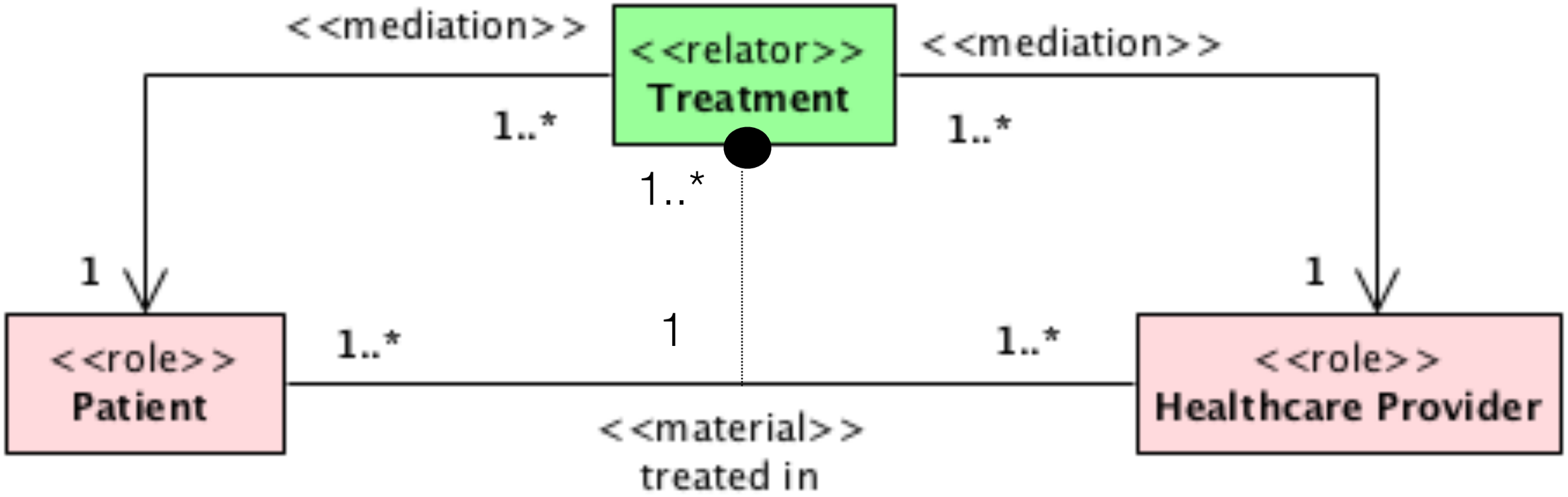
- Given a treatment, there is **exactly one patient**, **exactly one healthcare provider** but **both** patient and healthcare provider **can participate in many treatments**
- Given a treatment, there are **possibly many patients**, **exactly one healthcare provider** but **both** patient and healthcare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

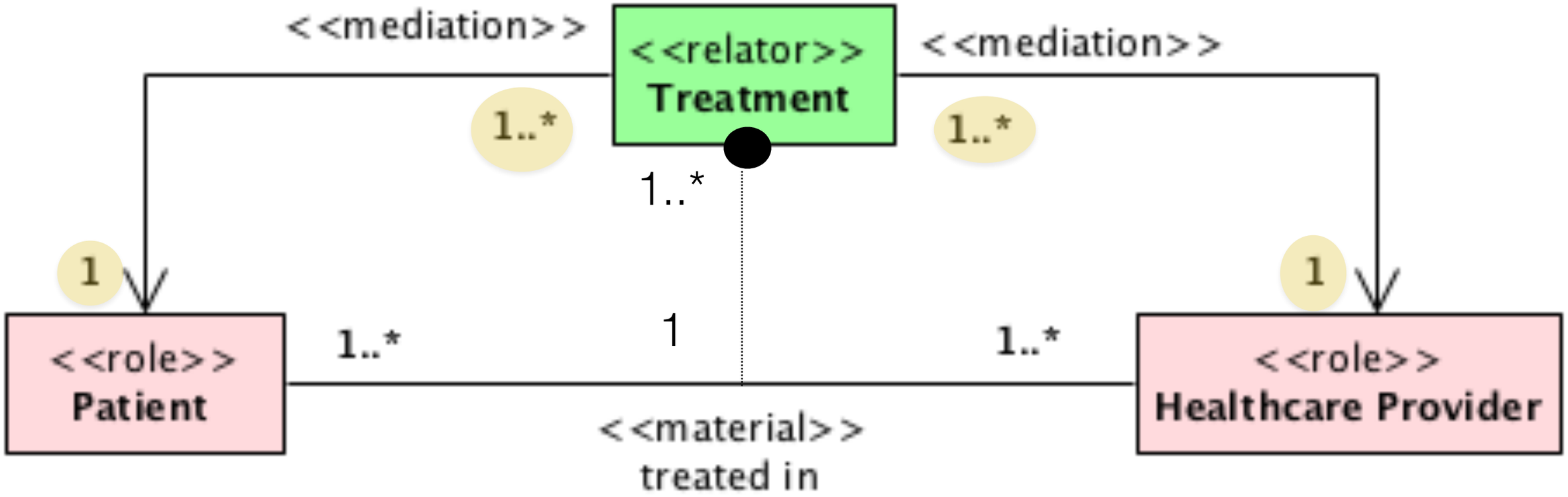
How to interpret 1..* ?

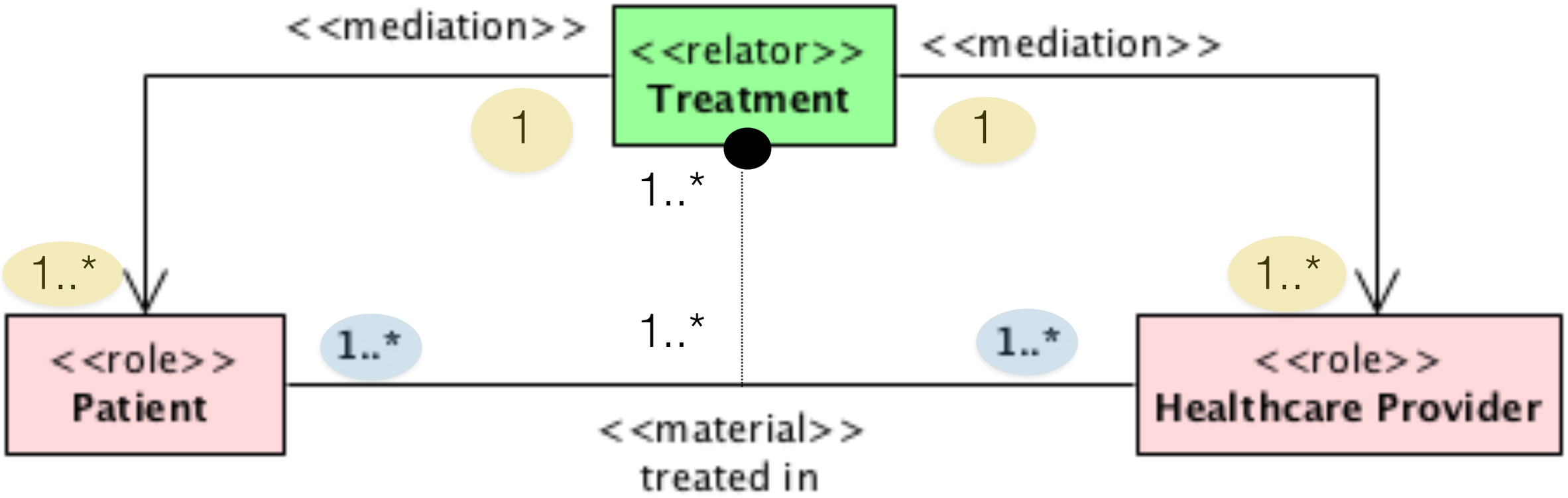
- Given a treatment, there is **exactly one patient**, **exactly one healthcare provider** but **both** patient and healthcare provider **can participate in many treatments**
- Given a treatment, there are **possibly many patients**, **exactly one healthcare provider** but **both** patient and healthcare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

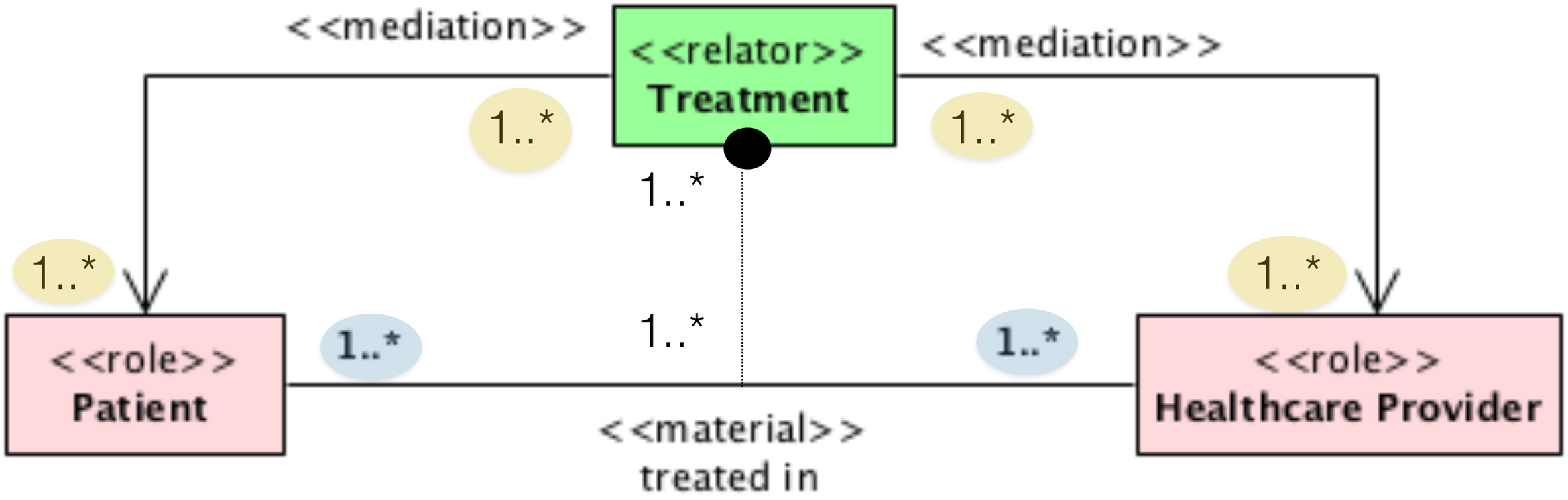

purchases
«roleMixin»
Customer
*
*
«roleMixin»
Supplier
*
«roleMixin»
PurchasedItem

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. …


<<mediation>>
<<relator>>
Treatment
<<mediation>>
1..*
1..*
1..*
1
1
1..*
<<role>>
Patient
<<role>>
Healthcare Provider
<<material>>
treated in


<<mediation>>
<<relator>>
Treatment
<<mediation>>
1..*
1..*
1..*
1
1
1..*
<<role>>
Patient
<<role>>
Healthcare Provider
<<material>>
treated in


<<mediation>>
<<relator>>
Treatment
<<mediation>>
1
1
1..*
1..*
1..*
1..*
<<role>>
Patient
<<role>>
Healthcare Provider
<<material>>
treated in


<<mediation>>
<<relator>>
Treatment
<<mediation>>
1..*
1..*
1..*
1..*
1..*
1..*
<<role>>
Patient
<<role>>
Healthcare Provider
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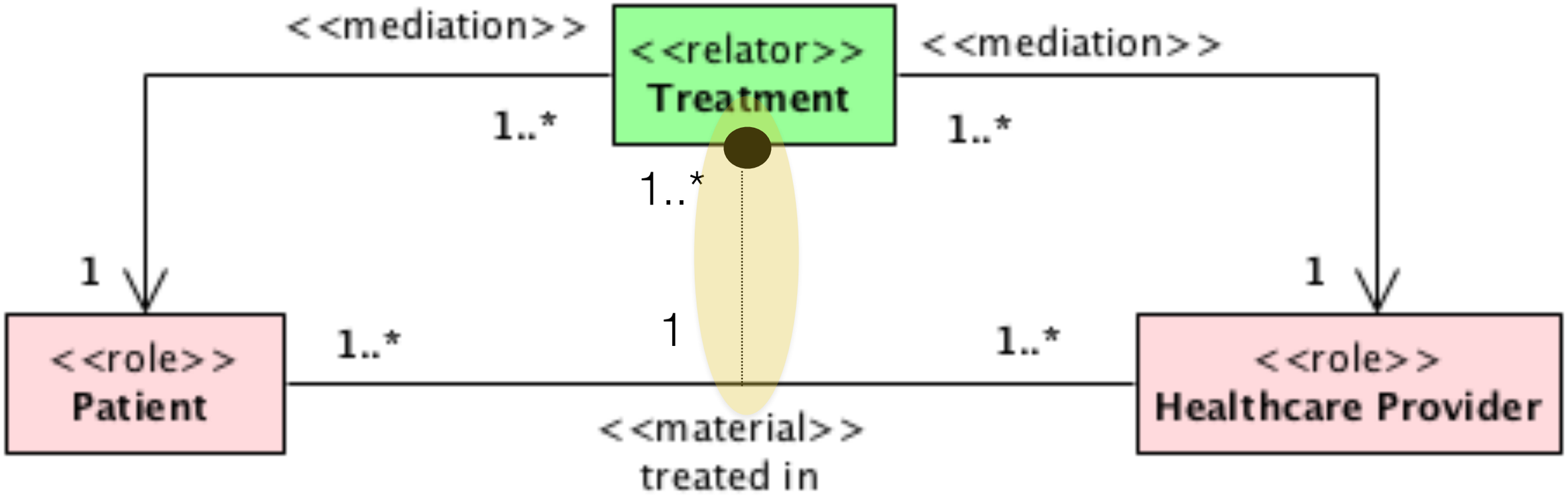
treated in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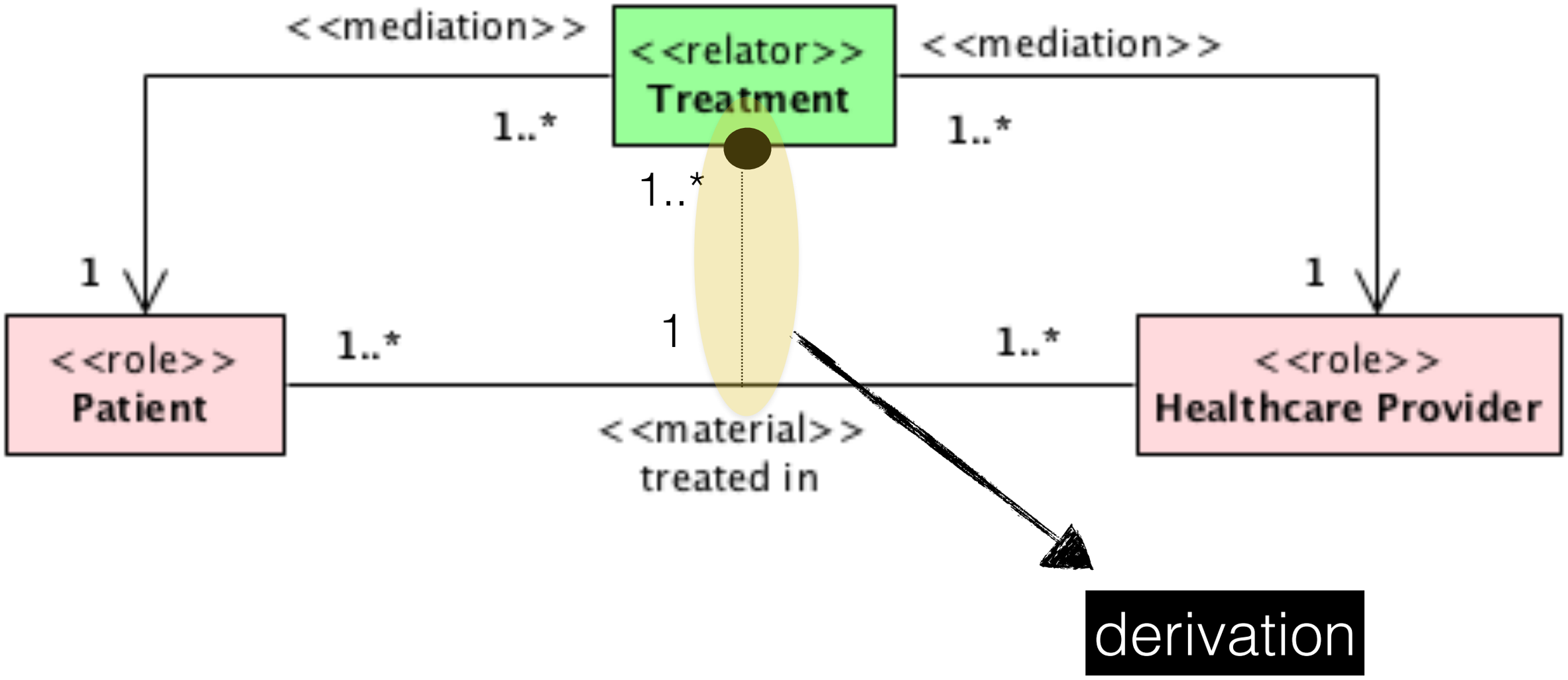
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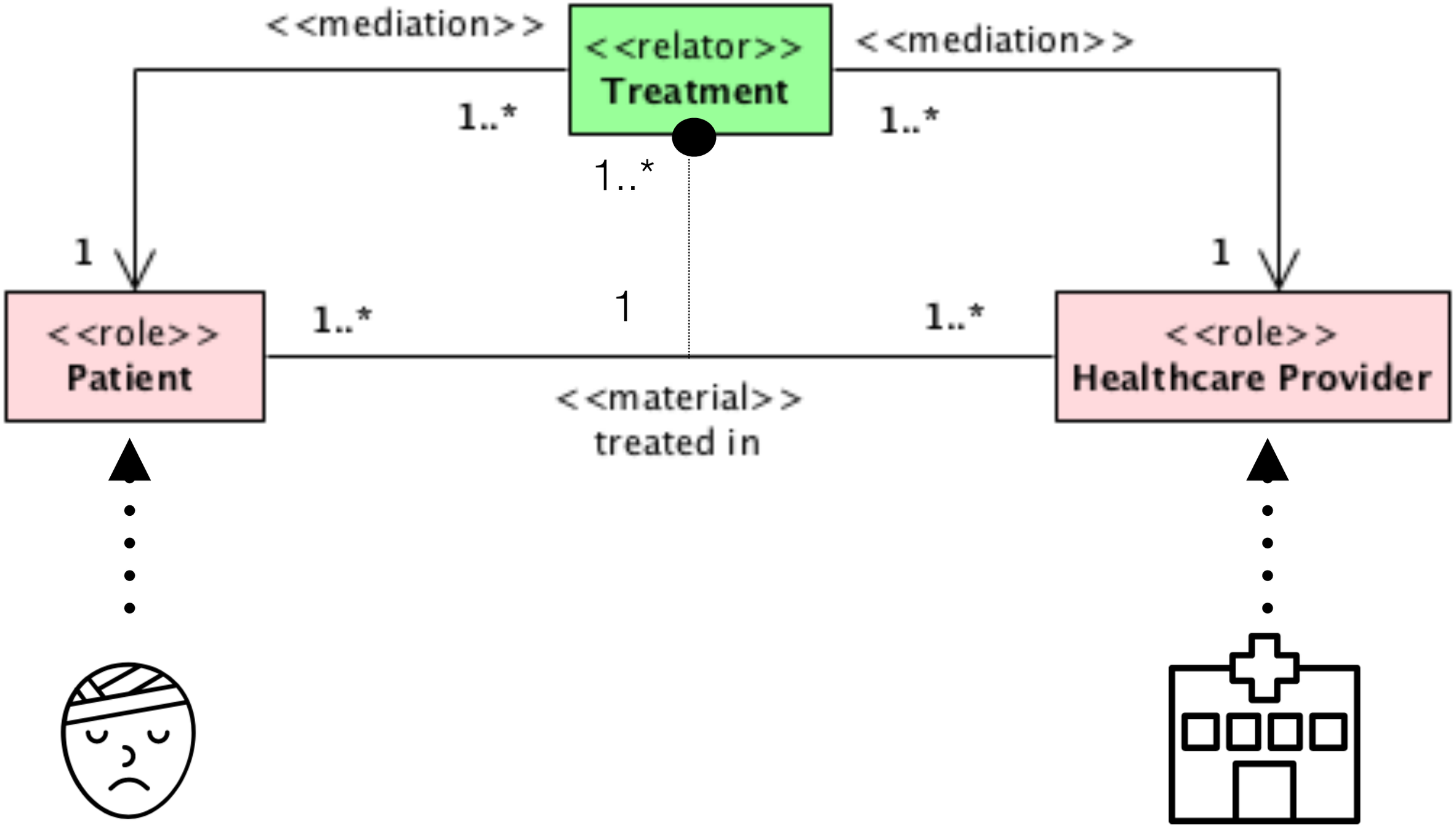
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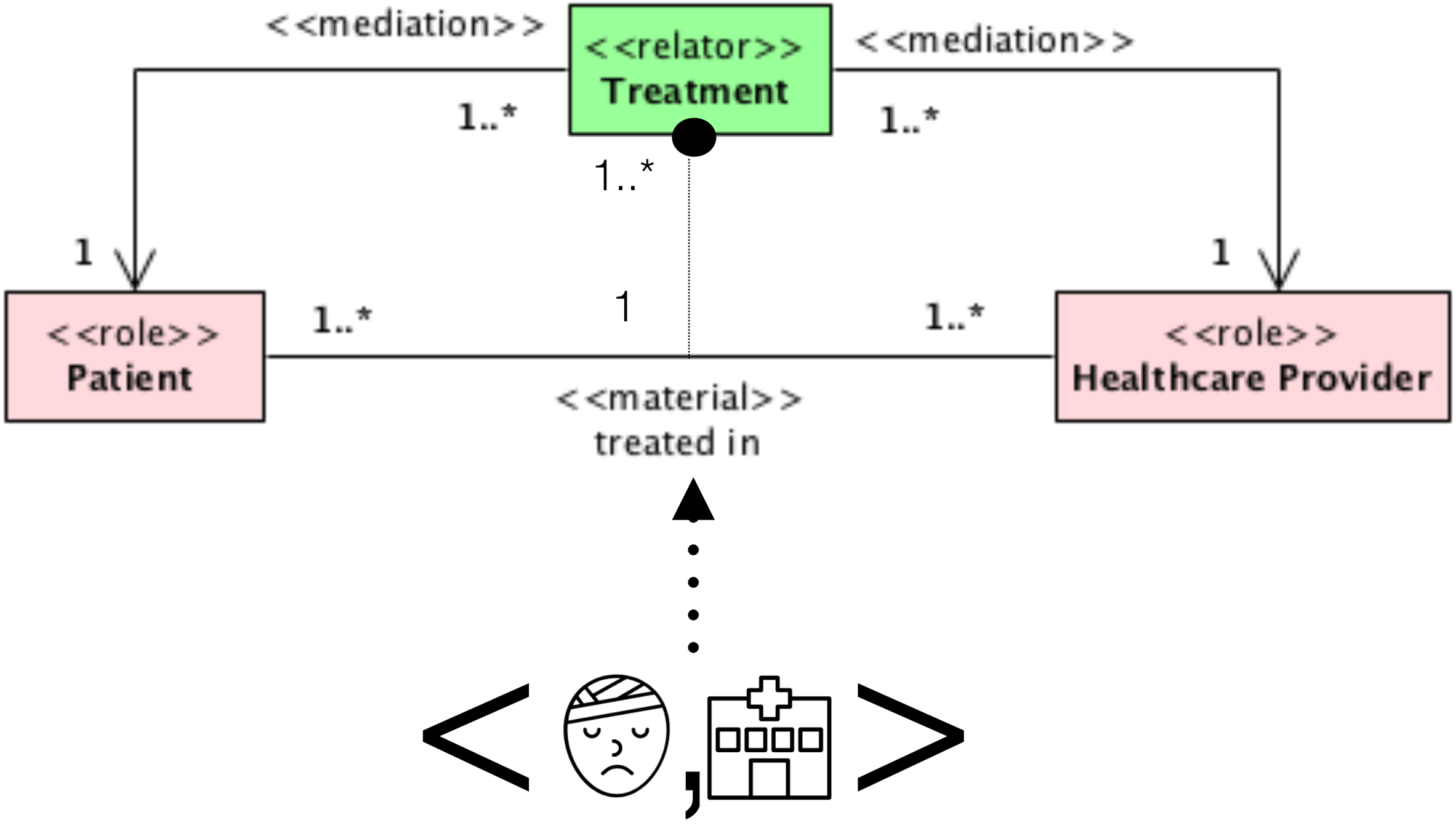
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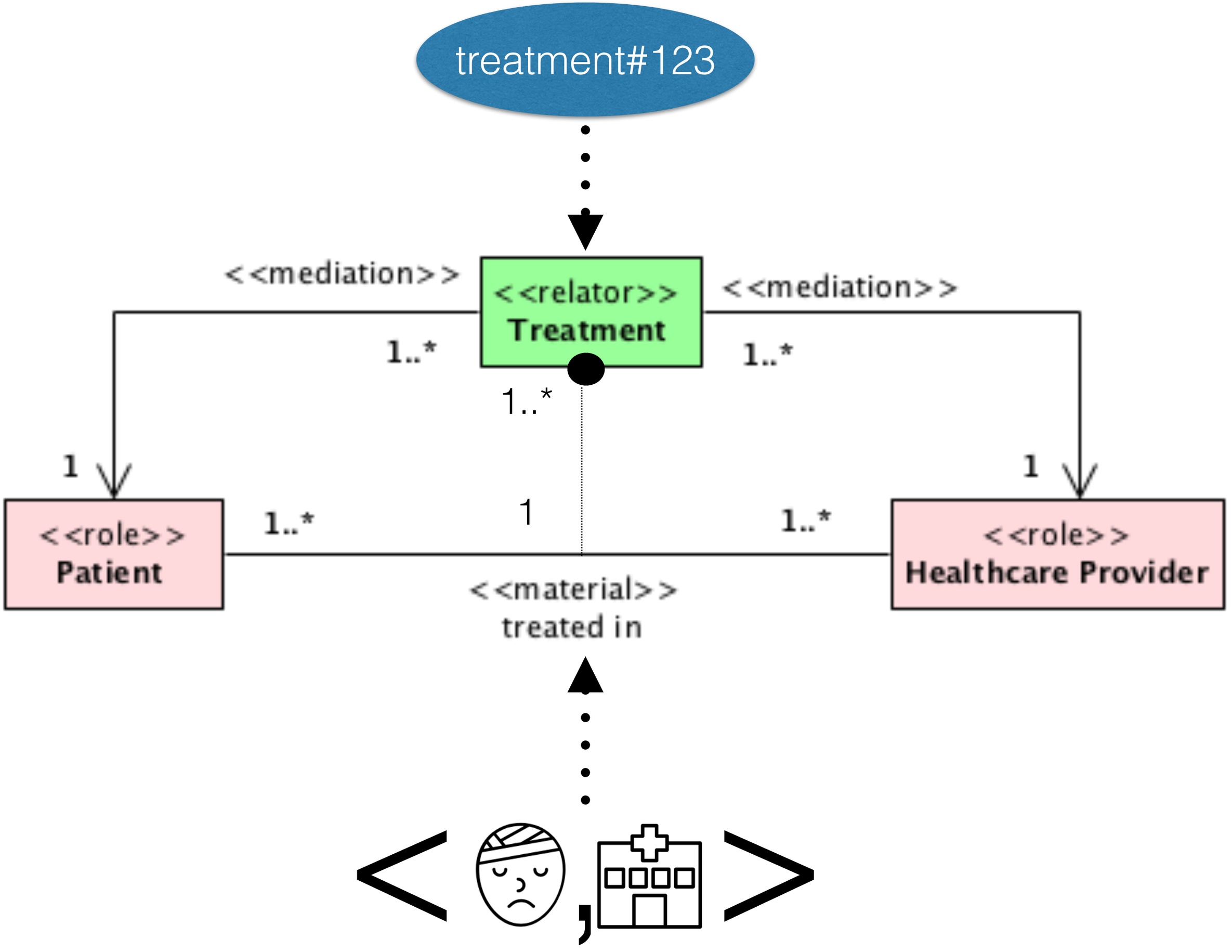
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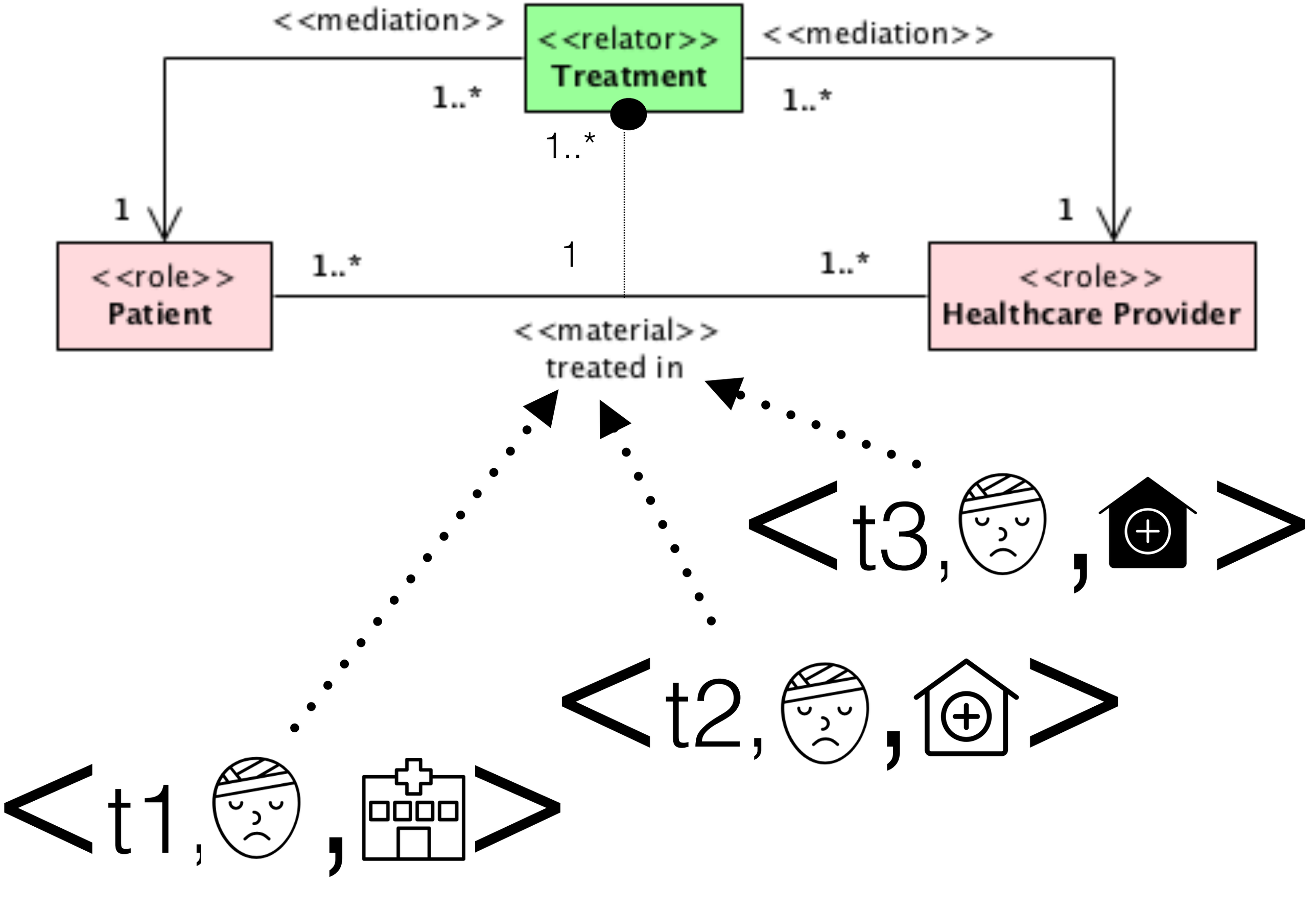
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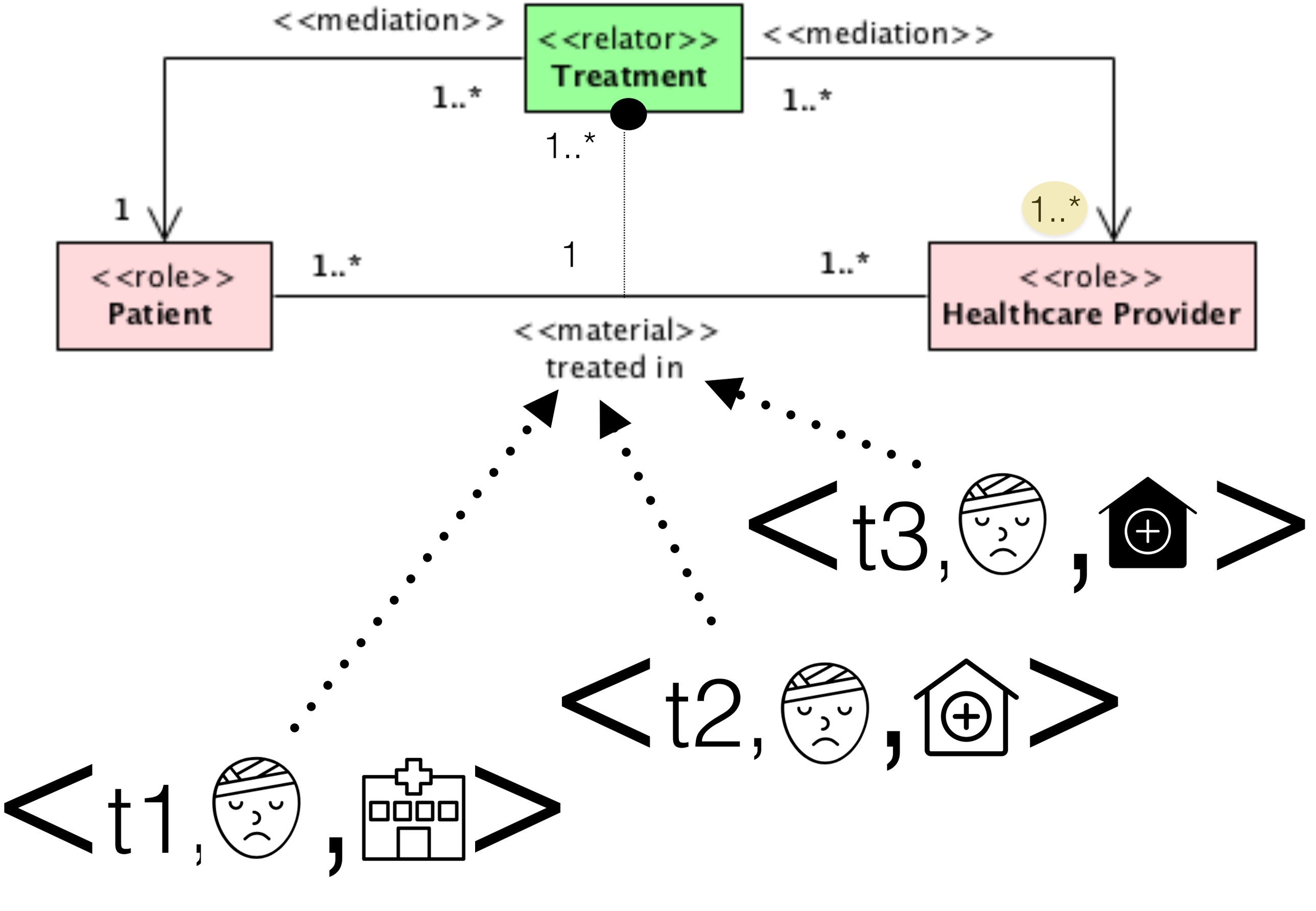
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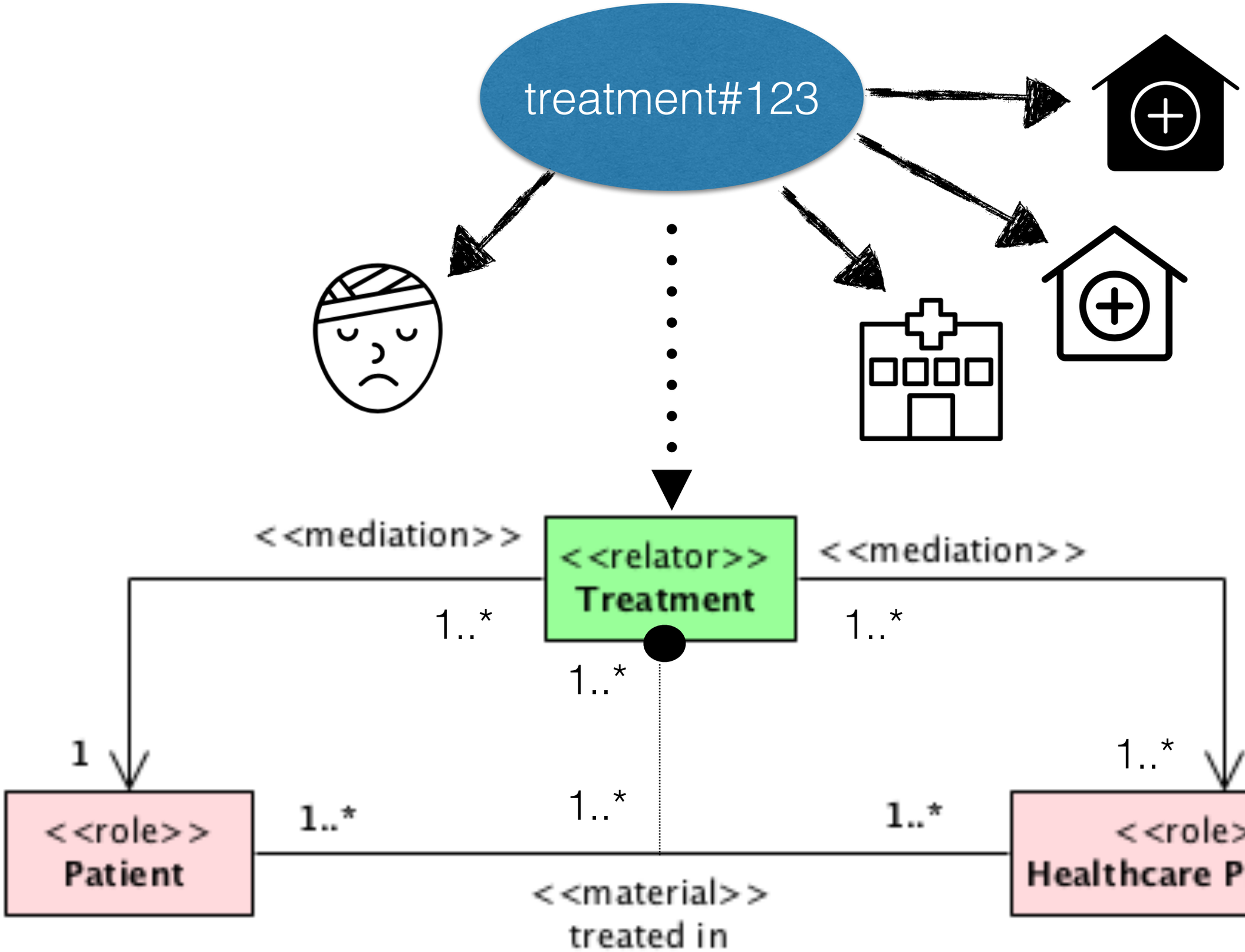
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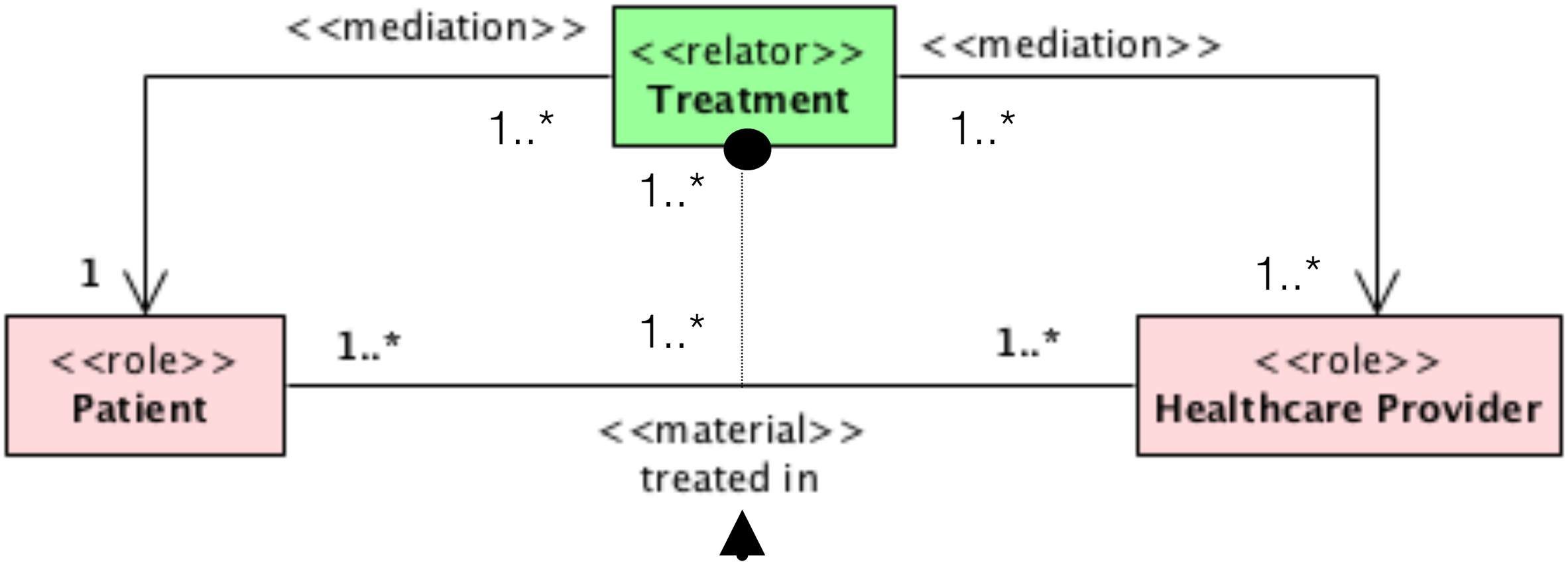
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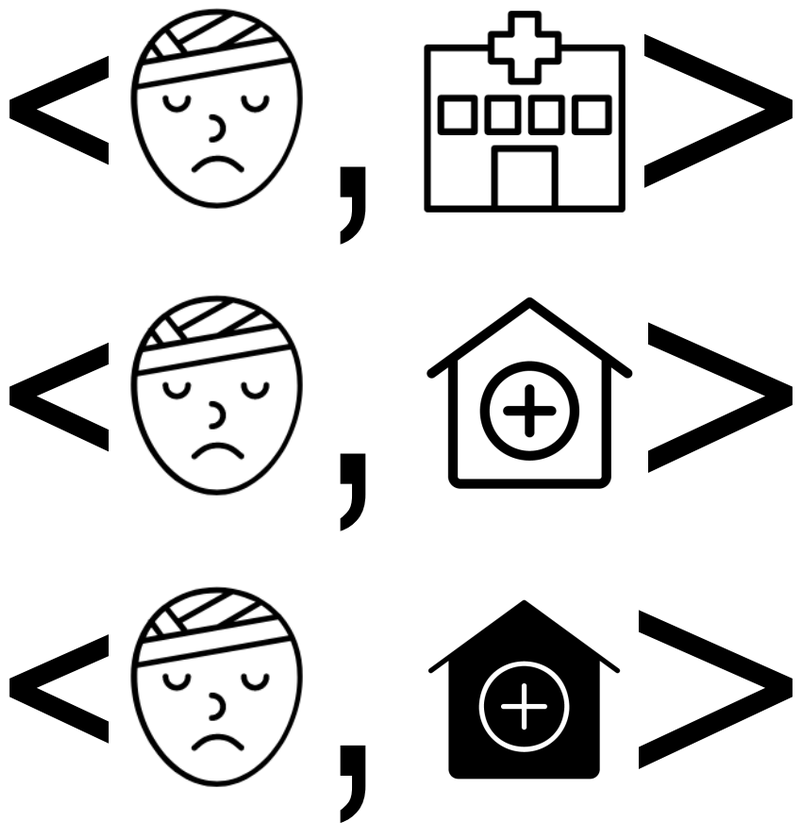

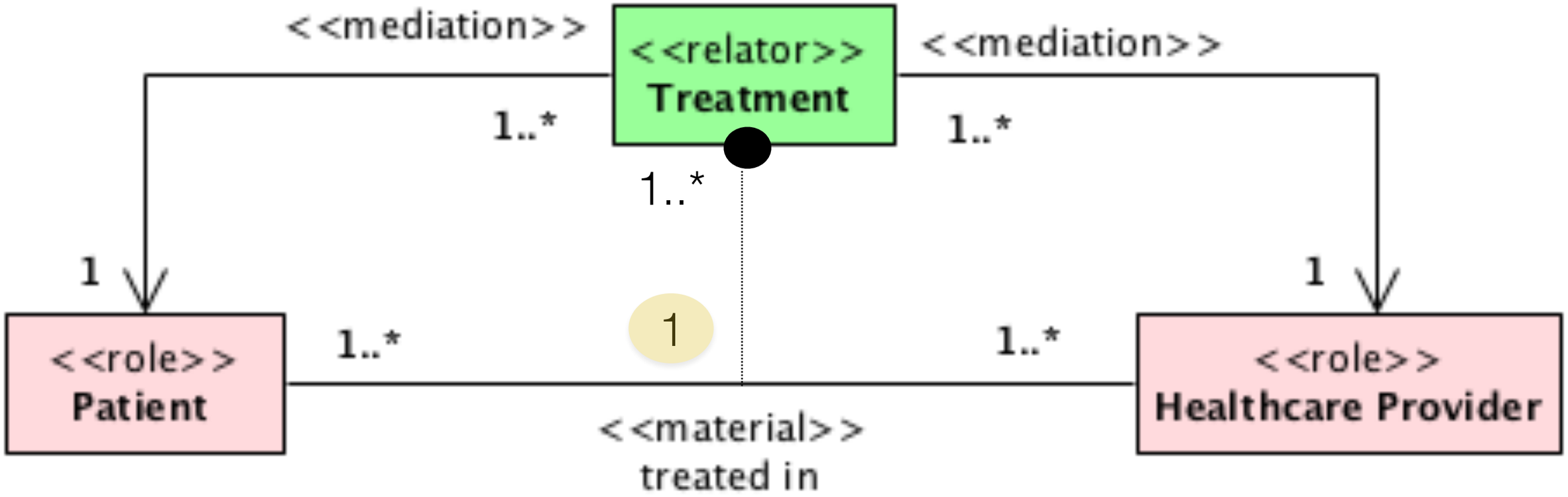
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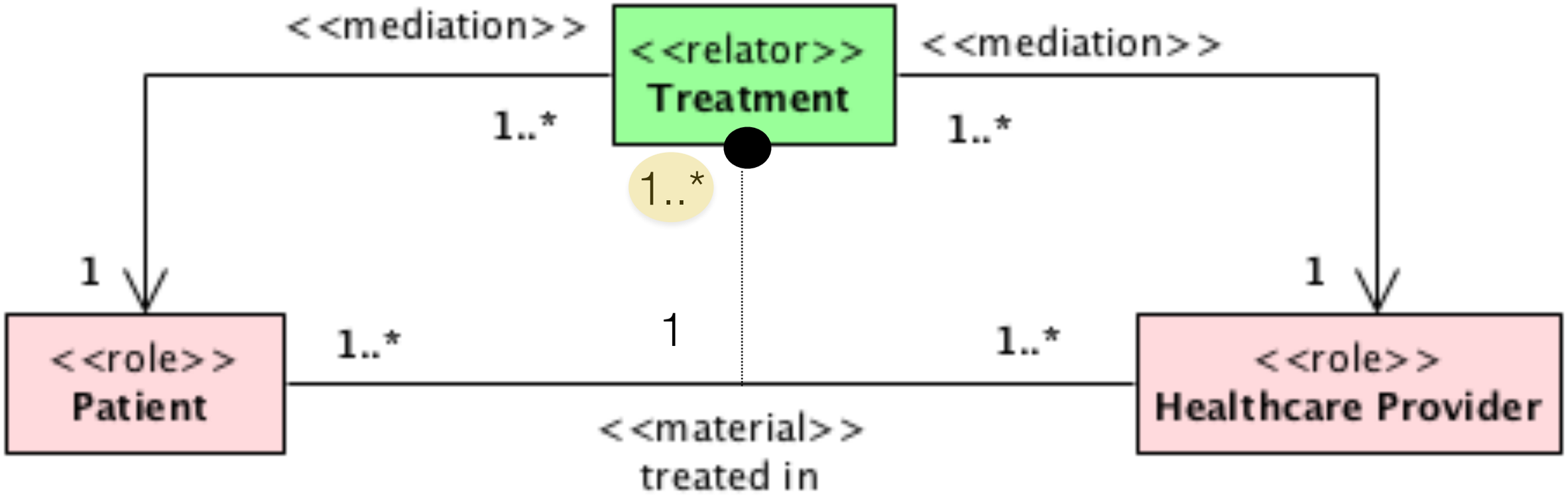
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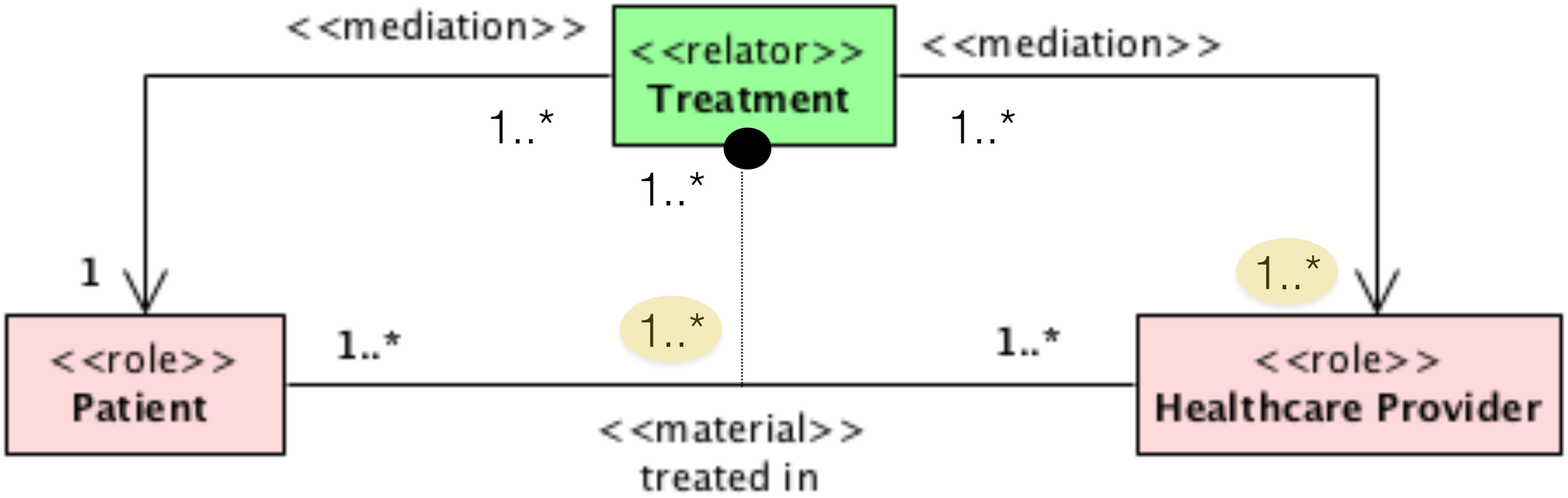
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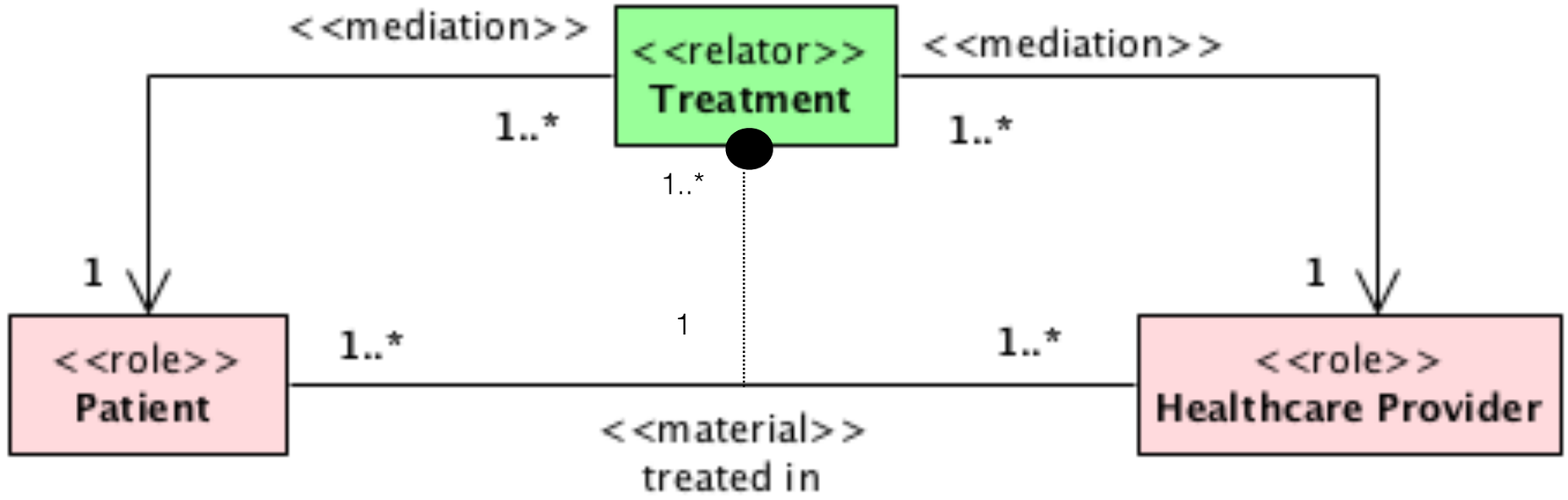
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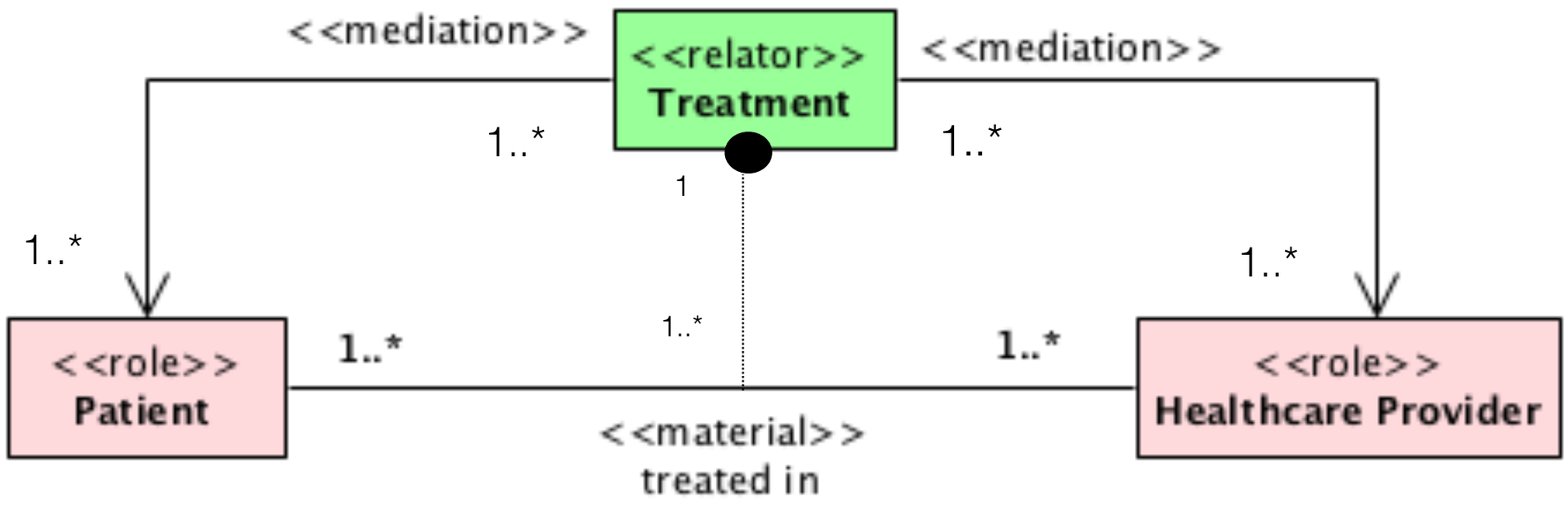
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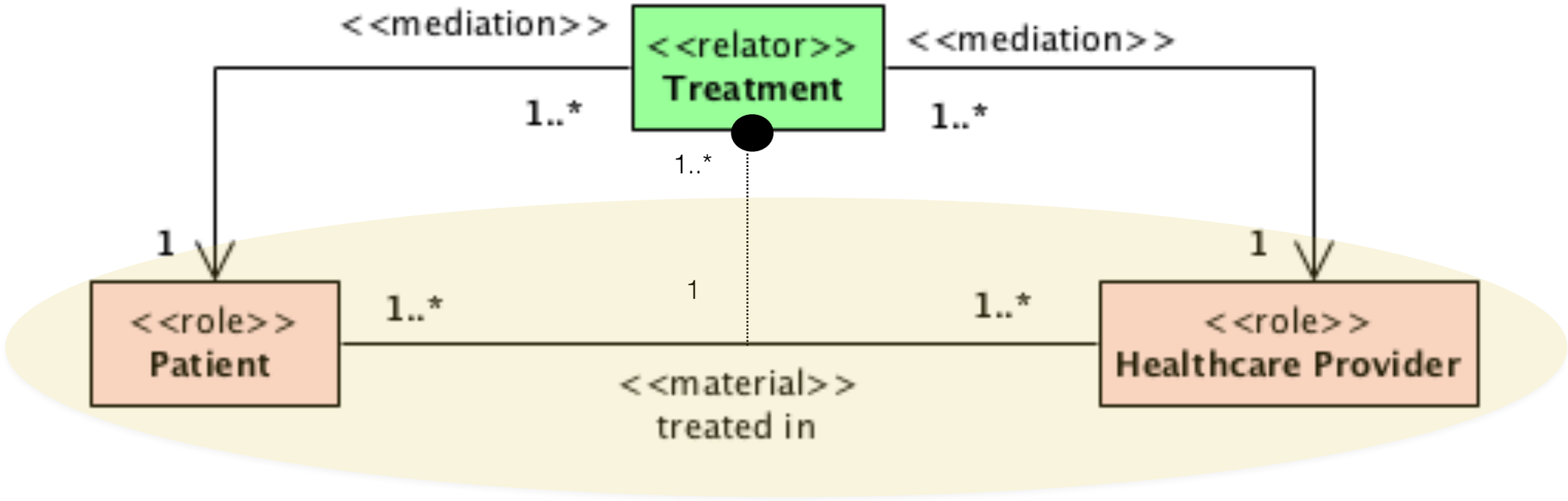
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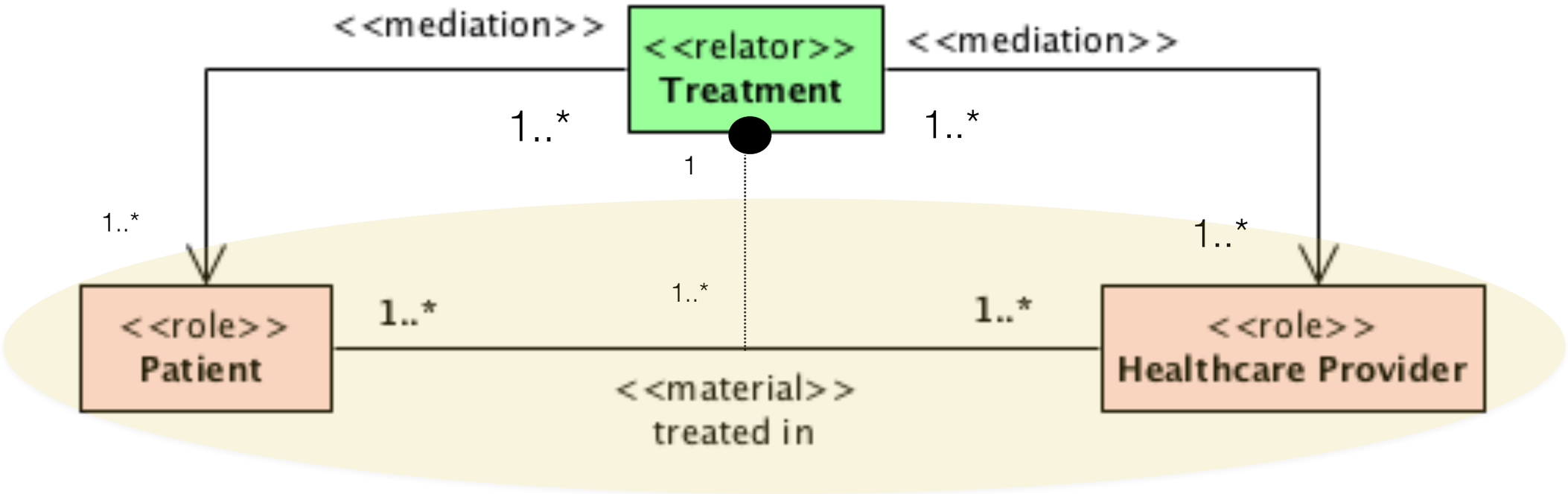
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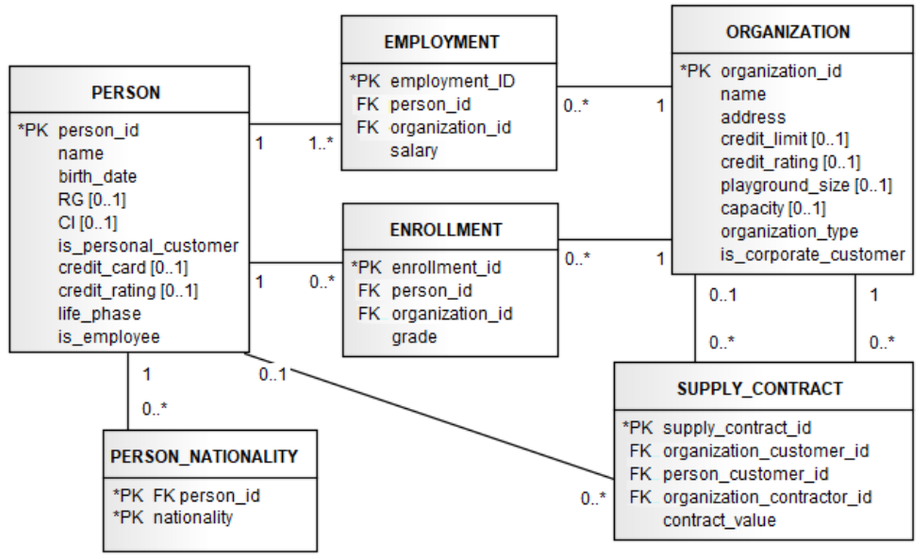
Value and **Value Proposition**, **Risk**, **Preference**, **Service**, Product **Offerings** and Economic **Transactions**, **Contracts**, **Trust**, **Privacy**, **Money**

These are all relational phenomena, which require a rich theory and expressive modeling support for relationships!

Ontological Concerns

Design and **Implementation** Concerns



Ontological Concerns

Design and **Implementation** Concerns

OLED File Edit Diagram View Project Verification Validation Transformation Help 34% Fri 20:04 Giancarlo Guizzardi

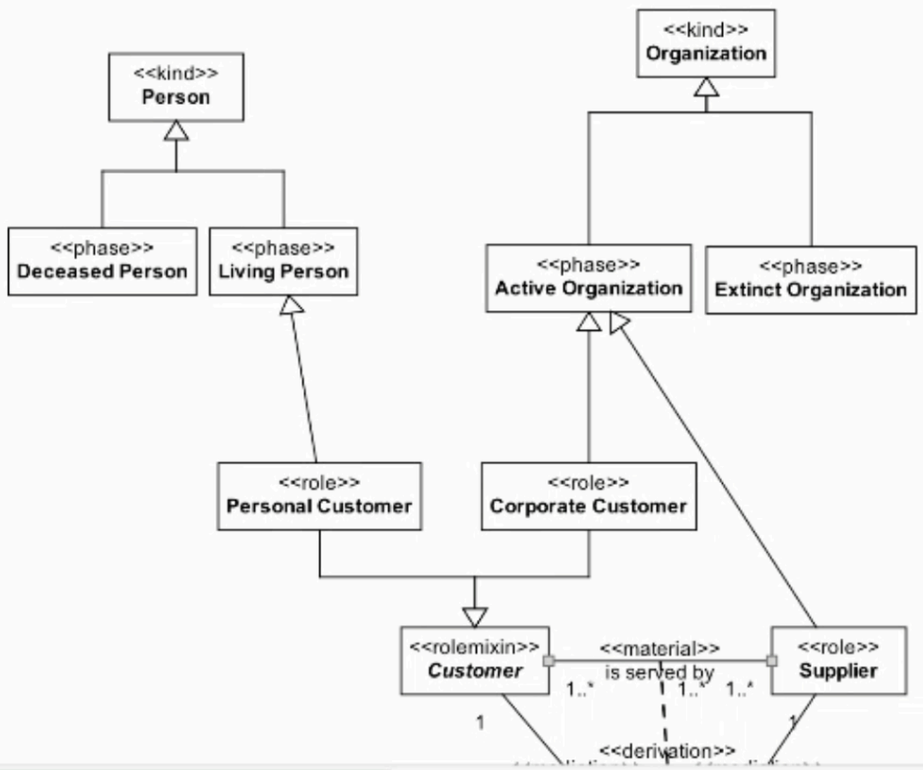
OLED – ER2014.oled

Toolbox

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

Editor

100%



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
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    - «Phase» Active Organization
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    - «Kind» Organization
    - GeneralizationSet partition2 { Activ
    - «RoleMixin» Customer
    - «Relator» Service Contract
    - «Role» Supplier
      - Generalization Active Organizat
    - «Role» Corporate Customer
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      - Generalization Customer
    - «Role» Personal Customer
      - Generalization Living Person
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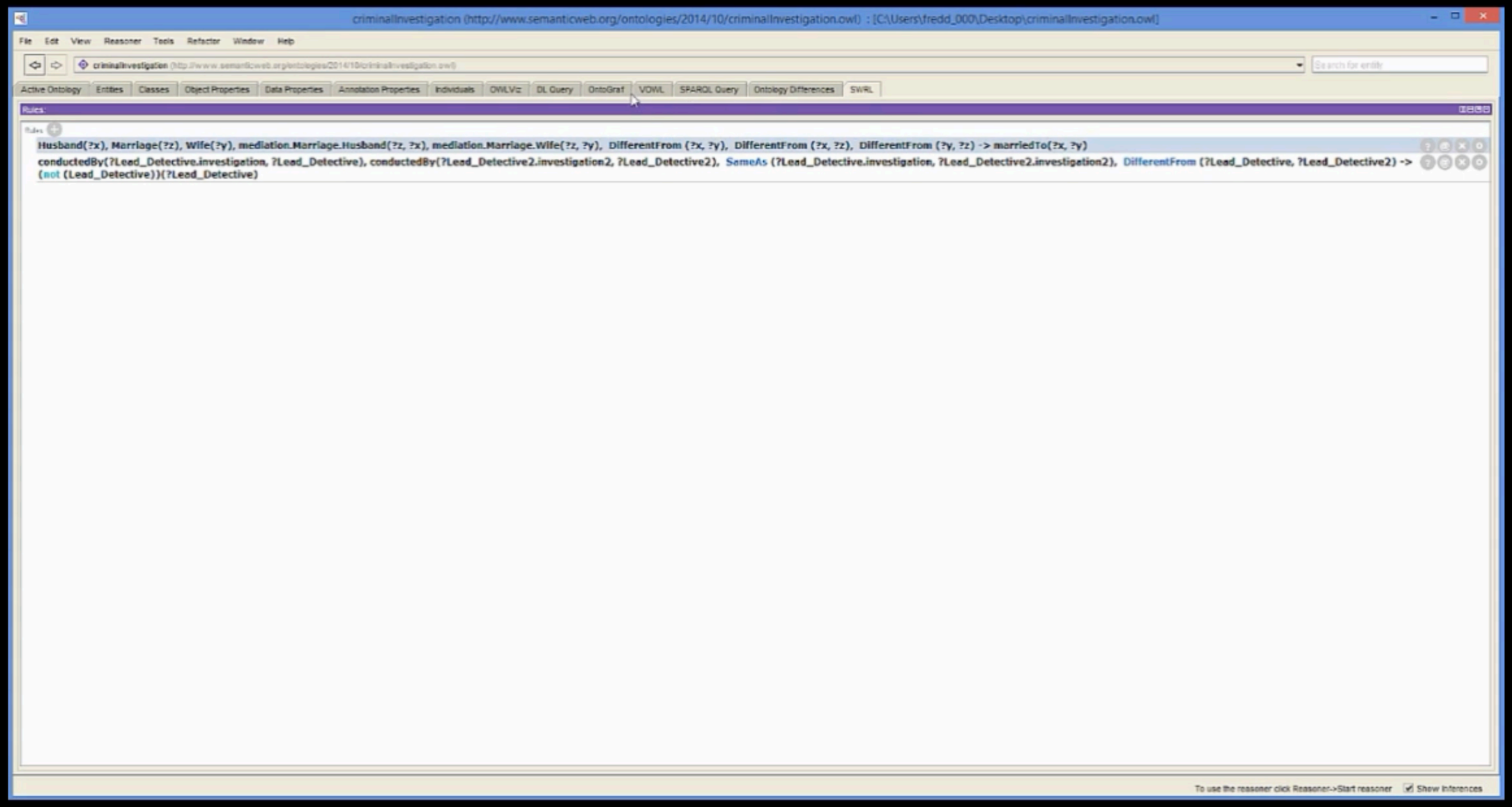
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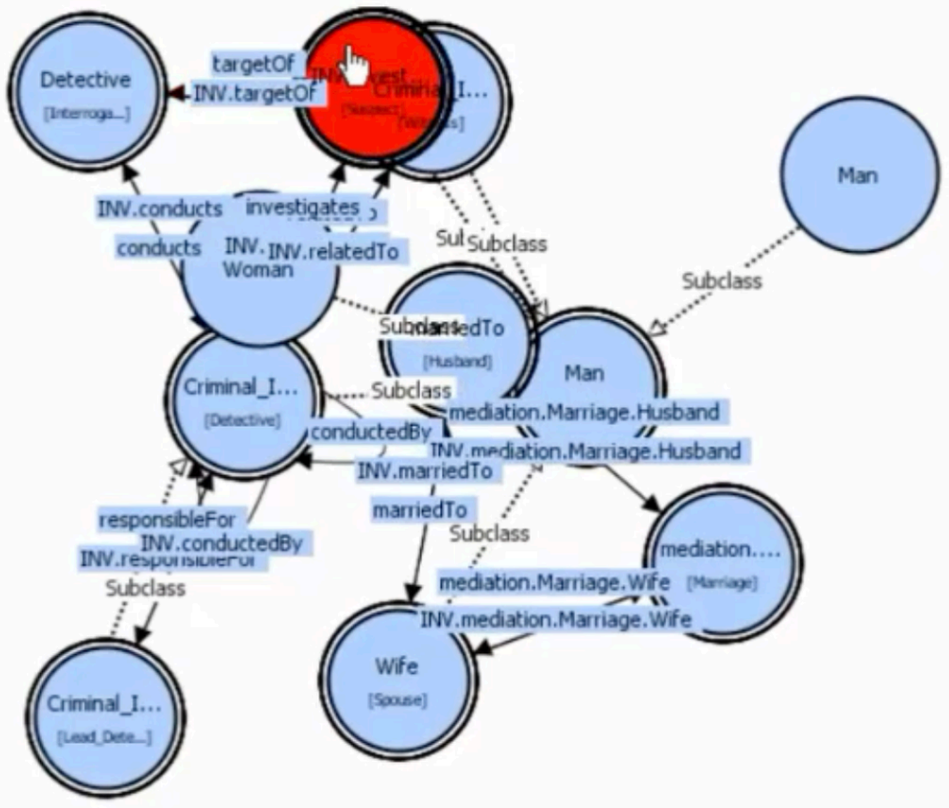
File Edit View Reasoner Tools Refactor Window Help
criminalInvestigation (http://www.semanticweb.org/ontologies/2014/10/criminalInvestigation.owl)
Search for entity
Active Ontology Entities Classes Object Properties Data Properties Annotation Properties Individuals OWLViz DL Query OntoGraf VOWL SPARQL Query Ontology Differences SWRL
Rules:
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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Take Away Messages

- **ontology** is inevitable and it is fundamental for semantic **interoperability**

- …but we have to do it right, e.g., separating ontological issues from design and implementation issues

- and we need models that reveal the real-world **semantics** underlying a given representation. Description is not enough, we need **Explanation**!

Follow-up **References**

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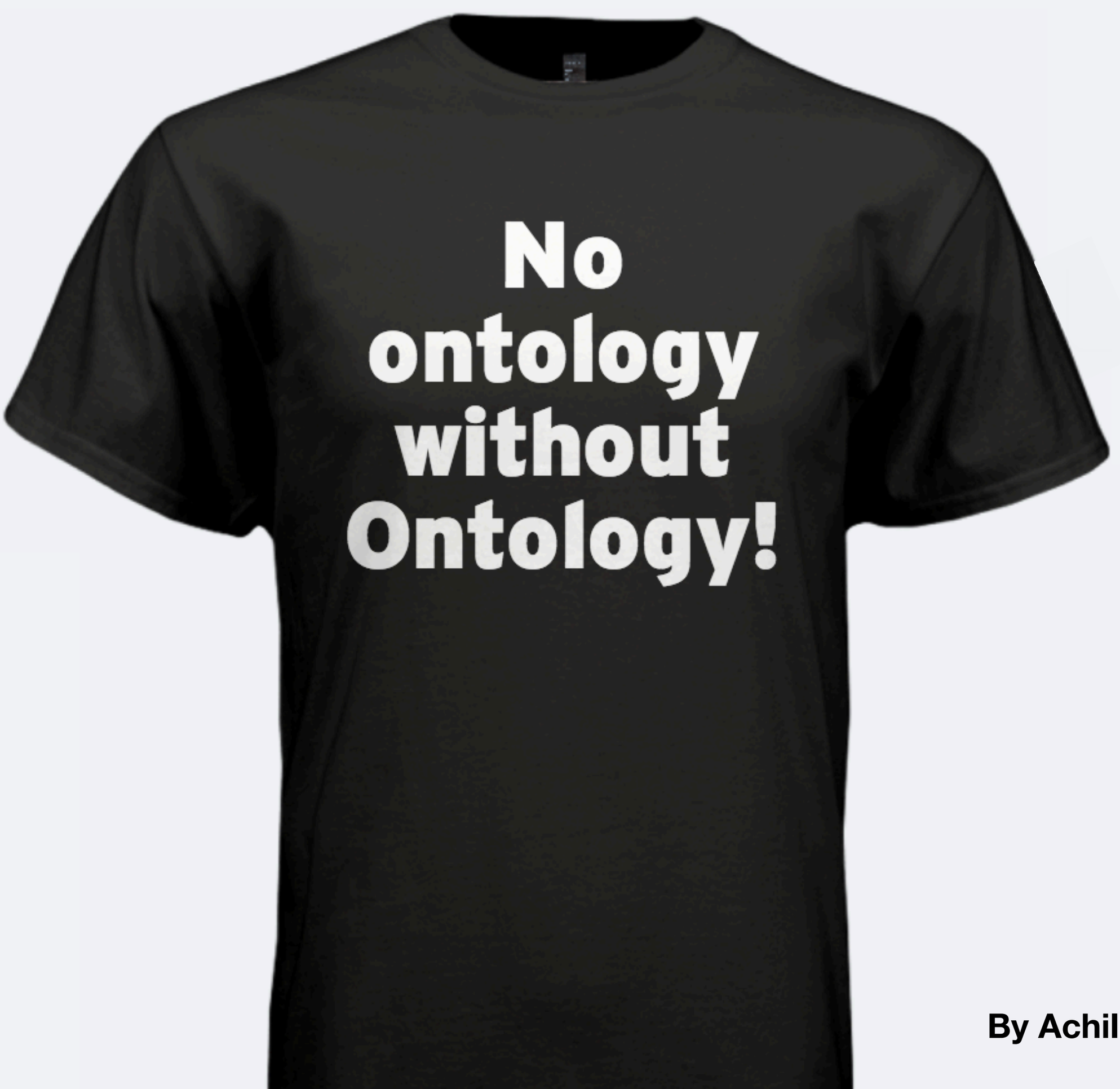
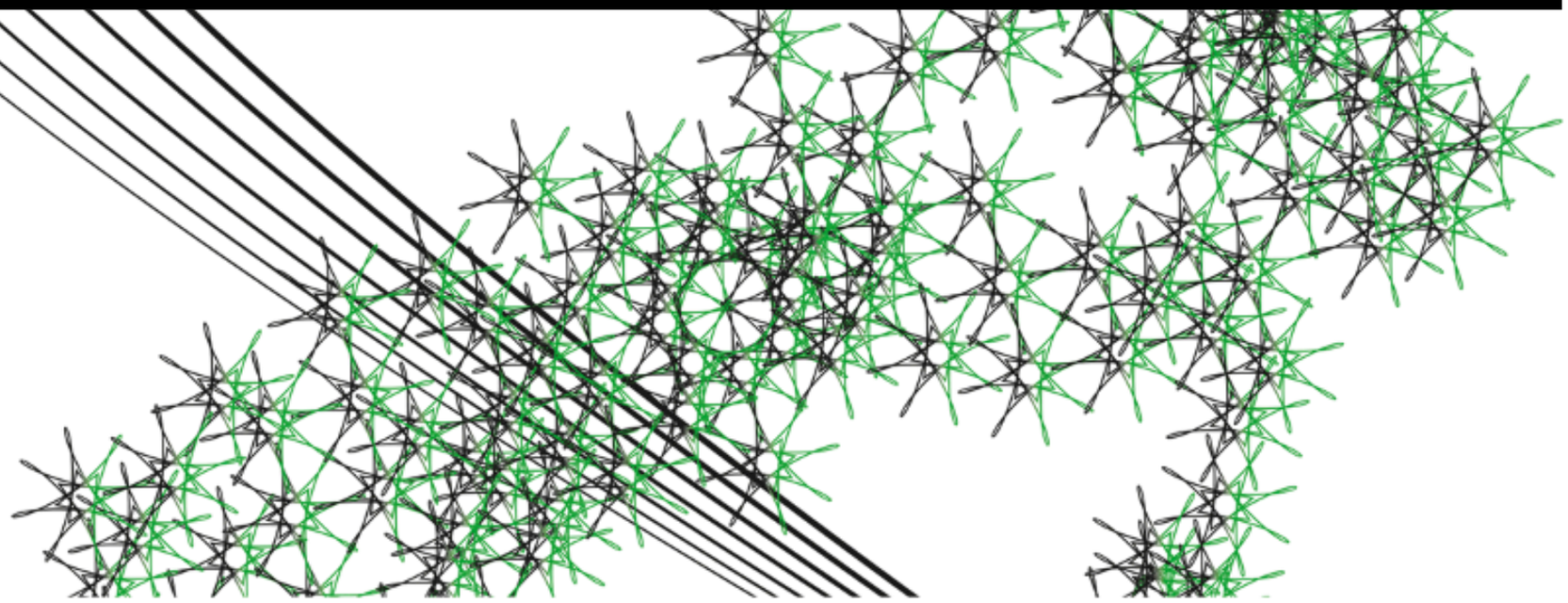
- Giancarlo Guizzardi: Agent Roles, Qua Individuals and the Counting Problem. SELMAS (LNCS) 2005: 143-160



By Achille Varzi

UNIVERSITY OF TWENTE.



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