The *OntoClean* Methodology

- Conceptualization
- Conceptual Model
- User
- Methodology
- Ontology
- Minimal Top-Level Ontology
- Ontology-Driven Modeling Principles
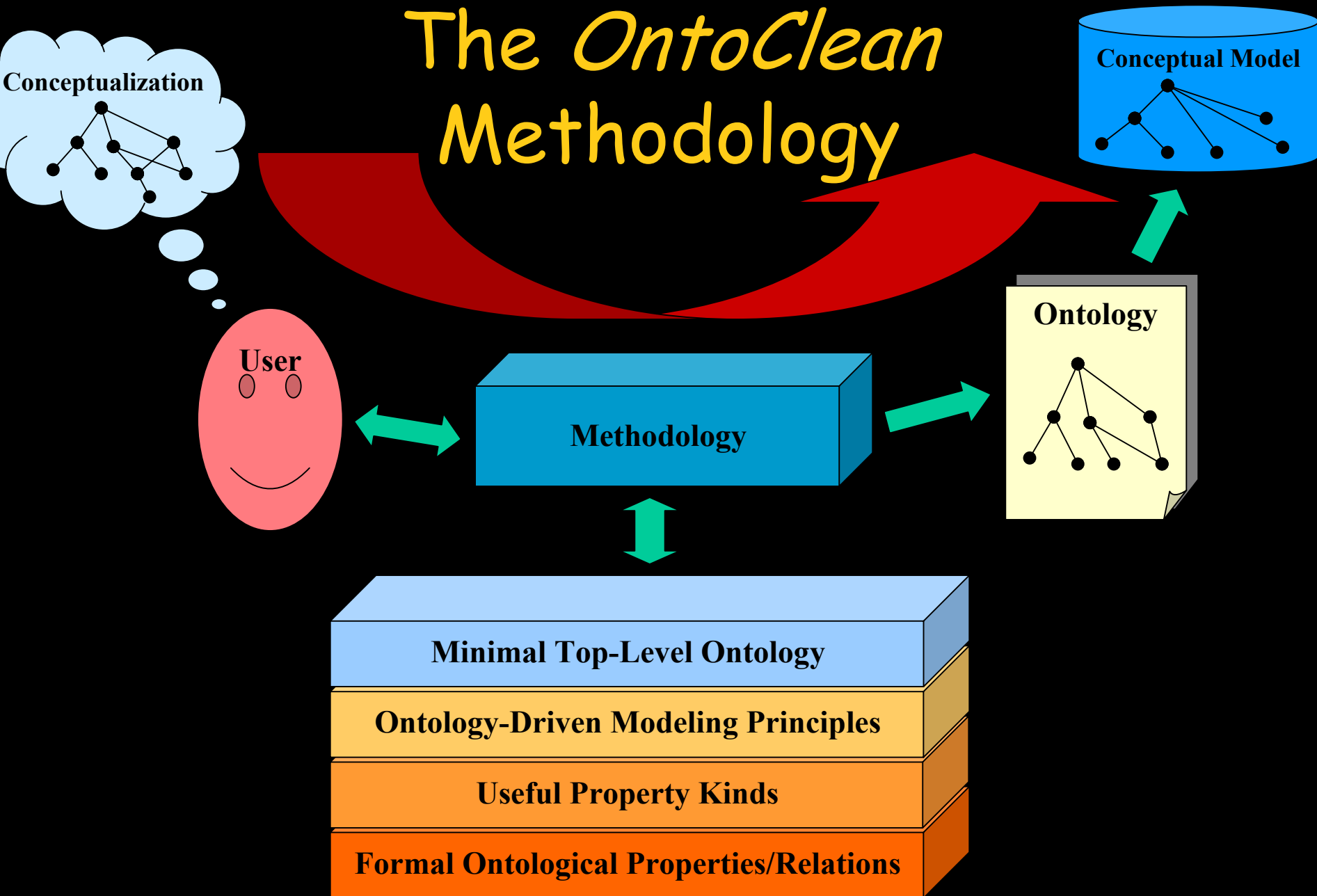- Useful Property Kinds
- Formal Ontological Properties/Relations

Summary

- Re-visiting common conceptual modelling constructs
- Some basic ontological distinctions: the DOLCE ontology

Re-visiting conceptual modelling constructs

- Instantiation
- Generalization
- Association
- Aggregation

The Instance-of Relation

How to decide whether something is an instance?

- Properties can be instances of meta-properties
- Hence, "being an instance" may be a subjective property
- But "being a particular" **IS NOT!**

- Particulars are always "ultimate" instances.
- Concrete entities are *always* particulars.
- So-called "temporal instances" are either temporal *parts* of a particular or instances of an abstract *class*.

Particulars and Universals

- Universals
  - Have multiple exemplifications
  - All abstract
- Particulars:
  - Have no exemplifications
  - Can be either concrete or abstract

Concrete entities are all particulars

Instance-of vs. membership (1)

- The problems of logical predication
  - x is an apple $\rightarrow$ Apple(x)
  - x is red $\rightarrow$ Red(x)
- Instance-of vs. class membership
  - John is a member of "Person" $\rightarrow$ Person(John)
  - Tree1 is a member of "BlackForest" $\rightarrow$ BlackForest(Tree1) ??

    (violates usual intended interpretation of unary predicates: property shared by all instances of the corresponding class. Doesn't pass the "is-a" test)

Instance-of vs membership (2)

- Instance-of:
  - Particular-universal
  - Universal-universal
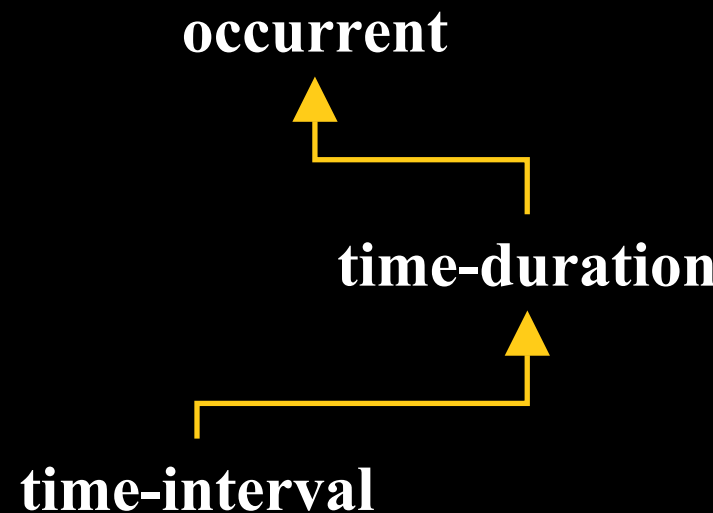- Membership:
  - Particular-particular

Overloading Subsumption
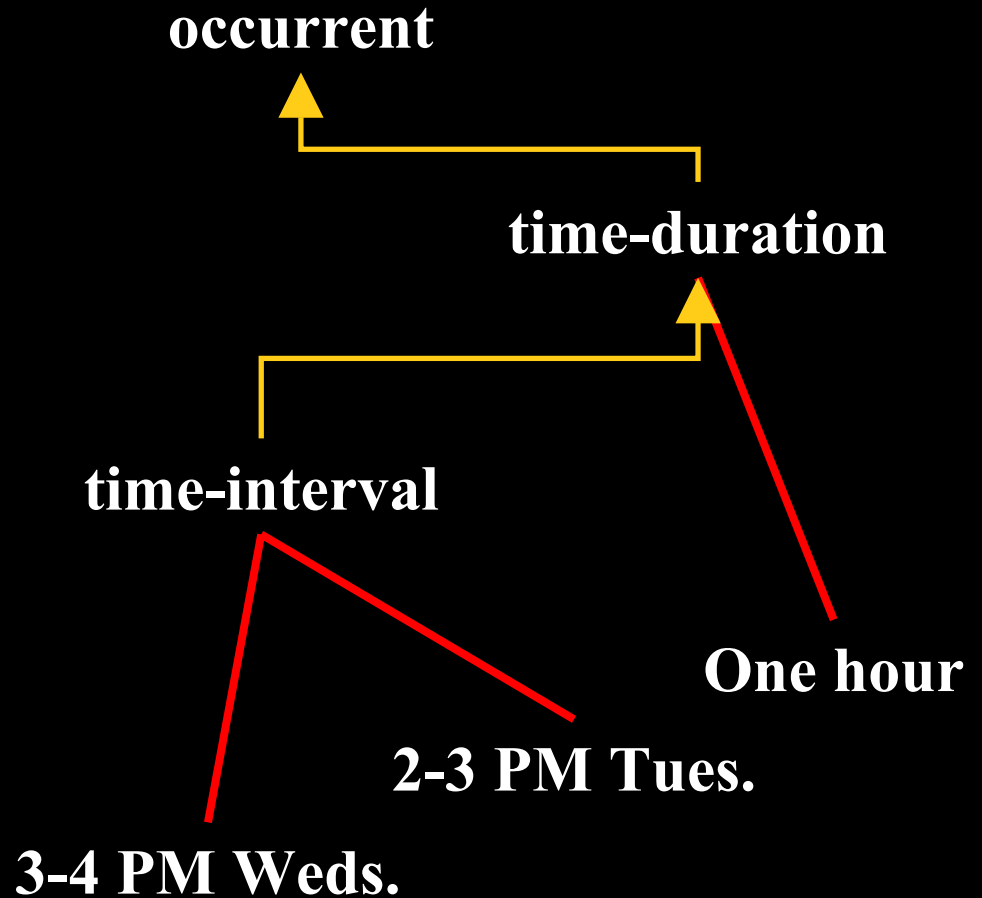## Common modeling pitfalls

- Instantiation
- Composition
- Disjunction
- Polysemy
- Constitution

Example - Identity

- Is *time-interval* a subclass of *time-duration*?
  – Initial answer: yes
- IC for *time-duration*
  – Same-length
- IC for *time-interval*
  – Same start & end

occurrent

time-duration

time-interval

Example - Identity

occurrent

time-duration

time-interval

One hour

2-3 PM Tues.

3-4 PM Weds.

Instantiation (1)

Does this ontology mean that **My ThinkPad** *is a* **ThinkPad Model**?

ThinkPad Model

Ooops…

T21

My ThinkPad (s# xx123)
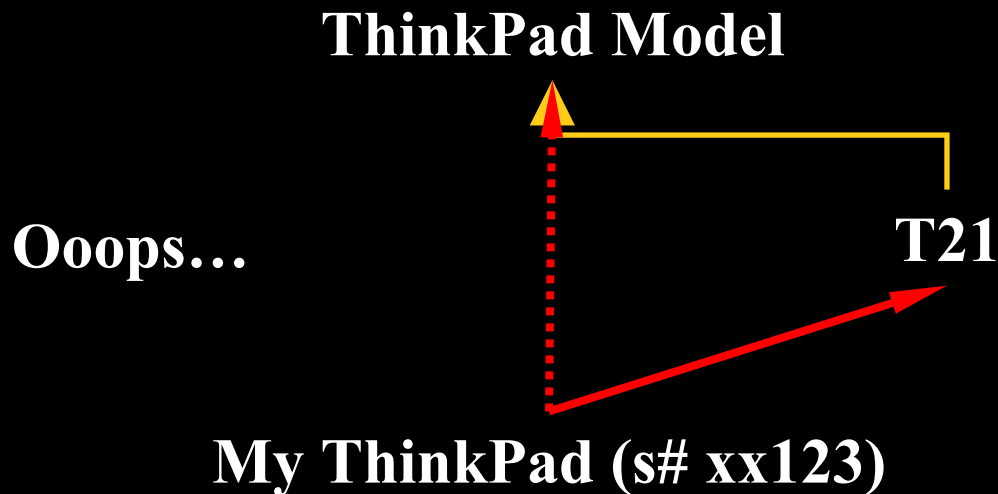
Question: What ThinkPad models do you sell?
Answer should NOT include My ThinkPad -- nor yours.

Instantiation (2)

Notebook Computer ⊘→ ThinkPad Model

T Series

model

My ThinkPad (s# xx123) → T 21

Composition (1)

Computer

Disk Drive   Memory

Micro Drive
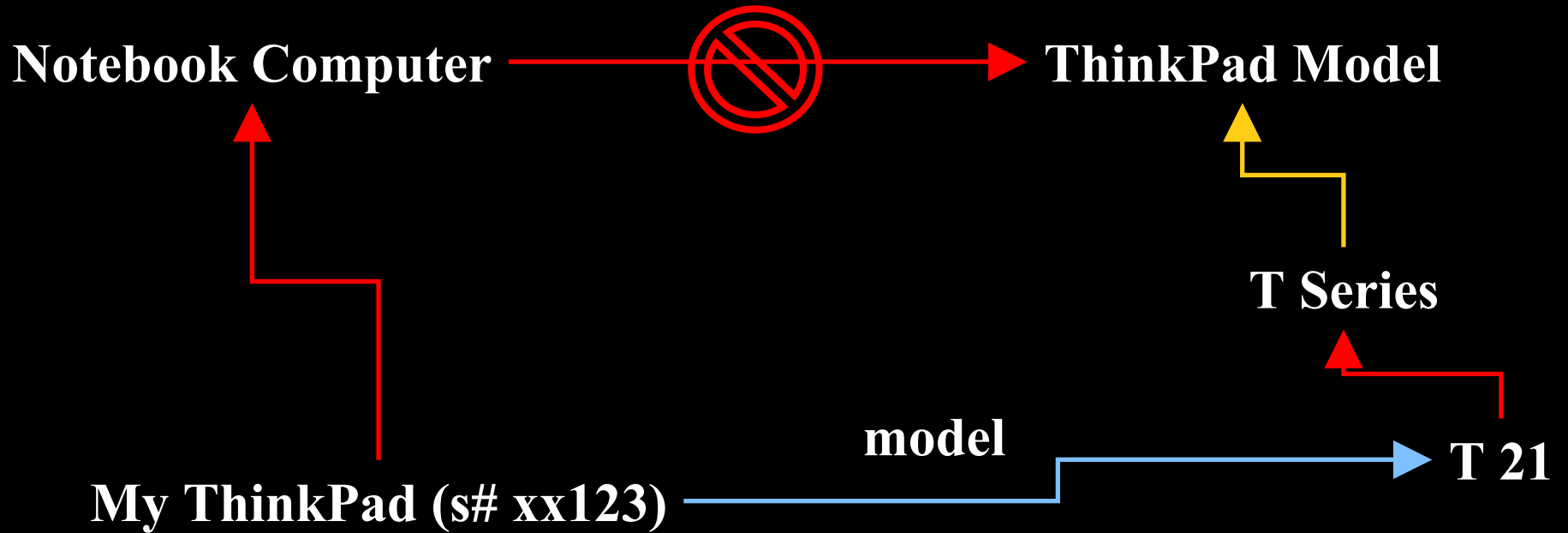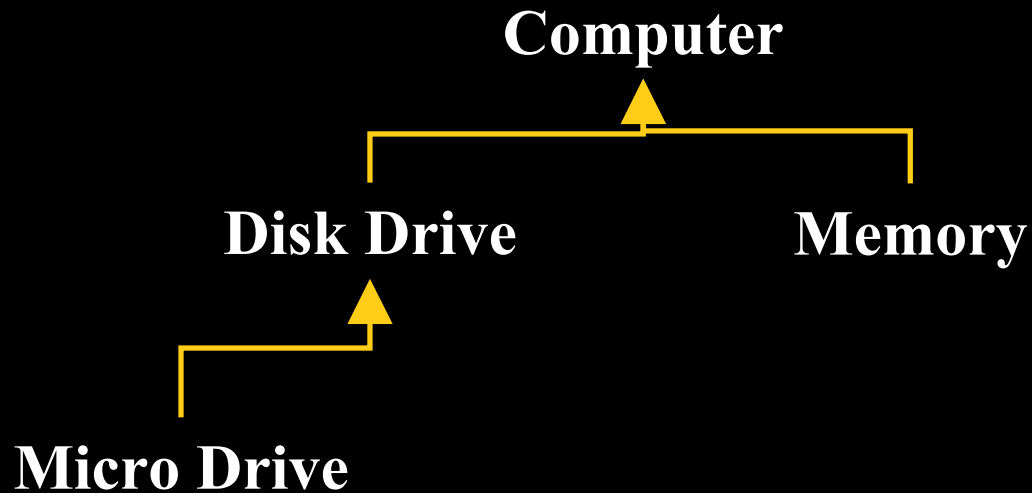
Question: What kinds of computer do you sell?
Answer should NOT include Disk Drives or Memory.

Composition (2)

Computer

Has-part

Disk Drive   Memory

Micro Drive

Disjunction (1)

Computer $\xrightarrow{\text{has-part}}$ Computer Part

Computer Part
↑
Disk Drive   Memory
↑   ↑
Micro Drive

Camera-15 $\xrightarrow{\text{has-part}}$ Flashcard-110
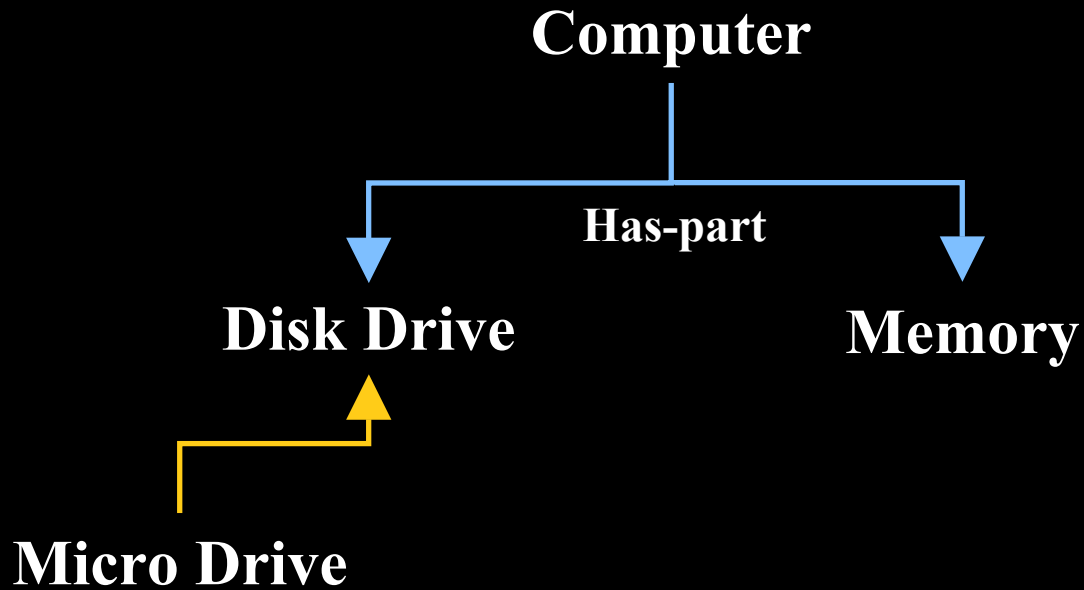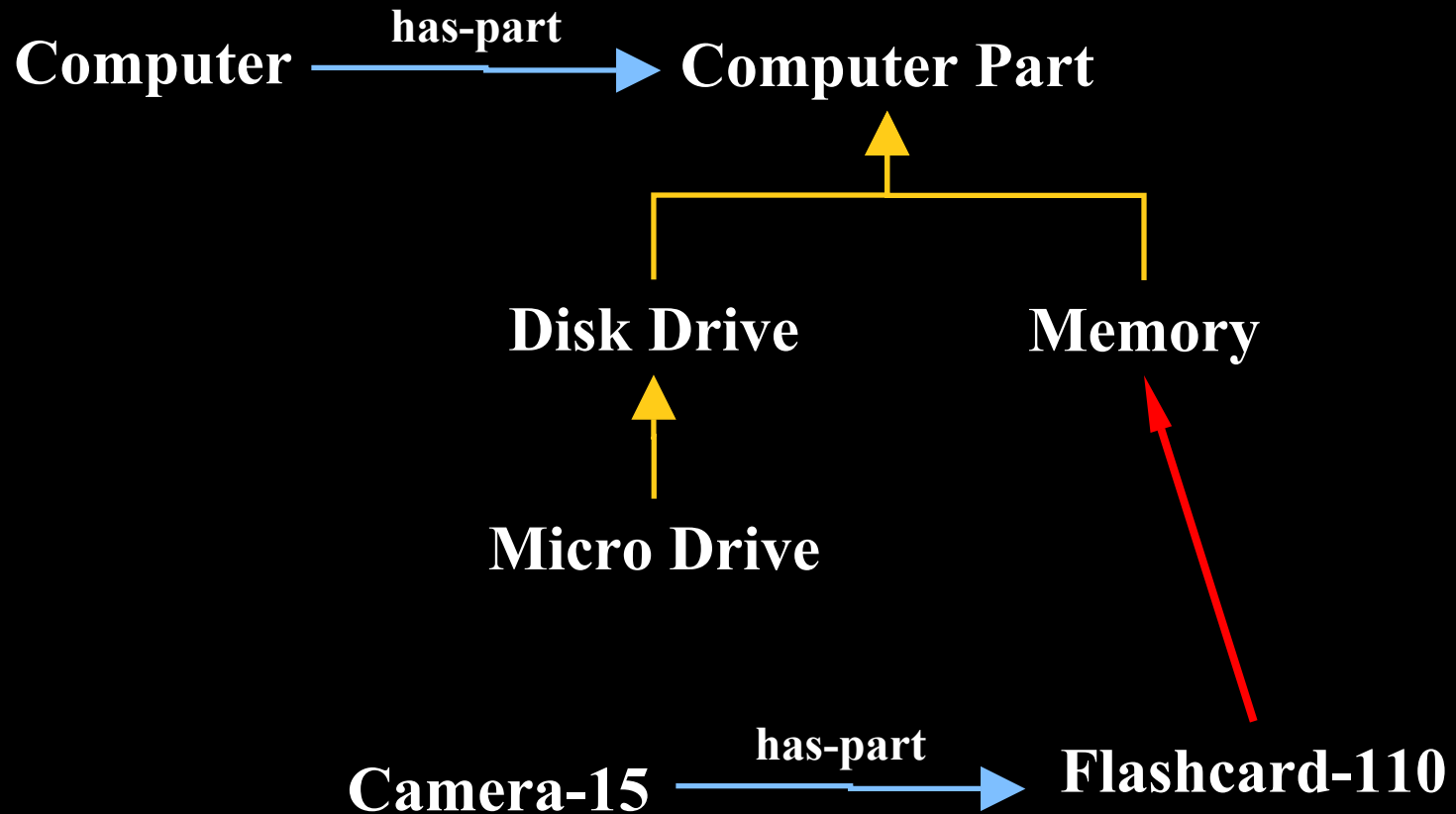
Unintended model: flashcard-110 is a computer-part

Disjunction (2)

Computer $\xrightarrow{\text{has-part}}$ Disk Drive ∨ Memory ∨ …

Polysemy (1)
(Mikrokosmos)

Physical Object   **Abstract Entity**

Book

.....
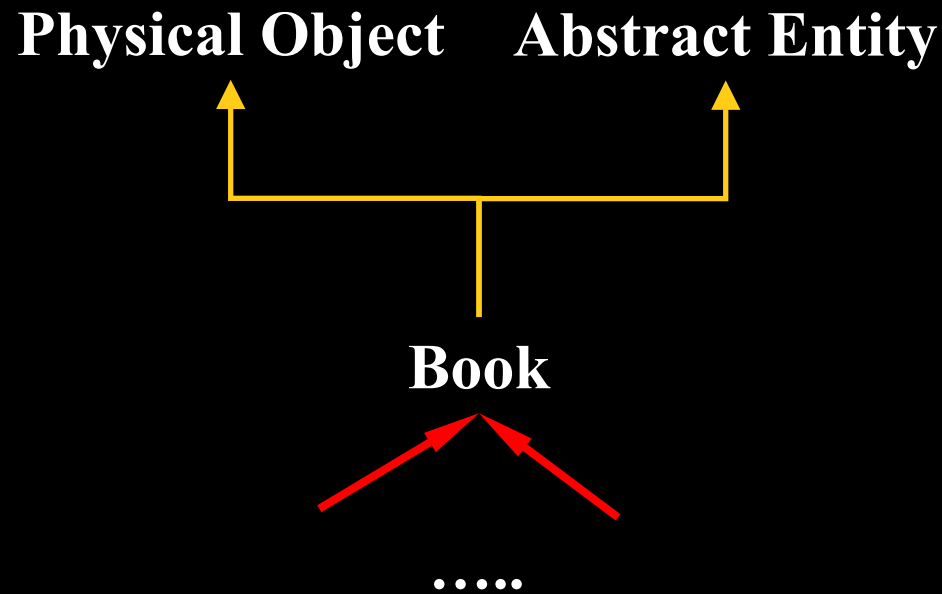
Question: How many books do you have on Hemingway?
Answer: 5,000

Polysemy (2)
(WordNet)

Physical Object   **Abstract Entity**

**Book
Sense 1**

**Book
Sense 2**
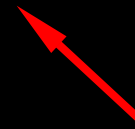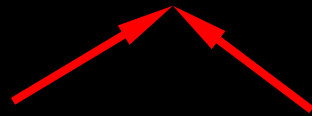
.....   **Biography of Hemingway**

Constitution (1)
(WordNet)

Entity

↑

Amount of Matter

↑

Physical Object

Metal   Clay

↑
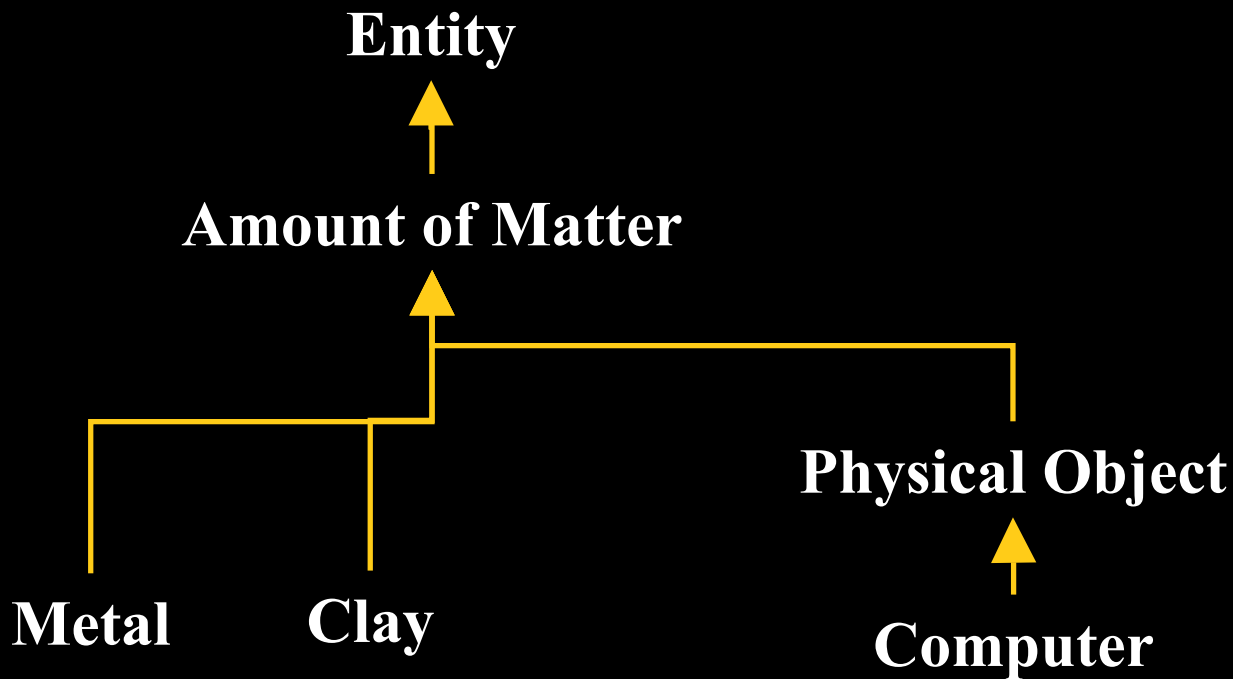
Computer

Question: What types of matter will conduct electricity?
Answer should NOT include computers.

Constitution (2)

Entity

Amount of Matter ← constituted — Physical Object

Metal   Clay

Computer
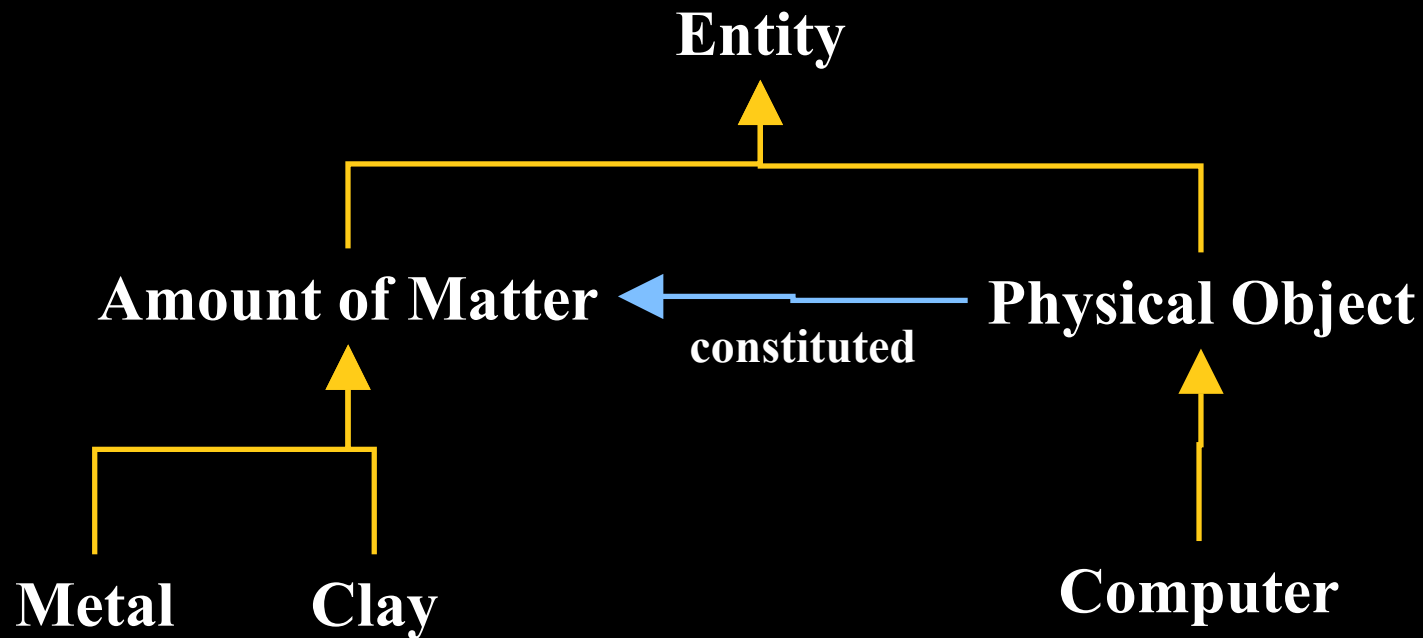
Part-of vs. part-*whole* relations

- portion/mass
- component/integral object
- member/collection
- Member/social organization

- stuff/object
- place/area
- feature/activity

Part, Constitution, and Identity

- *Structure* may change identity
- *Mereological extensionality* is lost
- *Constitution* links the two entities
- Constitution is asymmetric (implies *dependence*)

a + b   Stack#1

a + b   K   Stack#1

D

a   b
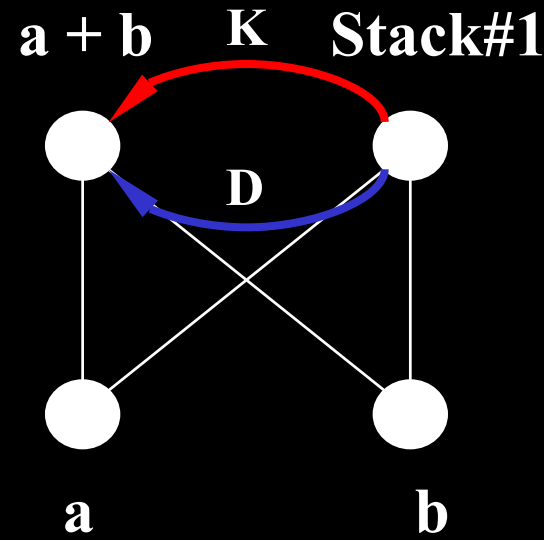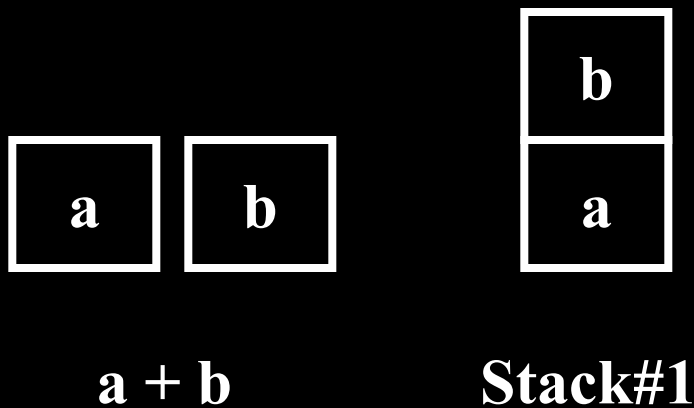
Attributes vs. Arbitrary Relations

- Woods' example
  - John
    - age: 32
    - hits: Mary
- Internal vs. external relations
- Woods' linguistic test
- The Attribute Consistency Principle:
  - Any X of Y is a X

Conceptualization

Conceptual Model

User

Methodology

Ontology

Minimal Top-Level Ontology

Ontology-Driven Modeling Principles

Useful Property Kinds

Formal Ontological Properties/Relations
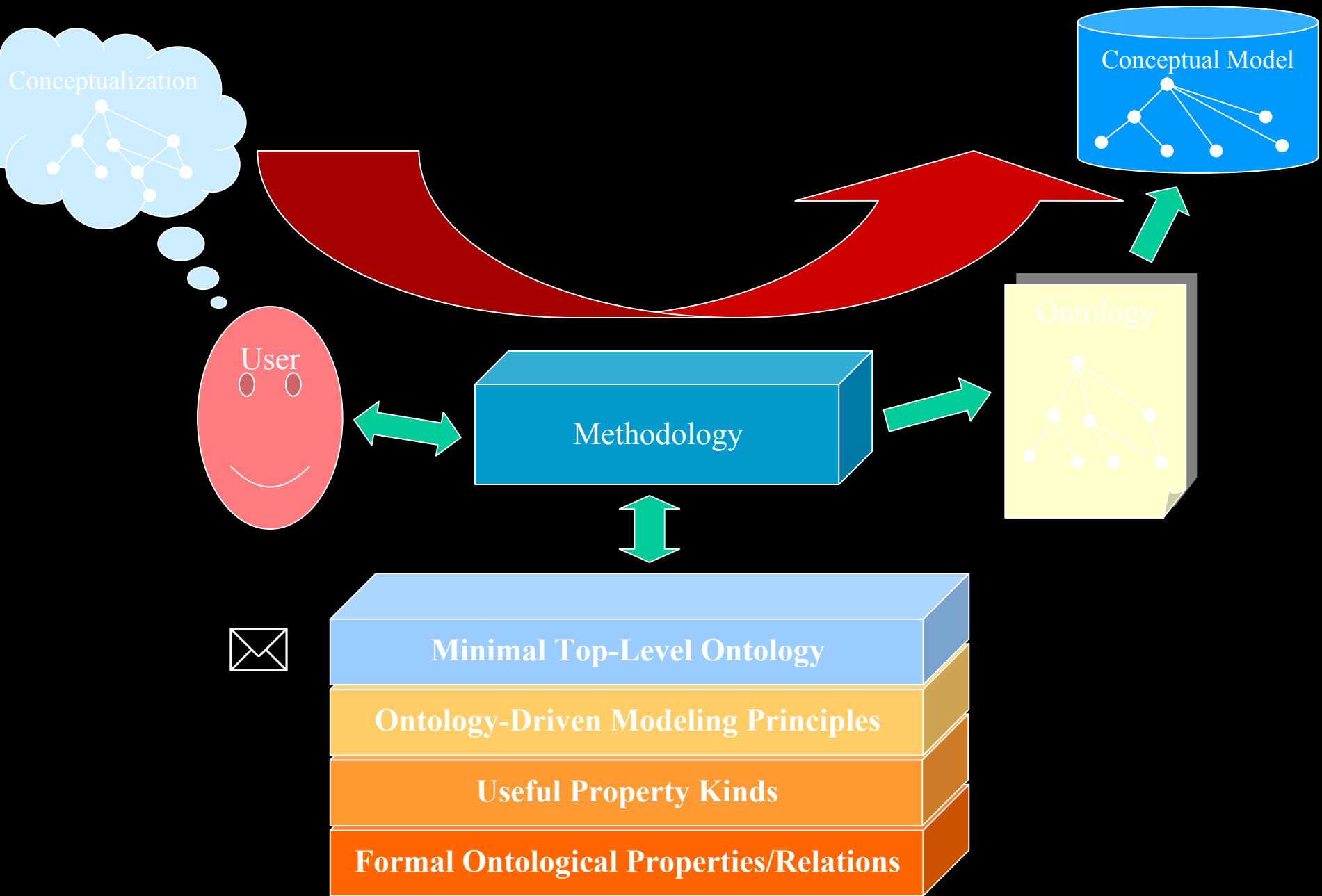
Developing foundational ontologies

- List the *basic options*
- Explore most relevant mutual *dependencies*
- Propose one preliminary upper level which is carefully *justified* and *positioned* with respect to the space of possible choices
- Add some *minimal ontologies* specifically relevant for selected domains
- Explore *alternative* upper levels

The WonderWeb Library of Foundational Ontologies

- No single upper level
- Rather, a (small) set of *foundational ontologies* carefully *justified* and *positioned* with respect to the space of possible choices
- *Basic options* clearly documented
- Clear *branching points* to allow for easy comparison of ontological options)

The WFO architecture

Choose Vision

4D

3D

Choose Subject

Top

Bank

Law

Single Module

Formal Links Between Visions & Modules

Single Vision
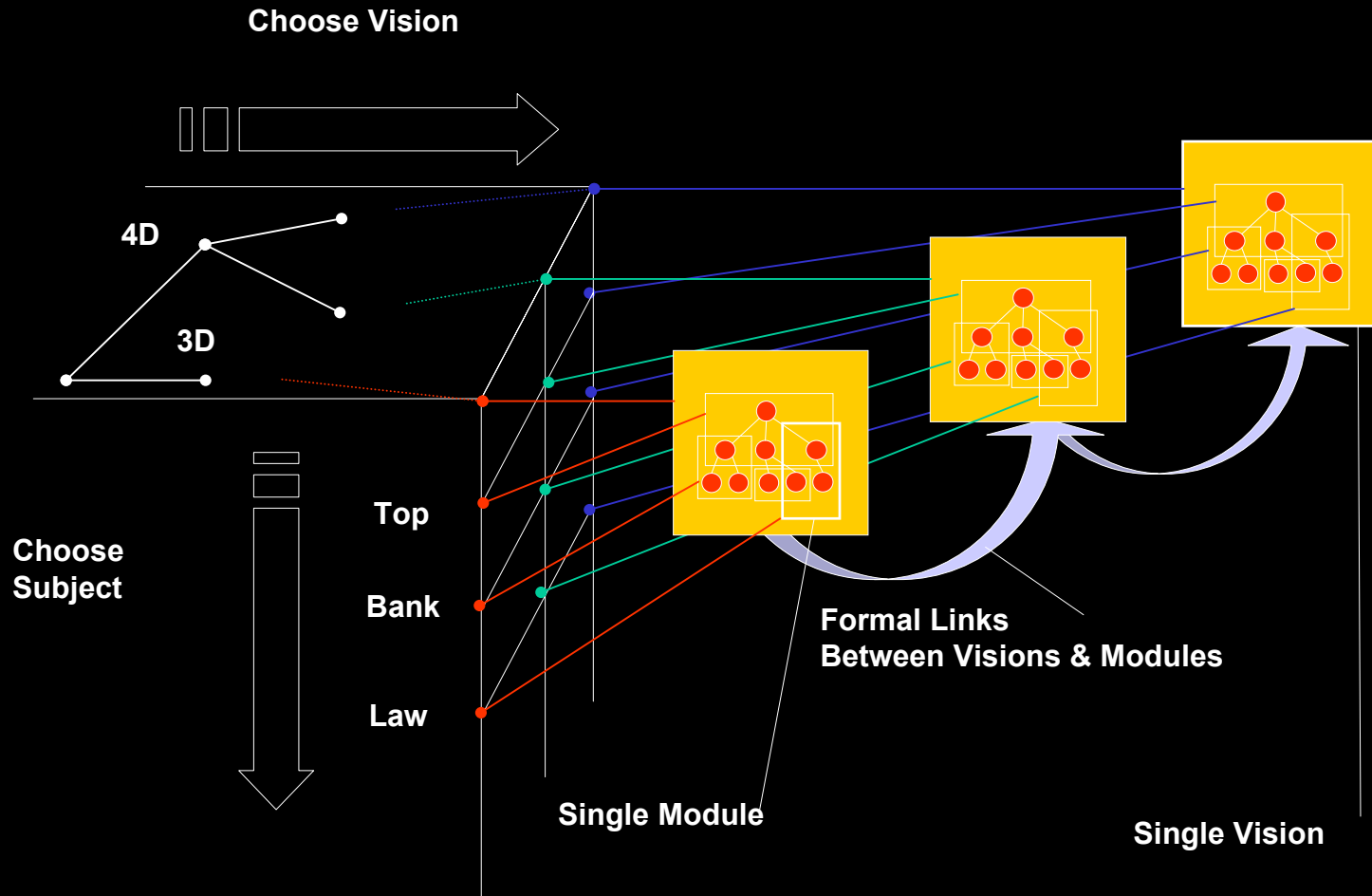
DOLCE: *a Descriptive Ontology for Linguistic and Cognitive Engineering*

- A first reference module for the Foundational Ontology Library
- Strong **cognitive bias** influenced by
  - Perception
  - Culture
  - Social conventions
- Rich axiomatization
- Categories as *conceptual containers*: no "deep" metaphysical implications

DOLCE's basic taxonomy

ndurant

    Physical

        Amount of matter
        Physical object
        Feature

    Non-Physical

        Mental object
        Social object

    …

erdurant

    Static

        State
        Process

    Dynamic

        Achievement
        Accomplishment

uality

    Physical

        Spatial location

        …

    Temporal

        Temporal location

        …

    Abstract

bstract

    Quality region

        Time region
        Space region
        Color region

        …

    …

002

Abstract vs. Concrete Entities

- Concrete: located in space-time (regions of space-time are located in themselves)
- Abstract - two meanings:
  - Result of an abstraction process (something common to multiple exemplifications)
    - ✉ *Not located in space-time*

- Mereological sums (of concrete entities) are concrete, the corresponding sets are abstract...

Endurance vs. Perdurance

- **Endurants**:
  - All proper parts are present whenever they are present (*wholly presence,* no temporal parts)
  - Exist in time
  - Can genuinely change in time
  - Need a time-indexed parthood relation
- **Perdurants**:
  - Only some proper parts are present whenever they are present *(partial presence,* temporal parts *)*
  - Happen in time
  - Do not change in time
  - Do not need a time-indexed parthood relation

Qualities and qualia

- Linguistic evidence
  - *This rose is red*
  - *Red is a color*
  - *This rose has a color*
  - *The color of this rose turned to brown in one week*
  - *The room's temperature is increasing*
  - *Red is opposite to green and close to brown*

- Every entity comes with certain qualities that permanently *inhere* to it and are *unique* of it
- Qualities are perceptually mapped into *qualia,* which are regions of *quality spaces*.
- Properties hold because qualities have certain locations in their quality spaces.
- Each *quality type* has its own quality space

Qualities

The rose and the chair have *the same color*:
- different color qualities inhere to the two objects
- they are located in the same quality region

Therefore,the same color attribute (red) is ascribed to the two
objects

Qualities

Quality attribution

Quality

Quality space

Rose   Red-obj

Color

Color-space

Has-part

Red-region

q-location

Has-part

Rose1   Color of rose1   Red421

Inheres

Has-quale
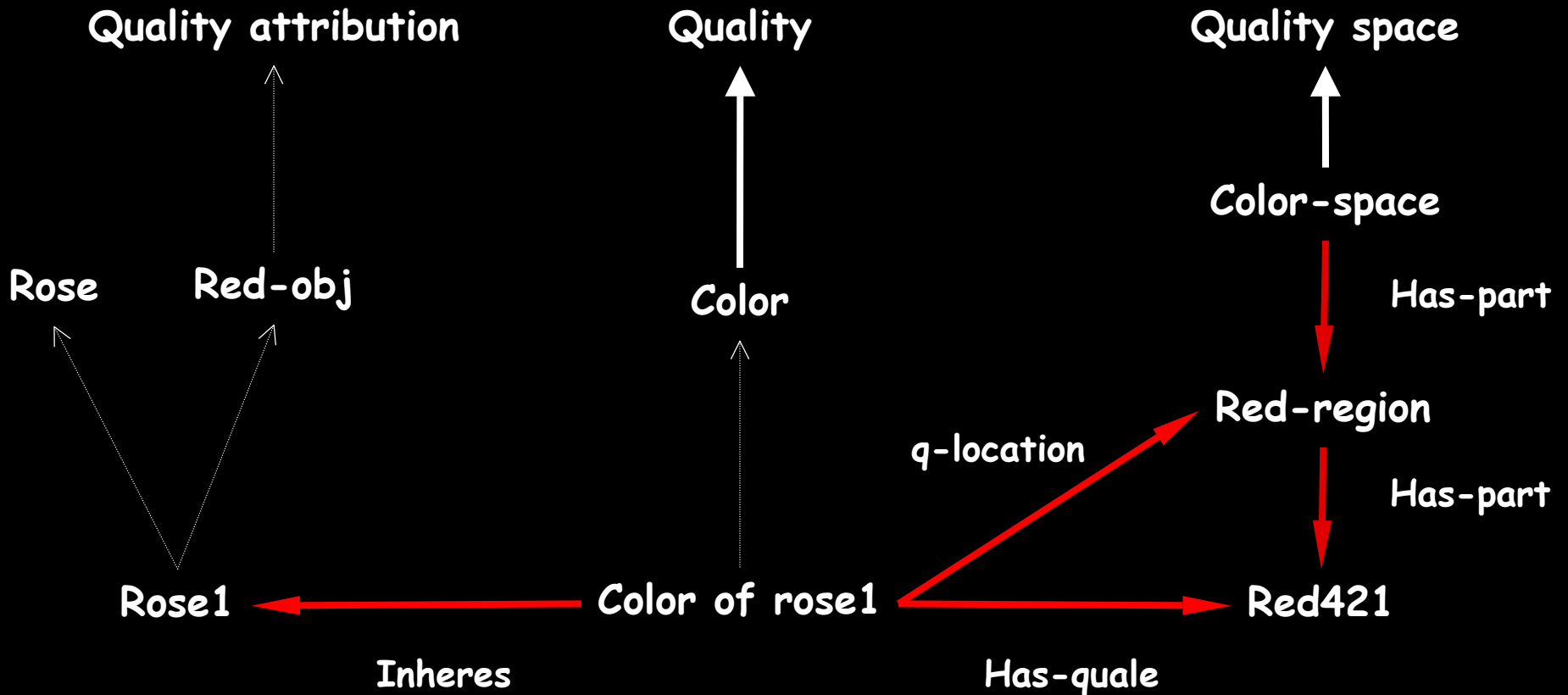
Aggregate vs. *Object*

- Both are *enduring* entities
- An object has a unity criterion, while an aggregate does not.

Physical vs. *Non-physical Object*

FIAT SpA

• Physical objects:
  – *inherent spatial localization*
  – *not dependent* on other objects (**physical objects, like cars**) or no inherent localization and be dependent on *agents* (**non-physical objects, like laws and institutions**).
•Non-physical objects can also be divided into *mental* (depending on *singular* agents) and *social* (depending on *communities* of agents).

Features

- **Features** are "parasitic" entities, that exist insofar their host exists.
- Features may be **relevant parts** of their host, or **places** (which are not parts of their hosts).
- All features are essential wholes, but no common unity criterion may exist for all of them (*U).

Abstracts

- **Abstracts** are entities that have no inherent spatial or temporal localization. Examples of **Abstract** are *propositions*, *sets*, *symbols*, *regions*, etc.
- *Quality regions* and *quality spaces* are relevant examples of abstract entities
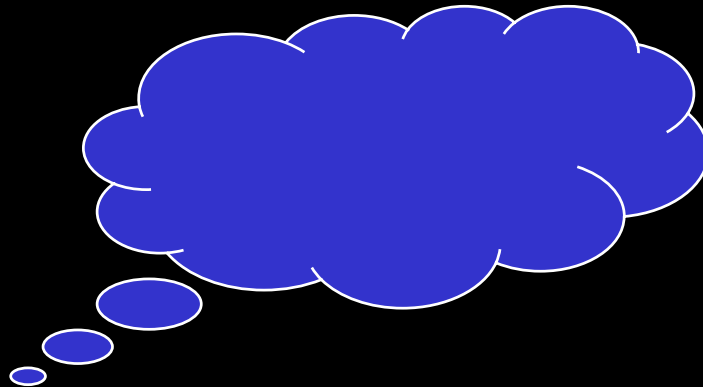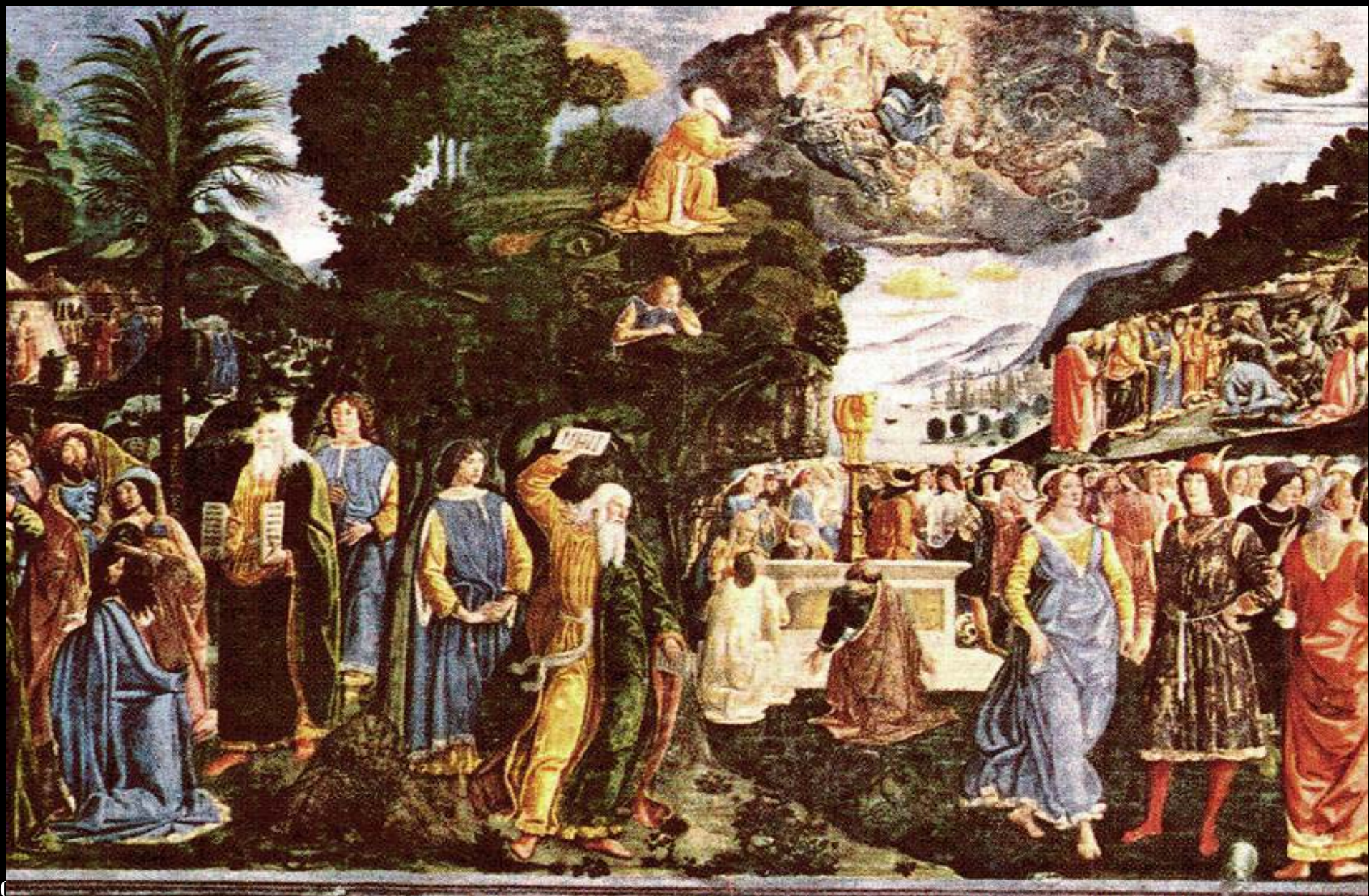
Figure Conventions

Given an entity x to be characterised as $D(x)$, its properties are written with the following compact syntax (in the 'attribute' slot of the next UML class diagrams):

- C $\qquad\qquad$ $\forall x\, D(x) \rightarrow C(x)$

- $NOT(C)$ $\qquad\quad$ $\forall x\, D(x) \rightarrow \neg C(x)$

- $R{:}C$ $\qquad\qquad$ $\forall x\, D(x) \rightarrow \exists y\, R(x,y) \wedge C(y)$

- $[SOME|{=}|{>}|{<}]$ $\quad$ $\forall x\, D(x) \rightarrow \exists_{(n|{>}n|{<}n)}(y)\, R(x,y) \wedge C(y)$

- $[ALL]R{:}C$ $\qquad$ $\forall x,y\, D(x) \rightarrow R(x,y) \rightarrow C(y)$

- $NOT(R{:}C)$ $\qquad$ $\forall x\, D(x) \rightarrow \neg\exists y\, R(x,y) \wedge C(y)$

Endurant

Enduring
[SOME]ParticipatesIn:Occurrence
[SOME]MSpeCnstDep:Quality

Amount of Matter

MereoInvariant

Arbitrary Sum

Pseudo-constant
[SOME]Part:Object

Object

Essential Whole
Heterogeneous Unity

Feature

Essential Whole
Heterogeneous Unity
[SOME]Host:Object
[SOME]GenConstDep:Object

Physical Object

[SOME]HasQuality:SpatialLocation
NOT(HasQuality:TemporalLocation)
NOT(SpeConstDep:Object)
[ALL]HasQuality:Physical Q

Non-physical Object

NOT(HasQuality:SpatialLocation)
[SOME]GenConstDep:AgentiveObj
[ALL]HasQuality:Abstract Q

Relevant Part

[SOME]PartOf:*Host

Place

NOT(PartOf:*Host)

Non-Agentive PhyObj

[SOME]GenKBy:AmountOfMat

Agentive PhyObj

[SOME]GenKBy:NonAgentPhyObj

Mental Object

[=1]SpeConstDep:AgentPhyObj

Social Object

[SOME]GenConstDep:Community

Physical Body

MereoInvariant

Ordinary Object

MereoVariable

Agentive SocObj

IntentionCarrier

Non-agentive SocObj

NOT(IntentionCarrier)

Community

[SOME]GenKBy:SocialAgent

Social Agent

[SOME]GenConstDep:AgentPhyObj

Endurants

Endurant

Enduring
[SOME]ParticipatesIn:Occurrence
[SOME]MSpeCnstDep:Quality

Amount of Matter

MereoInvariant

Arbitrary Sum

Pseudo-constant
[SOME]Part:Object

Object

Essential Whole
Heterogeneous Unity

Feature

Essential Whole
Heterogeneous Unity
[SOME]Host:Object
[SOME]GenConstDep:Object

Physical Object

[SOME]HasQuality:SpatialLocation
NOT(HasQuality:TemporalLocation)
NOT(SpeConstDep:Object)
[ALL]HasQuality:Physical Q

Non-physical Object

NOT(HasQuality:SpatialLocation)
[SOME]GenConstDep:AgentiveObj
[ALL]HasQuality:Abstract Q

Relevant Part

[SOME]PartOf:*Host

Place

NOT(PartOf:*Host)

Non-Agentive PhyObj

[SOME]GenKBy:AmountOfMat

Agentive PhyObj

[SOME]GenKBy:NonAgentPhyObj

Mental Object

[=1]SpeConstDep:AgentPhyObj

Social Object

[SOME]GenConstDep:Community

Physical Body

MereoInvariant

Ordinary Object

MereoVariable

Agentive SocObj

IntentionCarrier

Non-agentive SocObj

NOT(IntentionCarrier)

Community

[SOME]GenKBy:SocialAgent

Social Agent

[SOME]GenConstDep:AgentPhyObj

002

Perdurants

Perdurant/Occurrence

Perduring
[SOME]Participant:Endurant
[SOME]HasQuality:TemporalLocation
NOT(HasQuality:SpatialLocation)
[ALL]TemporalPart:Occurrence
[ALL]SpatialPart:Occurrence

State

Homeomeric

Process

Weakly-Homeomeric

Accomplishment

NOT(Homeomeric)

Non-Relational S	**Relational S**	**Activity**	**Phenomenon**
[=1]Participant:Endurant	[>1]Participant:Endurant	[SOME]GenConstDep:AgentiveObj	[SOME]SpeConstDep:Endurant

Qualities

Quality

[SOME]MSpeCnstDep:Entity
[SOME]InheresIn:Entity
[SOME]Quale:Region
[ALL]HasQuality:Quality
NOT(HasPart:Entity)

Temporal Q

[ALL]HasQuality:Temporal Q

Physical Q

[ALL]HasQuality:Physical Q

Abstract Q

[ALL]HasQuality:Abstract Q

Temporal Location

Spatial Location

Aesthetic Location

Abstracts

Abstract

NOT(ConstDep:Entity)
NOT(HasQuality:Location)
[ALL]Part:Abstract

Fact

Set

Region

[ALL]Part:Region
NOT(PresentAt:TimeInt)

Temporal Region

[ALL]Part:TemporalRegion

Abstract Region

[ALL]Part:AbstractRegion

Time Interval

Physical Region

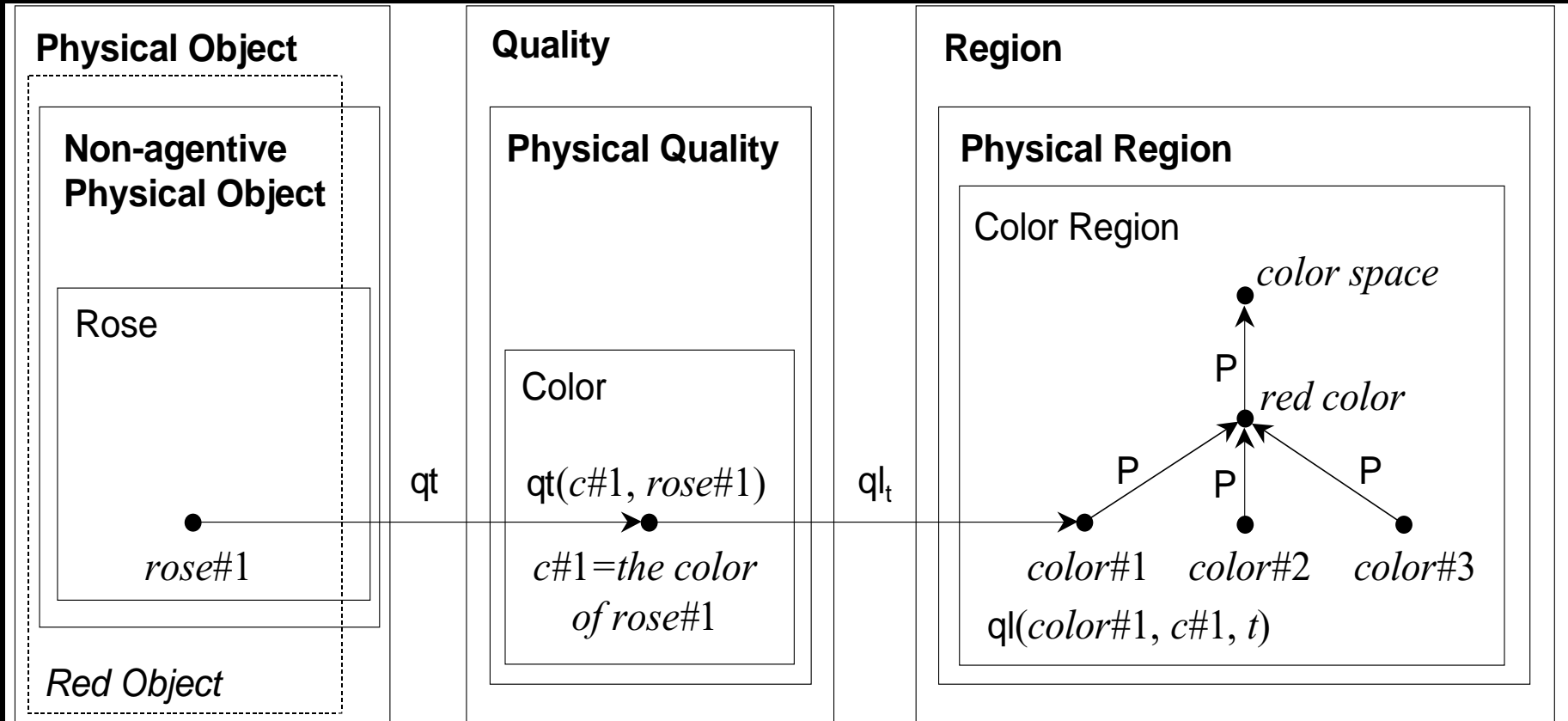[ALL]Part:PhysicalRegion
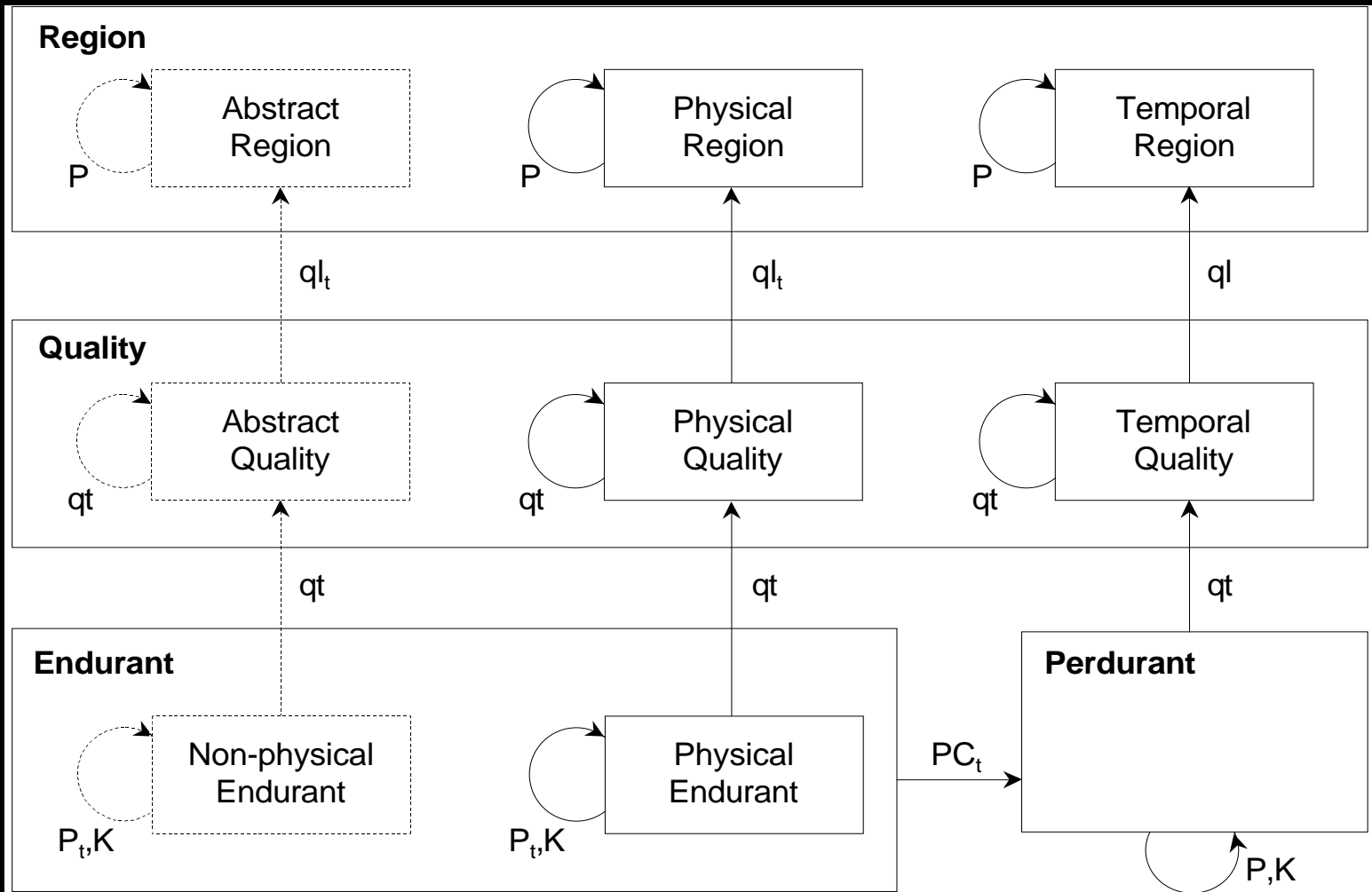
Aesthetic Region

Space Region

Basic Relations

- Parthood
  - Between quality regions (immediate)
  - Between arbitrary objects (temporary)
- Dependence
  - Specific/generic constant dependence
- Constitution
- Inherence (between a quality and its host)
- Quale
  - Between a quality and its region (immediate, for unchanging ent)
  - Between a quality and its region (temporary, for changing ent)
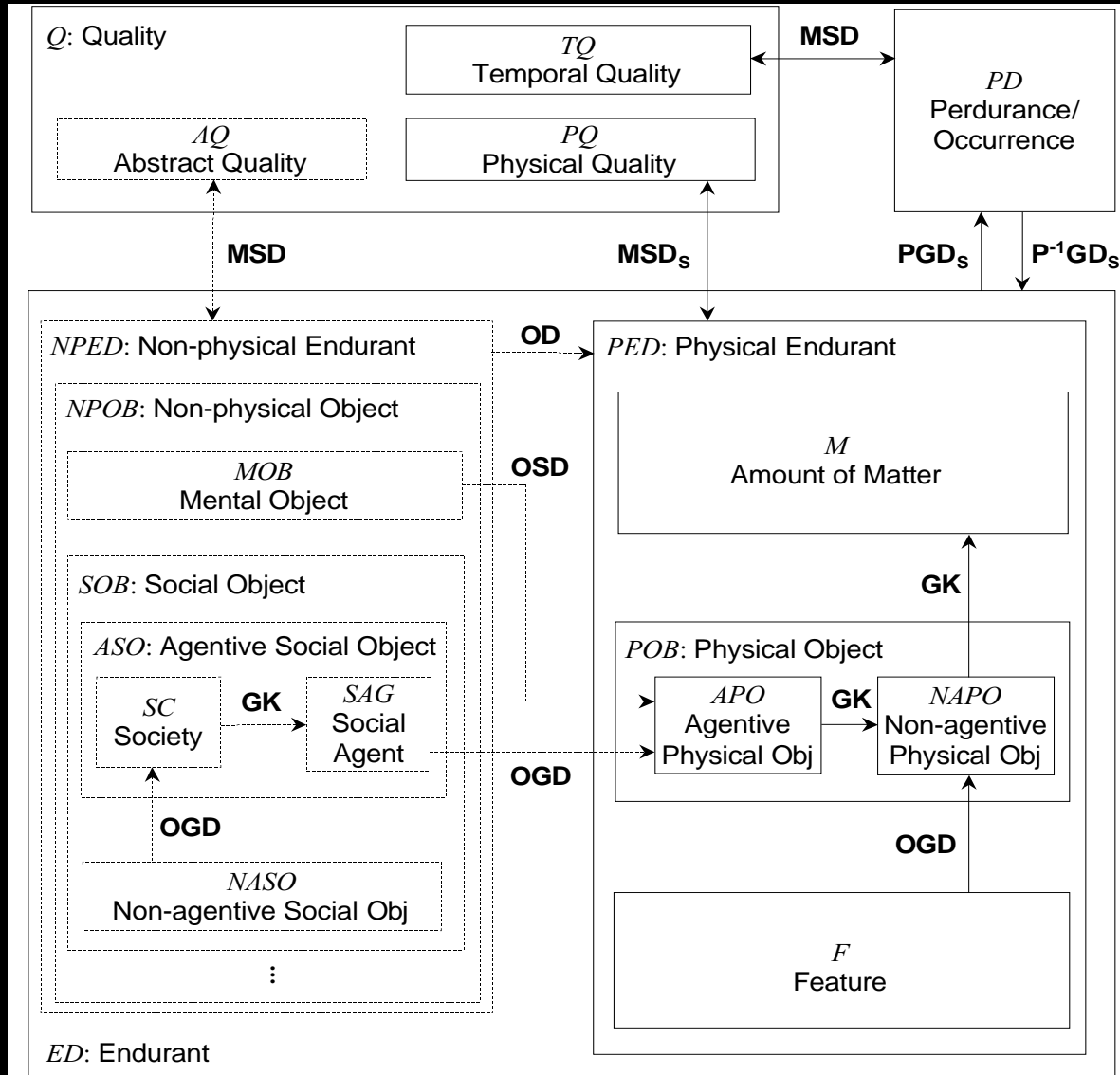- Participation
- Representation

Quality relations

Physical Object

Non-agentive Physical Object

Rose

$rose\#1$

Red Object

qt

Quality

Physical Quality

Color

qt($c\#1$, $rose\#1$)

$c\#1=the\ color$
$of\ rose\#1$

ql_t

Region

Physical Region

Color Region

color space

P

red color

P   P   P

$color\#1$ $color\#2$ $color\#3$

ql($color\#1$, $c\#1$, t)

Primitive relations and basic categories

Dependence relations

Participation relations

- Hold between a perdurant and its involved endurants
- Extremely relevant for domain modelling
- Current axiomatization covers:
  - constant vs. temporary
  - complete vs. partial
- Further distinctions are currently primitive (thematic roles)
  - *Agent, Theme, Substrate, Instrument, Product*
  - More is needed on event structure, intentionality, and artifacts to produce analytic definitions

Representation relations

- Ongoing axiomatization (semiotics ontology)
- Extremely relevant for domain modelling
- Concepts
  - PhysicalRepresentation vs. Expression
  - Expression vs. Content
  - Content vs. Reference
- Relations
  - *Realization, Interpretant, Reference, Description*
- Non-trivial dependences between **use** and **instantiation** of expressions and contents

Axiomatizing basic relations

- Ground axioms (mainly algebraic)
- Links to other relations
- Dependence on time
- FO Modal Theory (S5+Barcan)

- WonderWeb D17 v.2 for details

KIF example with PW

- P(w,x,y) = "x is part of y in the possible world w"
- P(w,x,y,t) = "x is part of y at time t in the possible world w"

```
; O(x, y) =df ∃z(P(z, x) ∧ P(z, y))  (Overlap)
(defrelation O (?w0 ?x ?y) :=
 (and (ENTITY ?x)
    (ENTITY ?y)
    (WORLD ?w0)
    (exists (?z) (and (ENTITY ?z)
             (P ?w0 ?z ?x)
             (P ?w0 ?z ?y)))))
```

Q&A for drafting the concepts

- (are the parts of the entities you're talking about all present whenever such entities are present?)
  - Yes
  → *Endurant*
- (can you count these entities?)
  - uncertain
- (do they resemble a definite object rather than an indefinite amount of matter?)
  - Yes
- (are these entities an undetachable part of something else?)
  - uncertain
  → *(Object ∨ Feature)*
- (for example, are they more like a table or like its edge?)
  - a table
- (can these entities exist independently of some agent that thinks, talks, or reason about them?)
  - uncertain
  → *Object*
- (are these entities constituted by matter?)
  - Yes
- (can these entities intend to do something, or believe, or desire something?)
  - No
- (ok, put your class in the <NonAgentivePhysicalObject> branching)

→ *PhysicalObject*

→ *NonAgentivePhysicalObject*

Some ongoing applications

- Ontology merging and building (e.g. fishery, bank norms)
- Catalogue creation/maintenance (e.g. portals)
- DB design and requirement analysis
- Behaviour description and detection
  - Quality/anomaly assessment from legacy DBs (money-laundering procedures)
  - Quality/anomaly assessment of runtime operations (service level agreement)