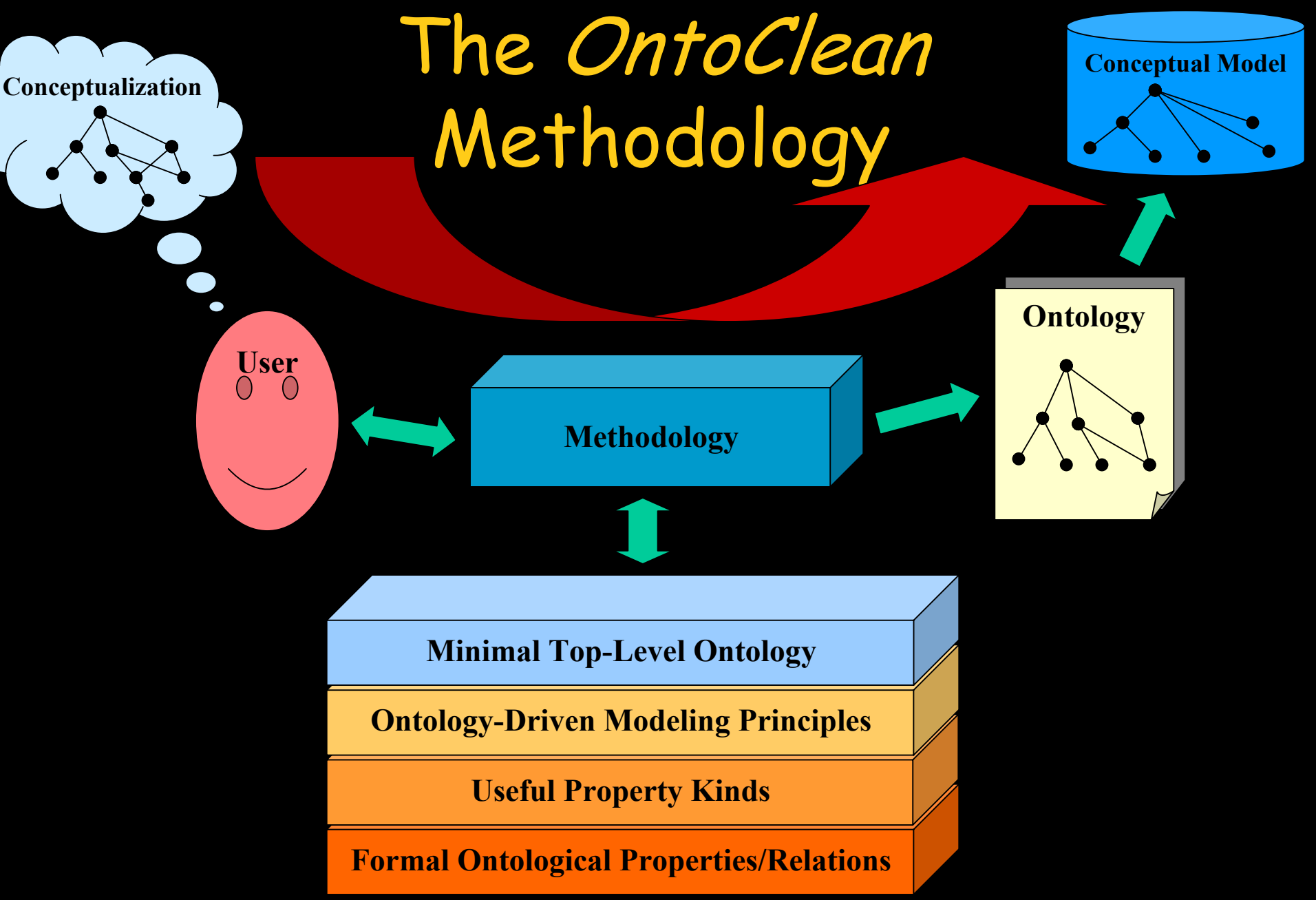
An Interdisciplinary Approach

- A *Unified Ontology-driven Modeling Methodology* for databases, knowledge bases and OO-systems
  - *Grounded* in reality
  - *Transparent* to people
  - *Rigorous*
  - *General*
- Based on
  - *Logic*
  - *Philosophy*
  - *Linguistics*

The *OntoClean* Methodology



Formal Ontology

- Theory of *formal distinctions and connections* within:
  - entities of the world, as we perceive it (*particulars*)
  - categories we use to talk about such entities (*universals*)
- Why *formal?*
  - Two meanings: *rigorous* and *general*
  - Formal logic: connections between truths - neutral wrt *truth*
  - Formal ontology: connections between things - neutral wrt *reality*
- *Goal: characterizing* particulars and universals by means of formal properties and relations.

The role of formal relations

- *Formal relations*
  - only depend on their relata
  - apply to multiple subdomains
- *Material relations*
  - Imply the existence of something besides the relata
  - Are specific of a few subdomains
- Role of formal relations
  - Formulate *general constraints* on the domain
  - Induce distinctions among entities that impose a a general structure on the domain.

Formal Ontological Analysis

- Theory of Parts
- Theory of Wholes
- Theory of Essence and Identity
- Theory of Dependence
- Theory of Qualities
- Theory of Composition and Constitution

Mereology

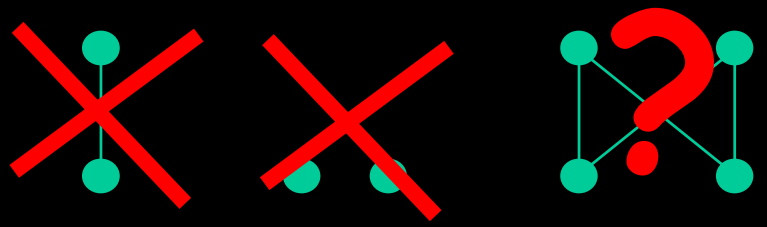
- Primitive: ***proper part-of*** relation (PP)
  - asymmetric
  - transitive
  - $Pxy =_{def} PPxy \vee x=y$
- Axioms:

upplementation: $PPxy \rightarrow \exists z\,(PPzy \wedge \neg\, z=x)$

rinciple of sum: $\exists z\,(PPxz \wedge PPyz \wedge \neg\, \exists\, w(PPwz \wedge \neg\,(Pwx \vee Pwy)))$

xtensionality: $x = y \leftrightarrow (Pwx \leftrightarrow Pwy)$

Excluded models:



Extensionality and mereological invariance

Extensionality: whenever the parts exist, *x* exists (*the whole is always the sum of its parts*)

Mereological invariance: *x* *always keeps its parts*

Examples of extensional entities:

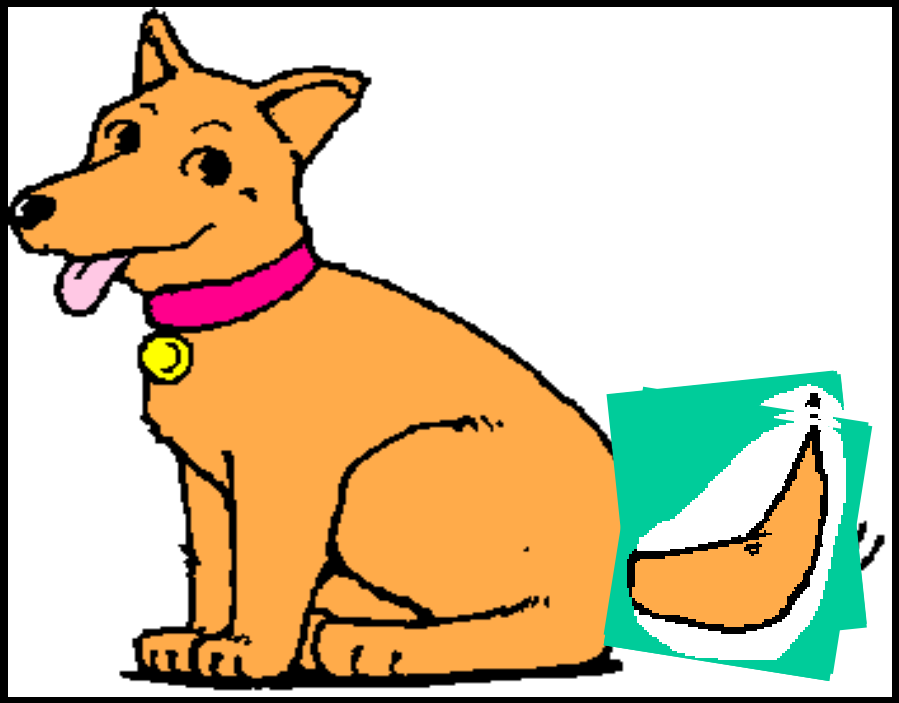
- Amounts of matter
- Regions
- Pluralities (pseudo-extensionality)

Mereologically invariant (but non-extensional) entities:

- A physical body (a lump of matter)

Identity and Unity

- Identity: is this my dog?
- Unity: is the collar part of my dog?



Unity

- A tentative formulation: *x* ***is a whole*** under ω iff ω is an *equivalence relation* that binds together all the parts of *x*, such that

$$P(y,x) \rightarrow (P(z,x) \leftrightarrow \omega(y,z))$$

but not

$$\omega(y,z) \leftrightarrow \exists x(P(y,x) \wedge P(z,x))$$

- P is the ***part-of*** relation
- ω can be seen as a ***generalized indirect connection***

Unity Refined

$\delta_R(x) =_{df} R(x, x)$

$\upsilon_R(x) =_{df} \Sigma_{\delta R}(x) \wedge \forall y,z((\delta_R(y) \wedge \delta_R(z) \wedge P(y, x) \wedge P(z, x)) \rightarrow R(y, z))$ (*x is unified by R*)

$\omega_R(x) =_{df} Max_{\upsilon R}(x)$ (*x is a whole under R*)

$\Sigma_\phi(x) =_{df} \forall y(P(y, x) \rightarrow \exists z(\phi(z) \wedge P(z, x) \wedge O(z, y)$ (*sum of* ϕ*s*

Kinds of Whole

- Depending on the ***nature of*** ω, we can distinguish:
  - ***Topological wholes*** (a piece of coal, a lump of coal)
  - ***Morphological wholes*** (a constellation)
  - ***Functional wholes*** (a hammer, a bikini)
  - ***Social wholes*** (a population)

* a whole can have ***parts that are themselves wholes*** (with a different ω)

Parts vs. components

- A proper part is a ***component*** iff it is a whole
- We can have topological components, morphological components, functional components….

Unity and Plurality

- Ordinary objects: ***wholes or sums of wholes***
  - Singular: ***no wholes as proper parts***
  - Plural: ***sums of wholes*** with a common unity condition
    - *Plural wholes* (the sum is ***also a whole***)
    - *Collections* (the sum is not a whole)
      - ***Members* of collections are special parts!**
- "Fiat" objects: everything else
- Role of *topological wholes* in perception (ordinary *things*)

Unity Disjointness Constraint

Properties with incompatible UCs are ***disjoint***

Essence and Rigidity

Certain entities have ***essential*** properties.
- John must have a brain.
- John must be a person.

Certain properties are essential to ***all*** their instances (compare ***being a person*** with ***having a brain***).

These properties are rigid - if an entity is ever an instance of a rigid property, it must always be.

Permanent vs. Essential Properties

- Being *always* a student
- Being *necessarily* a student

- Quantifying on *possibilia*

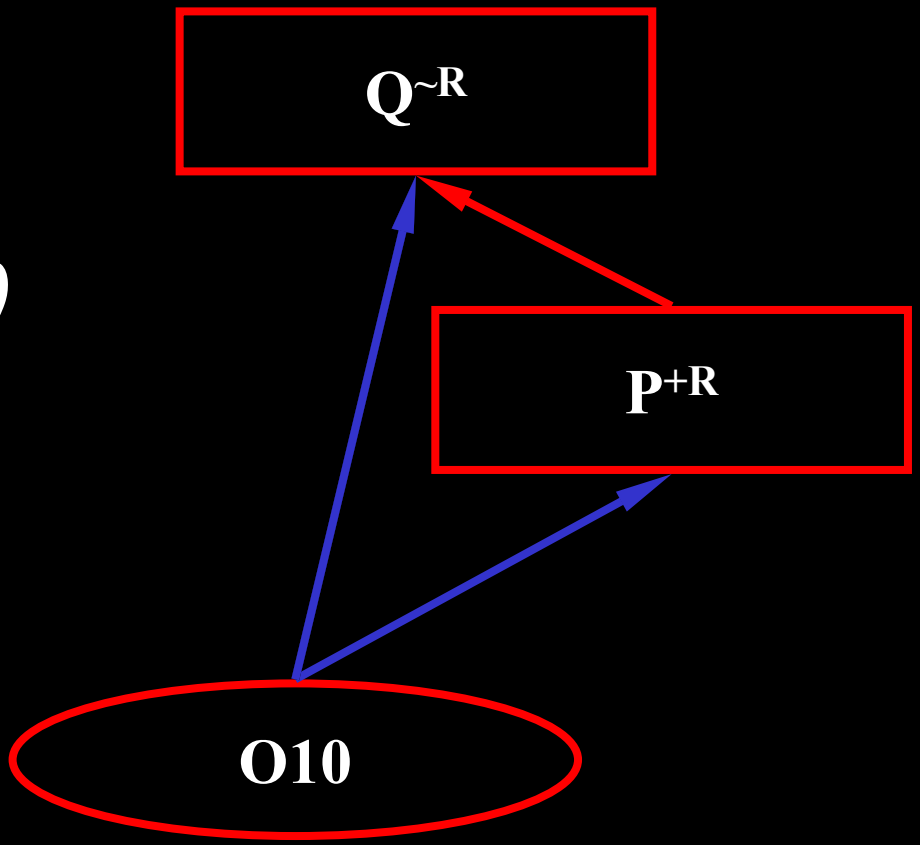
Formal Rigidity

- ϕ is rigid (+R): $\forall x \blacklozenge \phi(x) \rightarrow \blacksquare \phi(x)$
  - e.g. Person, Apple
- ϕ is non-rigid (-R): $\exists x \blacklozenge \phi(x) \wedge \neg \blacksquare \phi(x)$
  - e.g. Red, Male
- ϕ is anti-rigid (~R): $\forall x \blacklozenge \phi(x) \rightarrow \neg \blacksquare \phi(x)$
  - e.g. Student, Agent

Rigidity Constraint

$+R \not\subset {\sim}R$

- Why?
  - $\forall x P(x) \rightarrow Q(x)$



Identity as a *primitive* relation

Identity is a *primitive equivalence relation* that satisfies Leibniz's rule.

In general, ***identity can't be defined***.
What we can have are just ***informative constraints (identity criteria)***

...related to relevant ***classes*** of entities

...which are ultimately the result of ***our conceptualization*** of reality.

Synchronic Identity

- A plausible criterion:

  x and y are the same iff they have the same location

- Exceptions:
  - Immaterial objects (holes…)
  - Events (singing while taking a shower…)
  - Constituting entities (the statue's clay…)

Diachronic Identity

- It's hard, but terribly useful for commonsense
- Requires some notion of persistence
- In addition, the ***sameness*** (or continuity) of certain properties is required

Identity is not similarity!

- At different spatio/temporal locations, two things may be identical but not similar, and vice versa.
- Identity and similarity are ***different concepts.***
- Similarity may be seen as a generalization of geometrical ***congruence***
- Indiscernability of identicals (Leibniz's law) vs. identity of indiscernibles

Identity criteria

- *Classical formulation:*

$$\phi(x) \wedge \phi(y) \rightarrow (\rho(x,y) \leftrightarrow x = y)$$

- *Generalization:*

$$\phi(x,t) \wedge \phi(y,t') \rightarrow (\Gamma(x,y,t,t') \leftrightarrow x = y)$$

(synchronic: $t = t'$; diachronic: $t \neq t'$)

- In most cases, Γ is based on the *sameness* of certain *characteristic features*:

$$\Gamma(x,y,t,t') = \forall z\,(\chi(x,z,t) \wedge \chi(y,z,t'))$$

Heuristics for Identity

- Finding necessary *and* sufficient ICs for a given property may be ***very hard***.

- Heuristic 1: ***at least a sufficient IC***.
- Heuristic 2: ***some essential parts or qualities***
- Heuristic 3: ***some essential (non-rigid) properties***

Sortals and other properties

- **Sortals** (*horse, triangle, amount of matter, person, student...*)
  - Carry identity
  - Usually correspond to ***nouns***
  - High organizational utility
  - Main subclasses: ***types*** and ***roles***
- **Non-sortals** *(red, big, decomposable, eatable, dependent, singular...)*
  - No identity
  - Usually correspond to ***adjectives***
  - Span across different sortals
  - Limited organizational utility (but high semantic value)
- **Categories** *(universal, particular, event, substance...)*
  - No identity
  - Useful generalizations for sortals
  - Characterized by a set of (only necessary) formal properties
  - Good organizational utility

Local vs. Global ICs

- *Local* IC:

$$\phi(x, t) \wedge \phi(y, t) \rightarrow (\Gamma(x, y, t, t) \leftrightarrow x = y)$$

- *Global* IC:

$$\phi(x, t) \rightarrow (\Gamma(x, y, t, t) \leftrightarrow x = y)$$

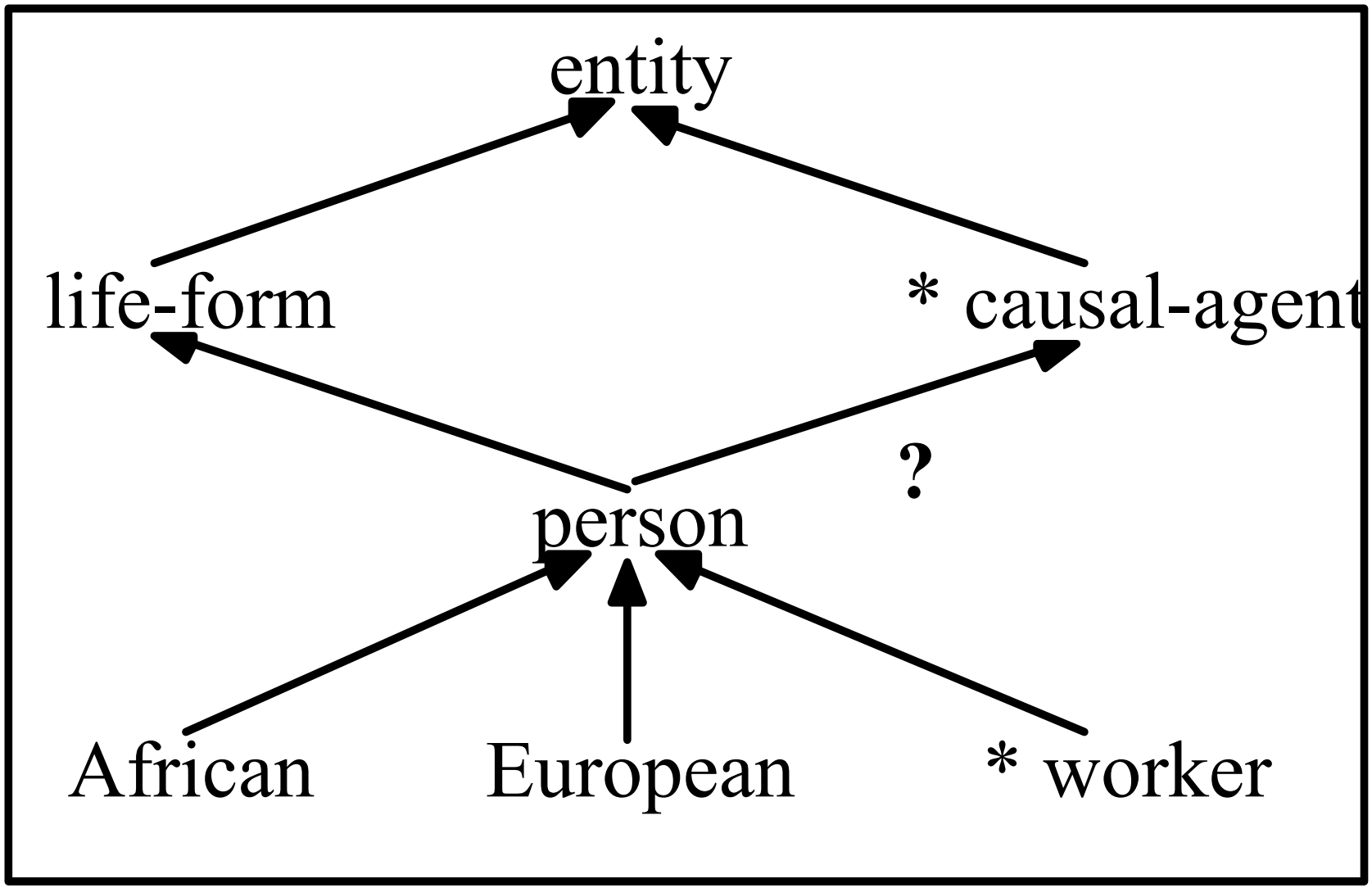
Carrying vs. Supplying Identity

- ***Supplying*** (global) identity (**+O**)
  - Having an IC (or essential property) that doesn't hold for a subsuming property
- ***Carrying*** identity (**+I**)
  - Not supplying identity, while being subsumed by a property that does.
- ***Common sortal principle***: x=y -> there is a common sortal supplying their identity
- Theorem: only rigid properties supply global identity

Sortal specialization

- ***Type*** specialization (e.g. Living being → Person)
  - New features (especially essential properties) ***affect identity***
  - Both necessary and sufficient ICs can be added while specializing types
    - Polygon: same edges, same angles
      - Triangle: two edges, one angle
    - Living being: same DNA, etc…?
      - Zebra: same stripes?
- ***Role*** specialization (e.g. Person → Student)
  - New features ***don't affect identity***

Types and Roles



Identity Disjointness Constraint

ICs impose ***constraints*** on sortals, making their ontological nature explicit:

Properties with incompatible ICs are ***disjoint***

Examples:

- sets vs. ordered sets
- persons and passengers
- amounts of matter vs. assemblies

Inheriting identity constraints

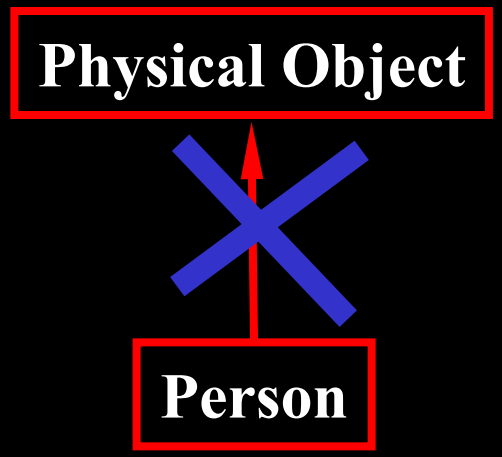
If P is rigid:

$$x \text{ is the same } P \text{ as } y \leftrightarrow x=y$$

x is the same P as y
every x is a Q

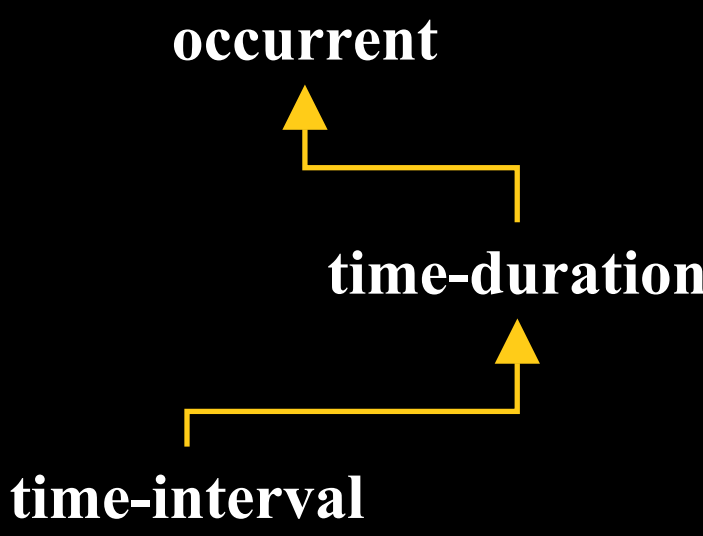
---

x is the same Q as y

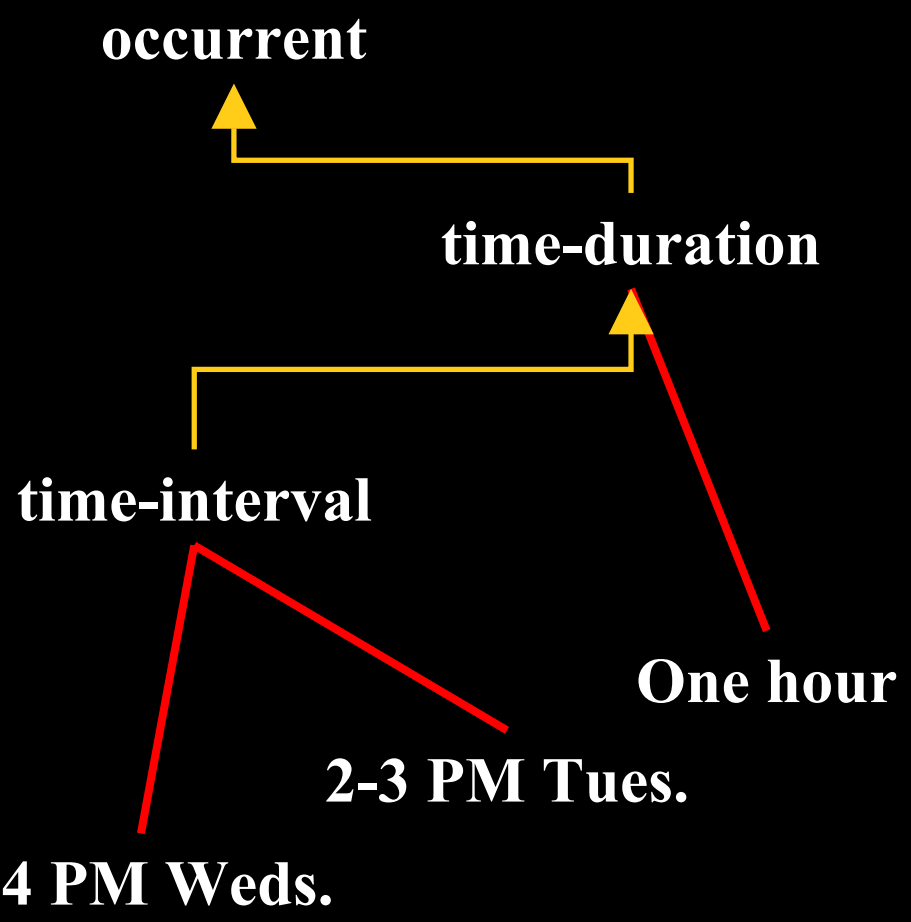


Example - Identity

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



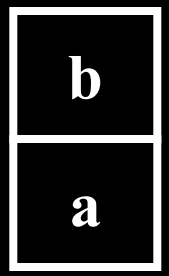
Example - Identity



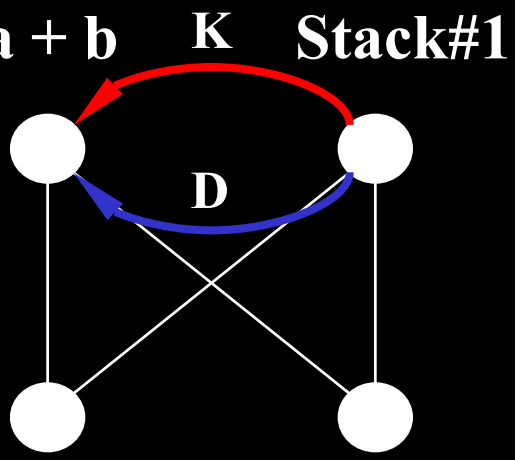
Part, Constitution, and Identity

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

a + b



Stack#1

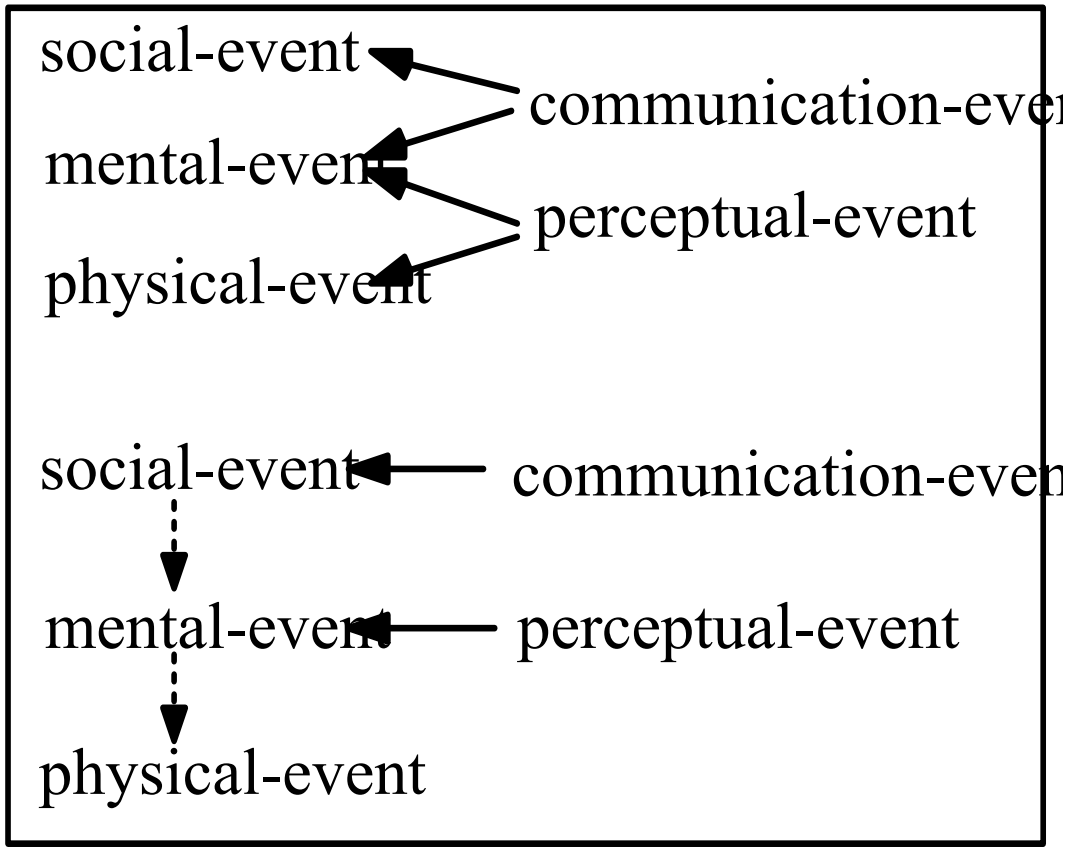


Ontological Levels and IC/UC Kinds

- Physical
  - Mereological *(an amount of matter, a collection)*
  - Topological *(a piece of matter)*
  - Morphological *(a cubic block, a constellation)*
- Functional *(a tool, a biological organ)*
- Biological *(a human body)*
- Cognitive/Intentional *(a person, a robot)*
- Social *(a company)*

- Correspond to different *kinds* of IC/UC
- All levels except the mereological one have *non-extensional* IC
- A *generic dependence* relation links higher levels to their immediate inferior.

How ontological levels simplify taxonomies



Why bother with this?

- ***Formal ontological analysis*** requires analyzing all properties according to their meta-properties – This is a ***lot*** of work!
- Why perform this analysis?
  - Makes ***modeling assumptions*** clear, which:
    - Helps resolving known conflicts
    - Helps recognizing unkown conflicts
  - Imposes ***constraints*** on standard modeling primitives (*generalization, aggregation, association*)
  - Elicits ***natural distinctions***
  - …results in more ***reusable ontologies***

Resolving Ontological Conflicts

- Two well-known ontologies define:
  - ***Physical Object is-a Amount of Matter*** (WordNet)
  - ***Amount of Matter is-a Physical Object*** (Pangloss)

Amount of Matter
- unstructured /scattered "stuff"
- Identity: mereologically extensional
- Unity: intrinsically none (anti-unity)

- Physical Object
  - Isolated material body
  - Identity - three options:
    - None
    - Non-extensional
    - Extensional
  - Unity: Topological

Conclusion: the two concepts are ***disjoint***. Physical objects are ***constituted*** by amounts of matter

Overloading Subsumption
Common modeling pitfalls

- Instantiation
- Constitution
- Composition
- Disjunction
- Polysemy

Taxonomic Constraints

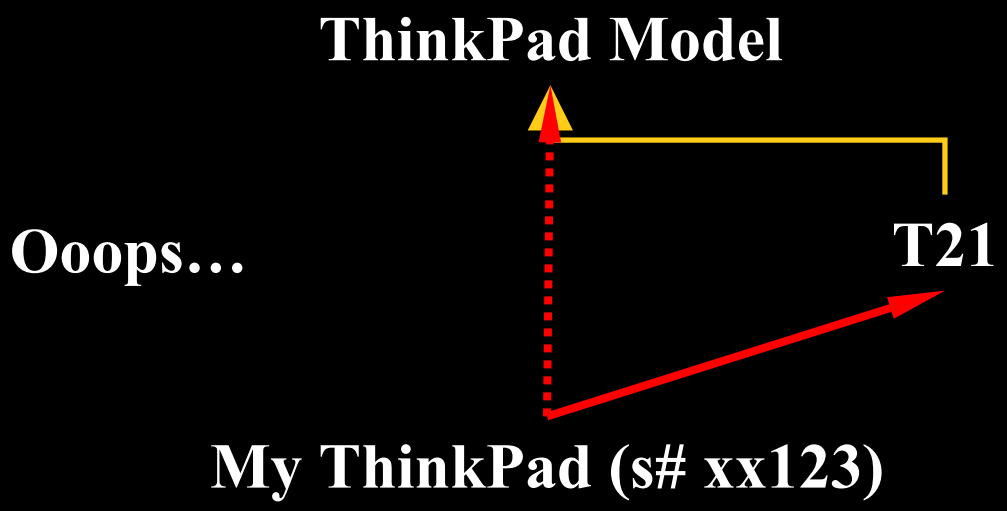
- $+R \not\subset \sim R$
- $-I \not\subset +I$
- $-U \not\subset +U$
- $+U \not\subset \sim U$
- $-D \not\subset +D$

- Incompatible IC's are disjoint
- Incompatible UC's are disjoint

- Categories subsume everything
- Roles can't subsume types

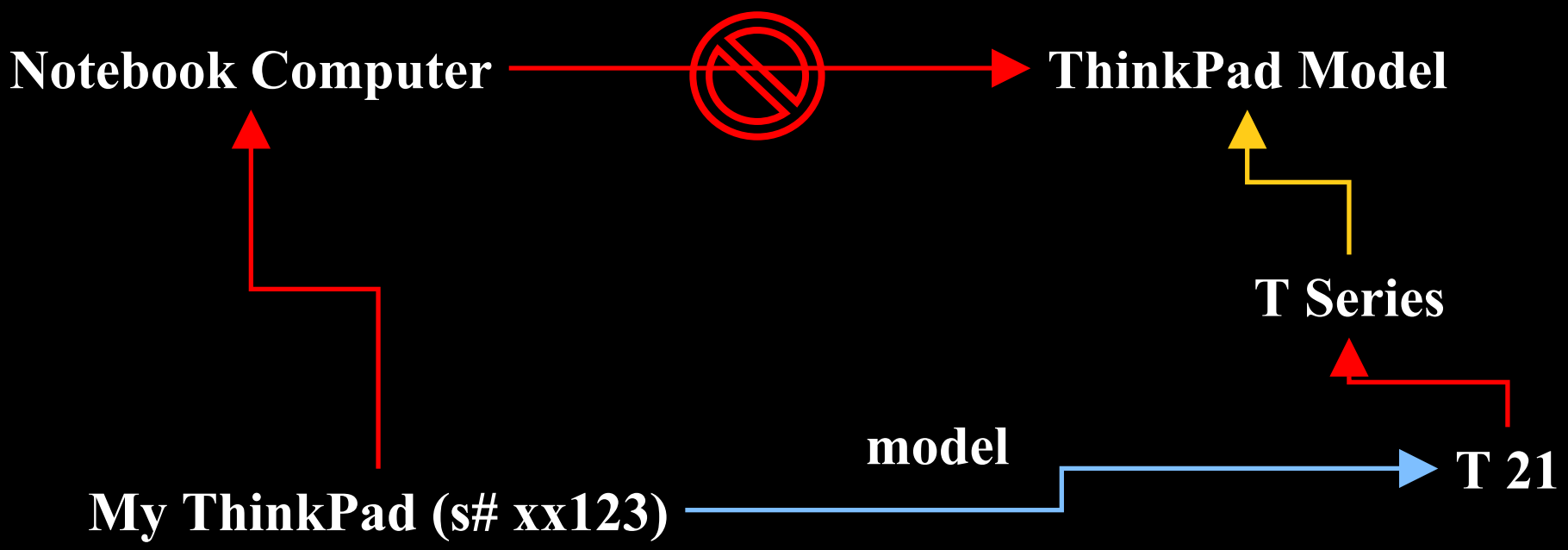
Instantiation (1)

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

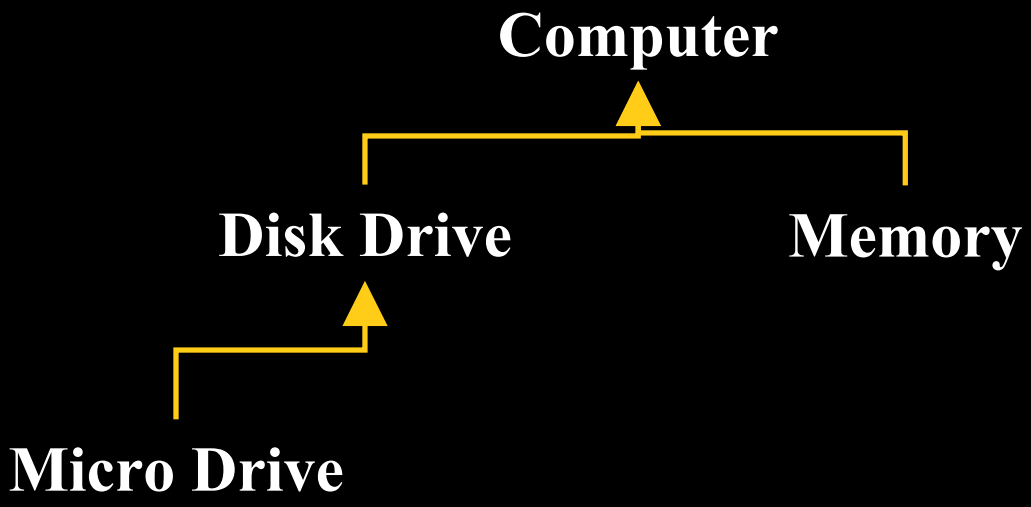


Question: What ThinkPad models do you sell?
Answer should NOT include My ThinkPad -- nor yours.

Instantiation (2)

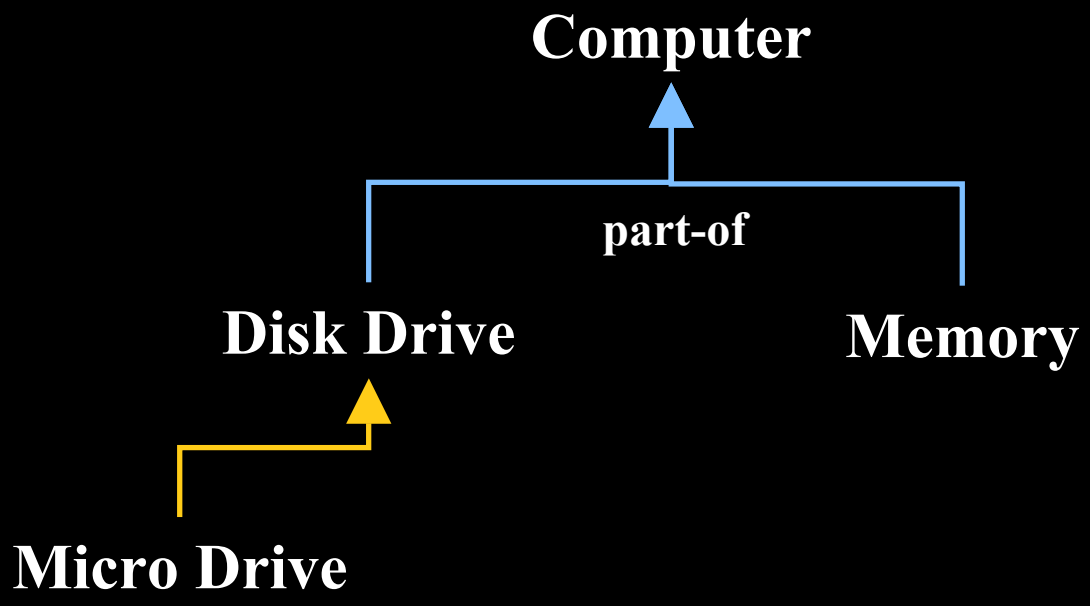


Composition (1)

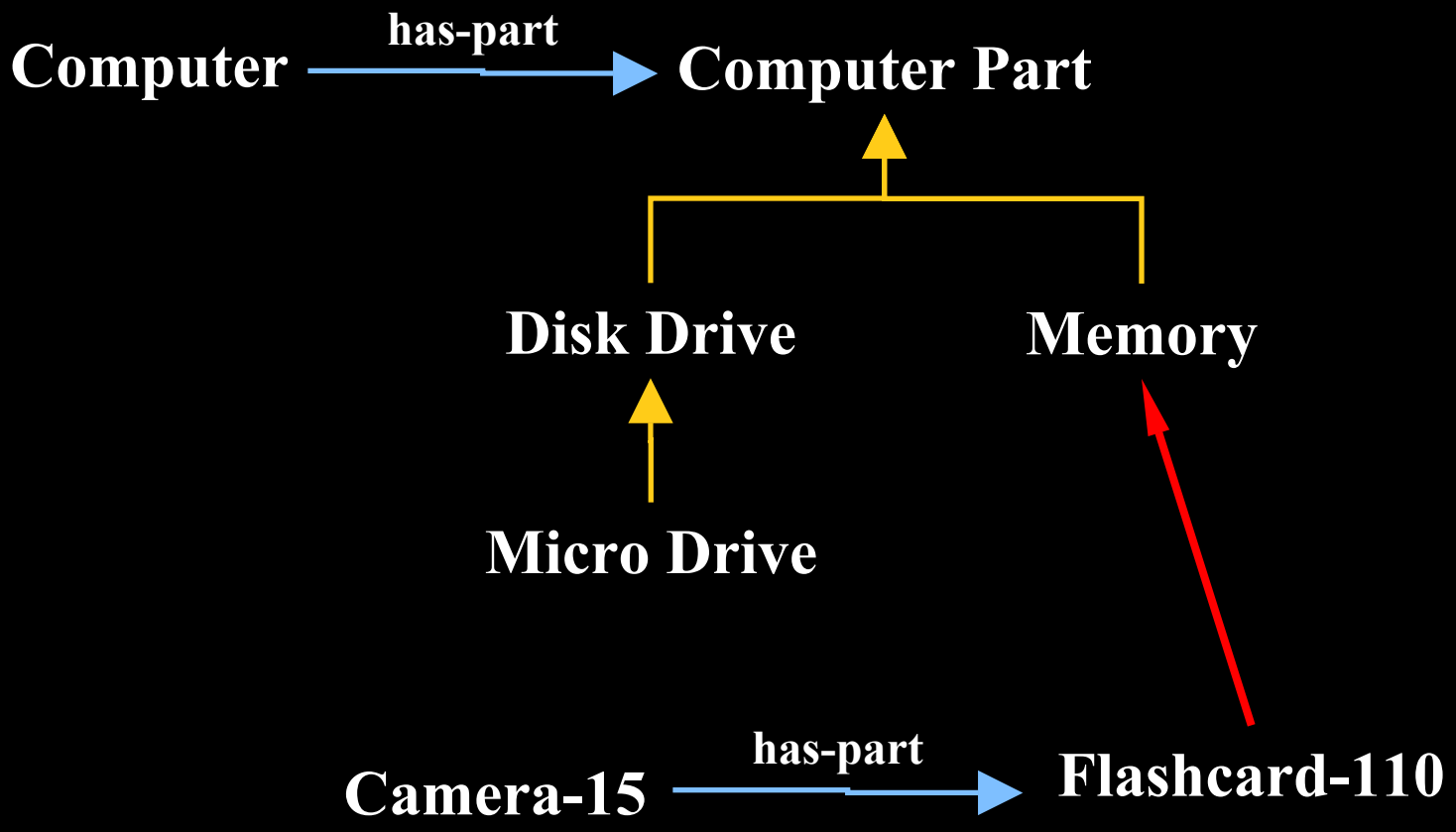


Question: What Computers do you sell?
Answer should NOT include Disk Drives or Memory.

Composition (2)



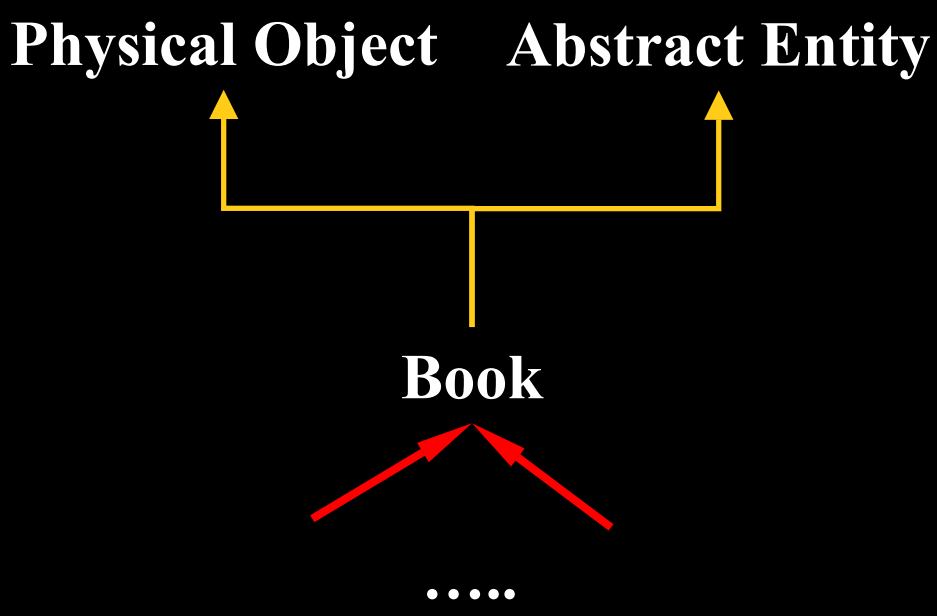
Disjunction (1)



Unintended model: flashcard-110 is a computer-part

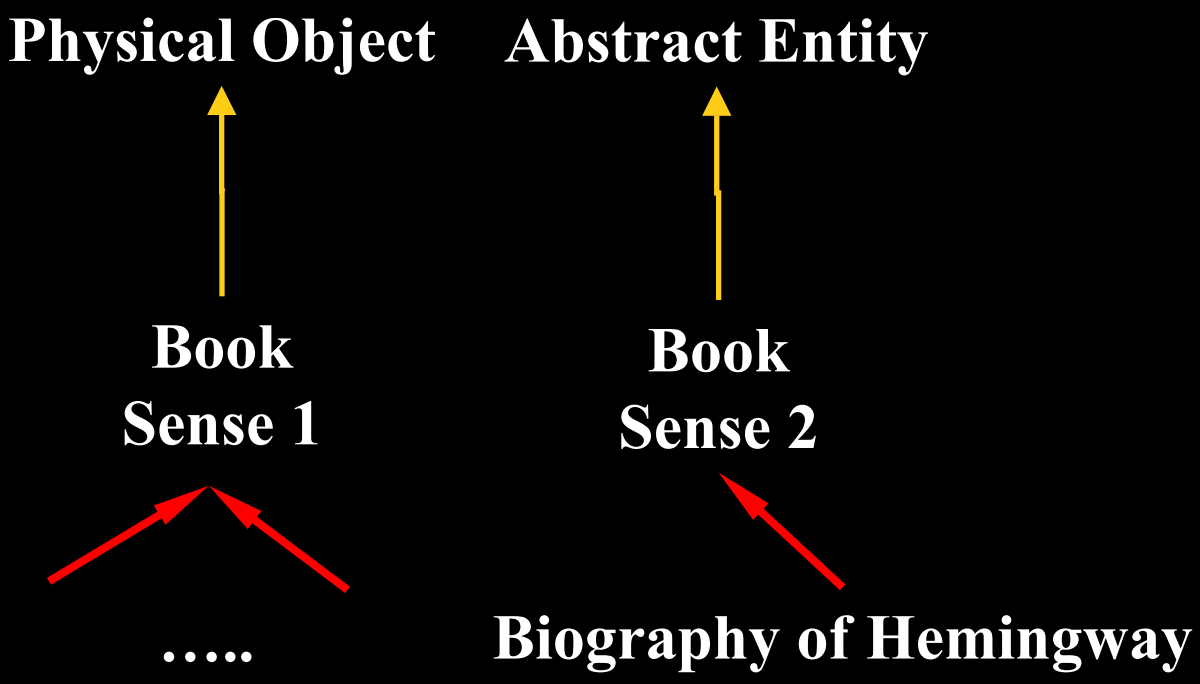
Disjunction (2)

Polysemy (1)
(Mikrokosmos)

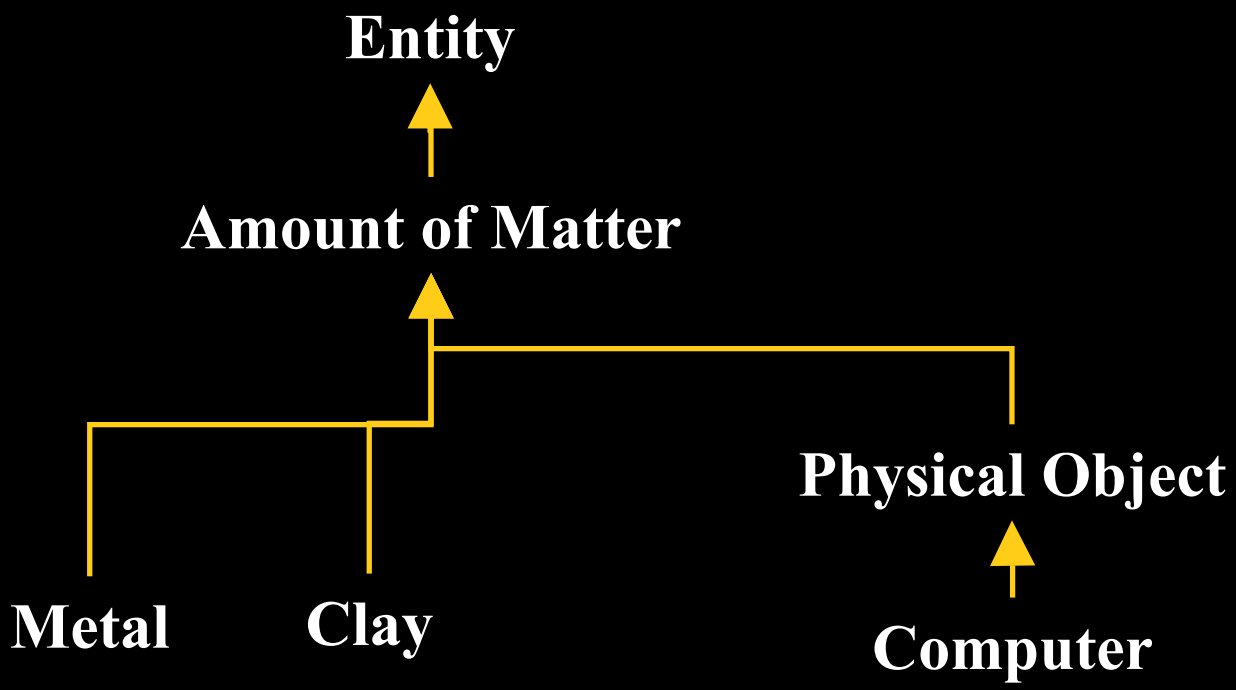


Question: How many books do you have on Hemingway?
Answer: 5,000

Polysemy (2)
(WordNet)

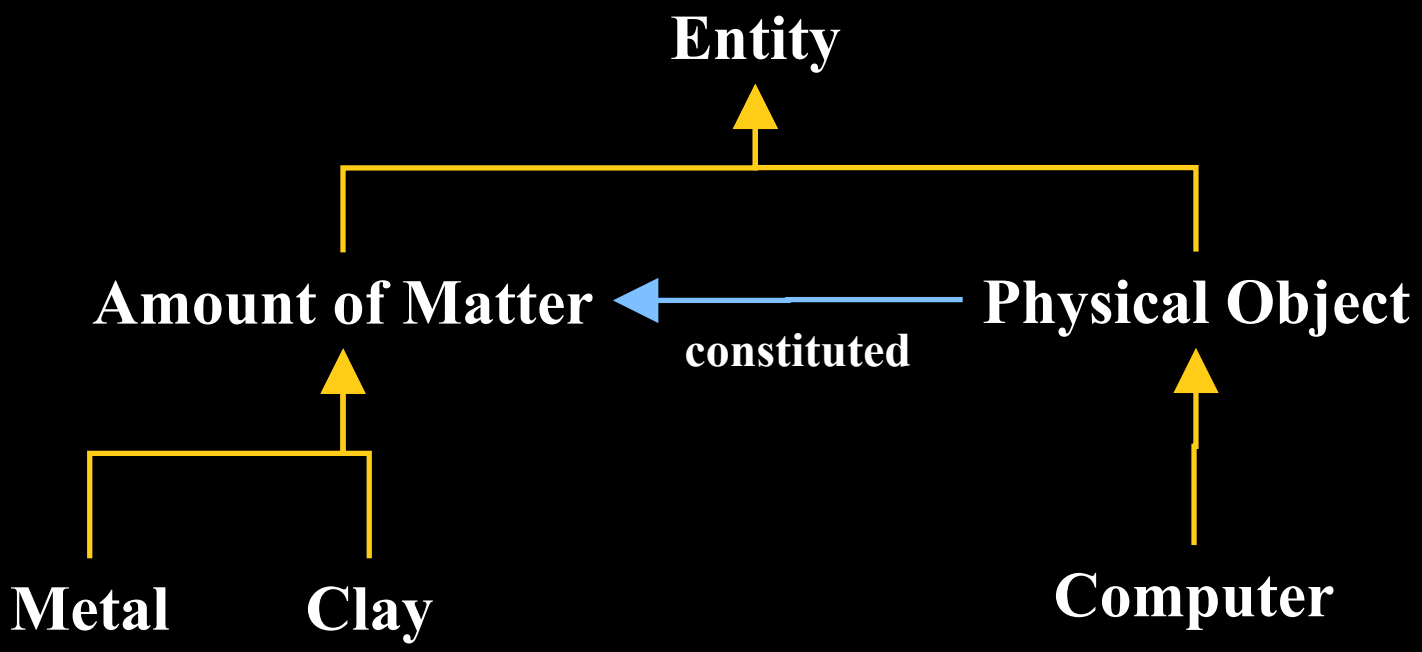


Constitution (1)
(WordNet)



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

Constitution (2)



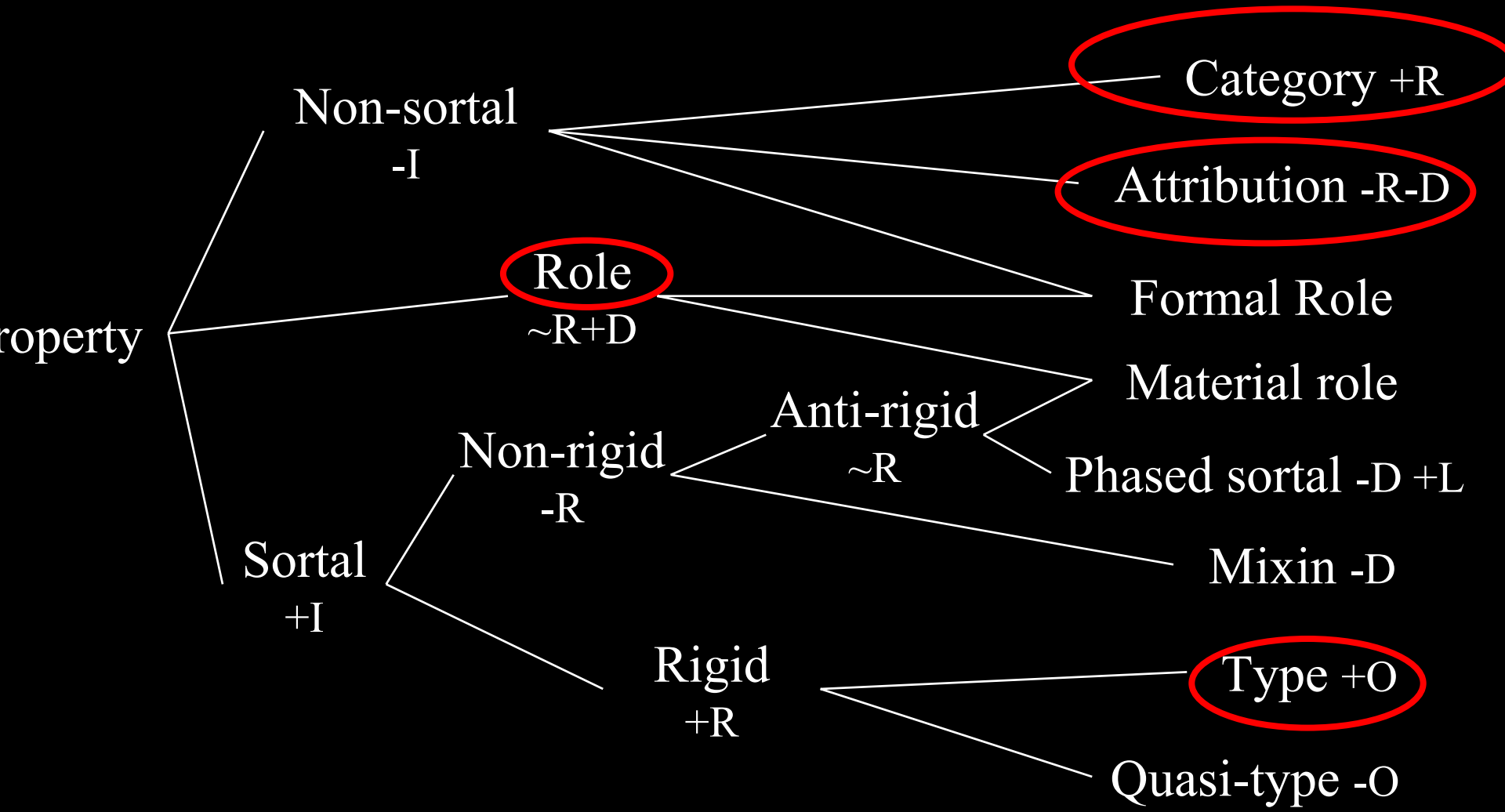
Property Dependence

- Does a property holding for x depend on something else besides x?
  - $P(x) \rightarrow \exists y\, Q(y)$
  - y should not be a part of x
- Example: Student/Teacher, customer/vendor

Basic Property Kinds Table

+	+	+	±	**Type**
-	+	+	±	**Quasi-type**
-	+	-	-	**Mixin**
-	+	~	+	**Mat. role**
-	+	~	-	**Phased sortal**
-	-	+	±	**Category**
-	-	~	+	**Formal role**
-	-	-	-	**Attribution**

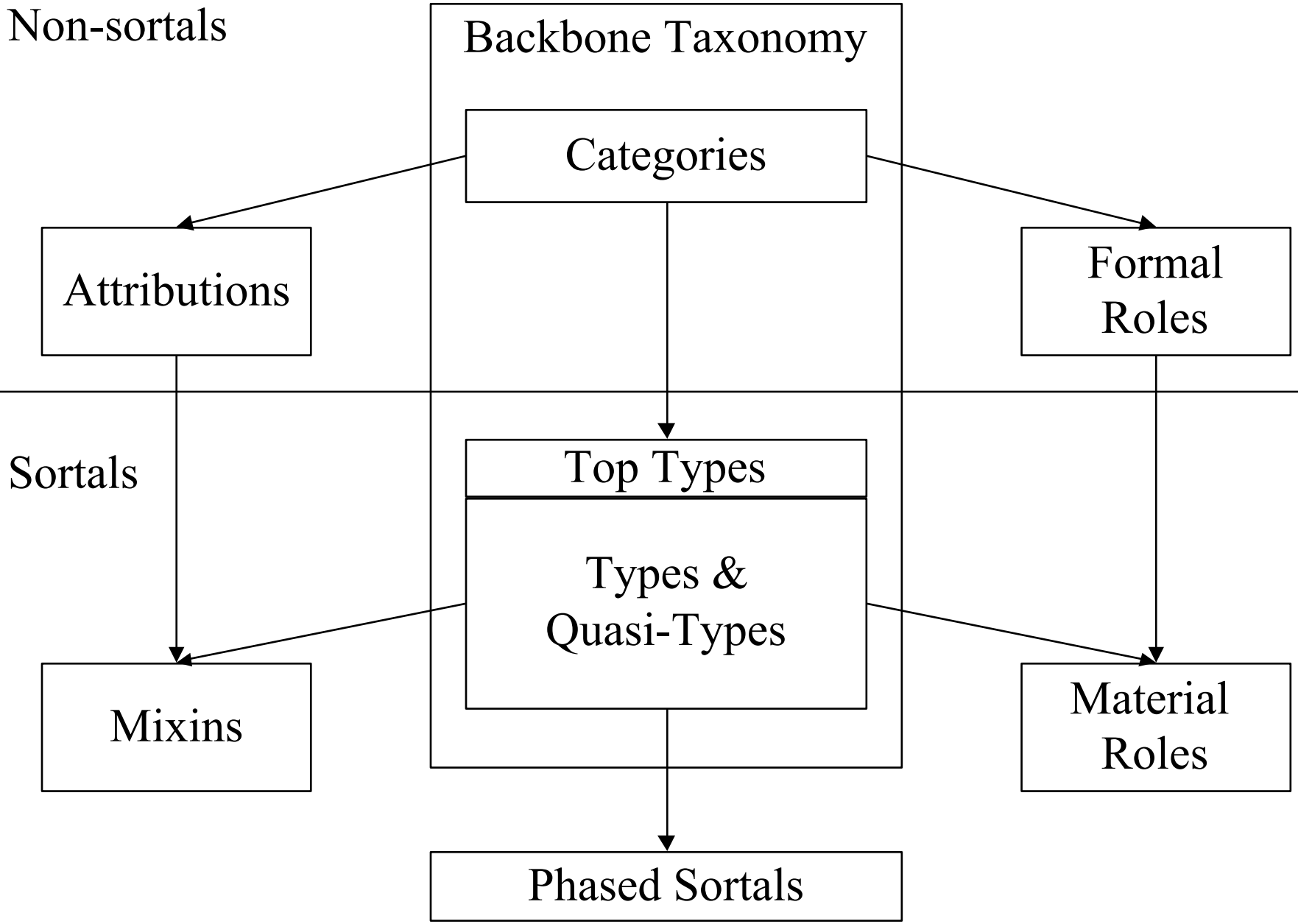
A formal ontology of properties



The *Backbone Taxonomy*

Assumption: ***no entity without identity***

- Since identity is supplied by types, every entity must instantiate a type
- The taxonomy of types spans the whole domain
- Together with categories, types form the ***backbone taxonomy***, which represents the ***invariant structure*** of a domain (rigid properties spanning the whole domain)


Non-sortals
Backbone Taxonomy
Categories
Attributions
Formal Roles
Sortals
Top Types
Types & Quasi-Types
Mixins
Material Roles
Phased Sortals

Well-founded ontology design

An *ontology-cleaning* example

Dealing with *Ontological Relativism*

- Deciding about the meta-properties carried by a given property…

Is up to **YOU!**

- But a ***common agreement*** must be achieved about the formal meaning (and practical utility) of meta-properties

Property Analysis
Entity, Location

- Entity
  - Everything is an entity
  - -I-U-D+R
  - Category
- Location
  - A generalized region of space.
  - +O: by its parts (mereologically extensional).
  - ~U: no way to isolate a location
  - -D+R
  - Type

Property Analysis
Amount of Matter, Red

- Amount of Matter
  - unstructured /scattered "stuff" as lumps of clay or some bricks
  - +O: mereologically extensional
  - ~U: intrinsically no unity
  - -D+R
  - Type
- Red
  - Really Red-thing, the set of all red-colored entities
  - -I-U-D-R
  - Formal Attribution

Property Analysis
Agent, Group

- Agent
  - An entity playing a part in some event
  - -I-U: no *universal* IC/UC
  - +D: on the event/action participating in
  - ~R: no instance is necessarily an agent
  - Formal role
- Group
  - An *unstructured* collection of wholes
  - +O: same-members
  - ~U: unstructured, no unity.
  - -D+R
  - Type

Property Analysis
Physical Object, Living Being

- Physical Object
  - Isolated material objects.
  - +O: same spatial location (only synchronic, no common diachronic IC).
  - +U: Topological
  - -D+R
  - Type
- Living Being
  - +O: same-DNA (only nec.)
  - +U: biological unity
  - -D+R
  - Type

Property Analysis
Food, Animal

- Food
  - +I-O~U: amt. of matter
  - +D: something that eats it.
  - ~R: being food is not necessary...
  - Material Role
- Animal
  - +O: same-brain
  - +U: biological unity
  - -D+R
  - Type

Property Analysis
Legal Agent, Group of People

- Legal Agent
  - A legally recognized entity
  - +L: All legal systems have a defined IC, has-same-legal-ID
  - -U: no universal unity
  - +D: on the legal body that recognizes it
  - ~R: not necessary
  - Material Role

- Group of People
  - See Group
  - +I-O~U-D+R
  - Quasi-type

Property Analysis
Social Entity, Organization

- Social Entity
  - A group of people together for social reasons
  - -I: no universal IC
  - +U: social-connection
  - -D+R
  - category
- Organization
  - A group of people together, with roles that define some structure
  - +O: same-mission and way of operating
  - +U: functional
  - -D+R
  - Type

Property Analysis
Fruit

- Fruit
  - An individual fruit, such as an orange or bannana
  - +O: same-plant, same-shape, etc. (only nec.)
  - +U: topological
  - -D+R
  - Type

Property Analysis
Apple, Red Apple

- Apple
  - +O: shape, color, skin pattern (only nec)
  - +U: topological
  - -D+R
  - Type
- Red-Apple
  - +I-O: from Apple
  - +U: from Apple
  - -D
  - ~R: no red apple is necessarily red
  - type-attribution mixin

Property Analysis
Vertebrate, Person

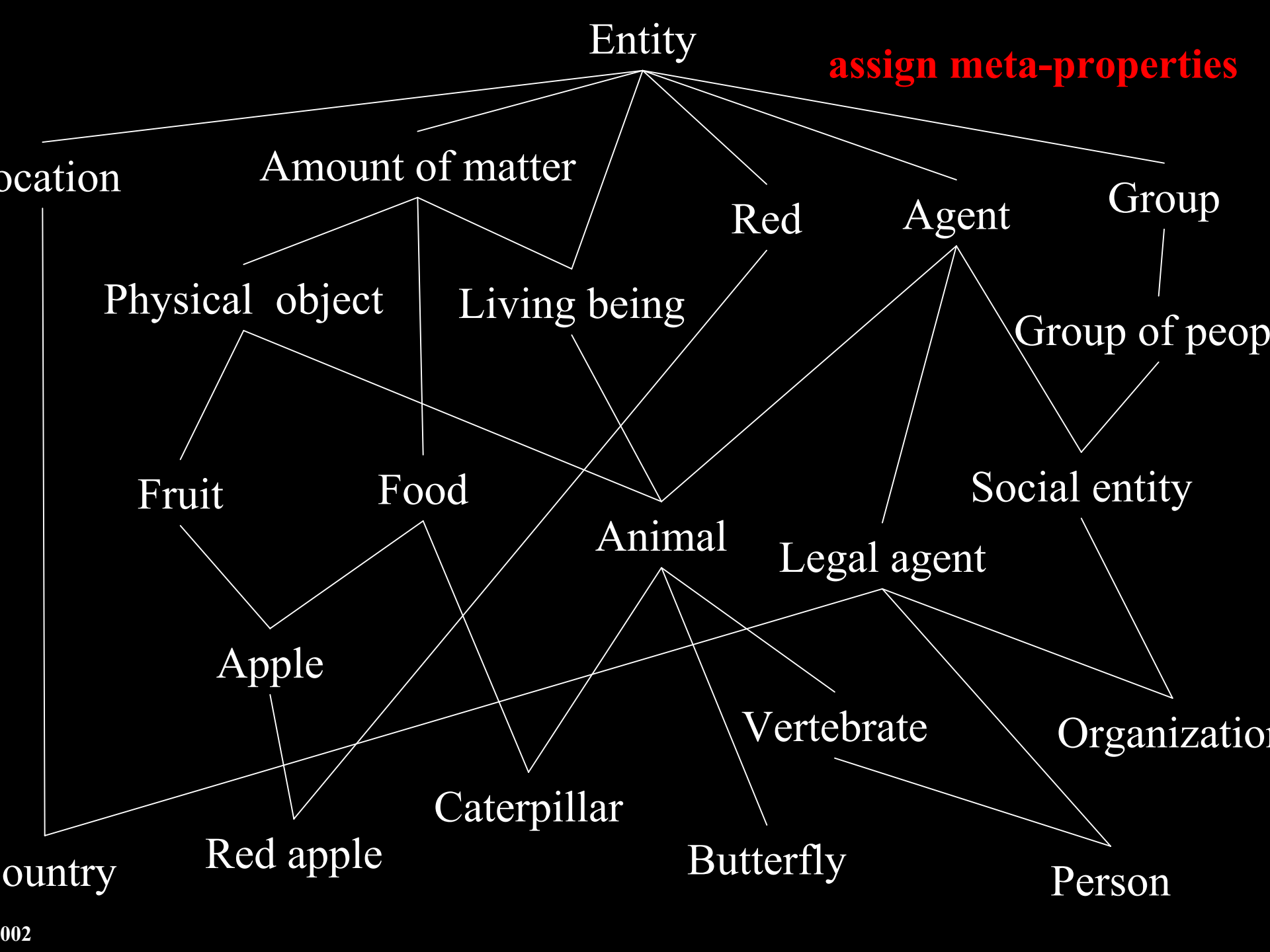
- Vertebrate
  - Really vertebrate-*animal*
  - *A* biological classification that adds new *membership* criteria (has-backbone)
  - +I-O: from animal
  - +U: from animal
  - -D+R
  - quasi-type
- Person
  - +O: same-fingerprint
  - +U: from animal
  - -D+R
  - Type

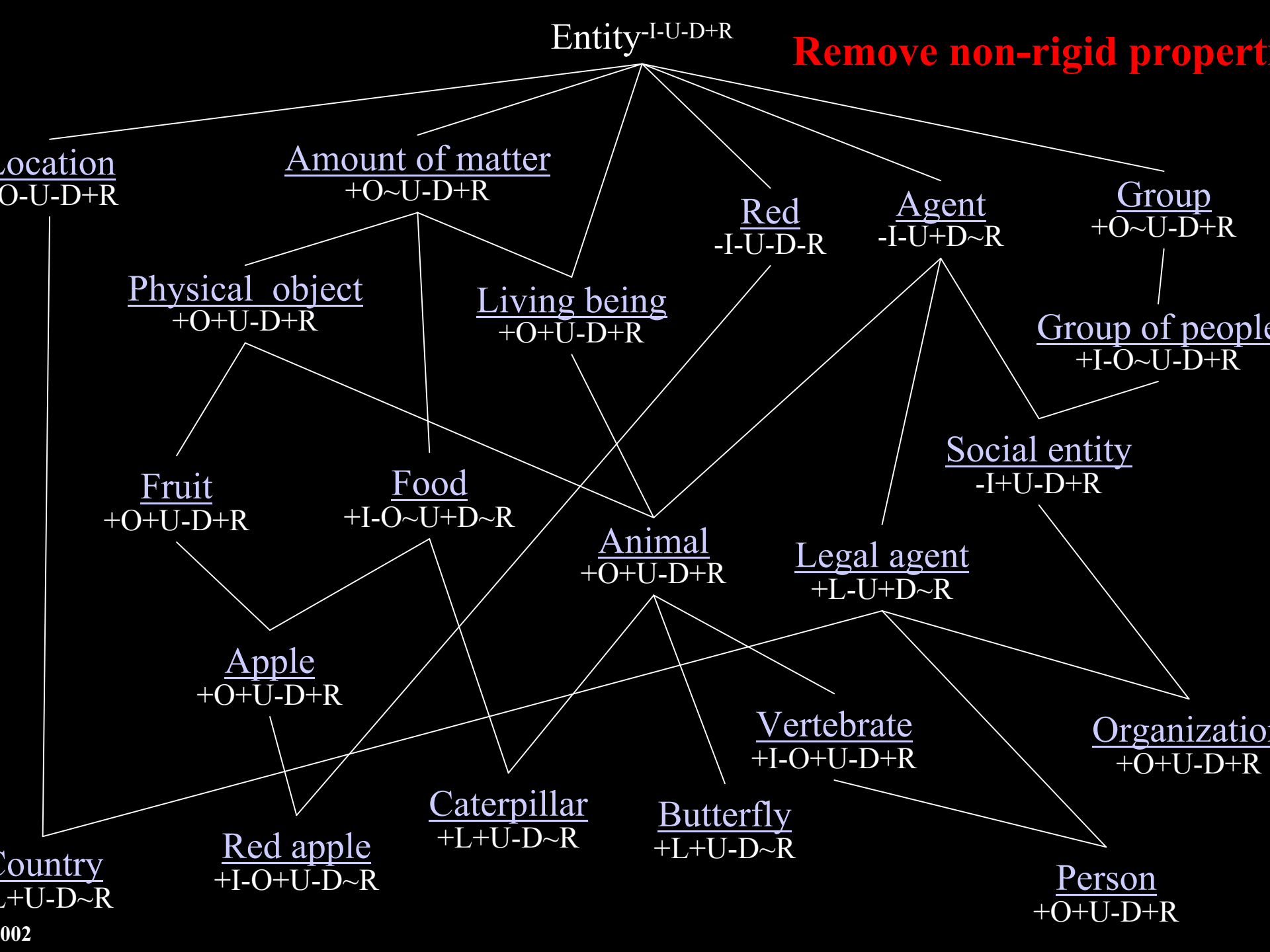
Property Analysis
Butterfly, Caterpillar

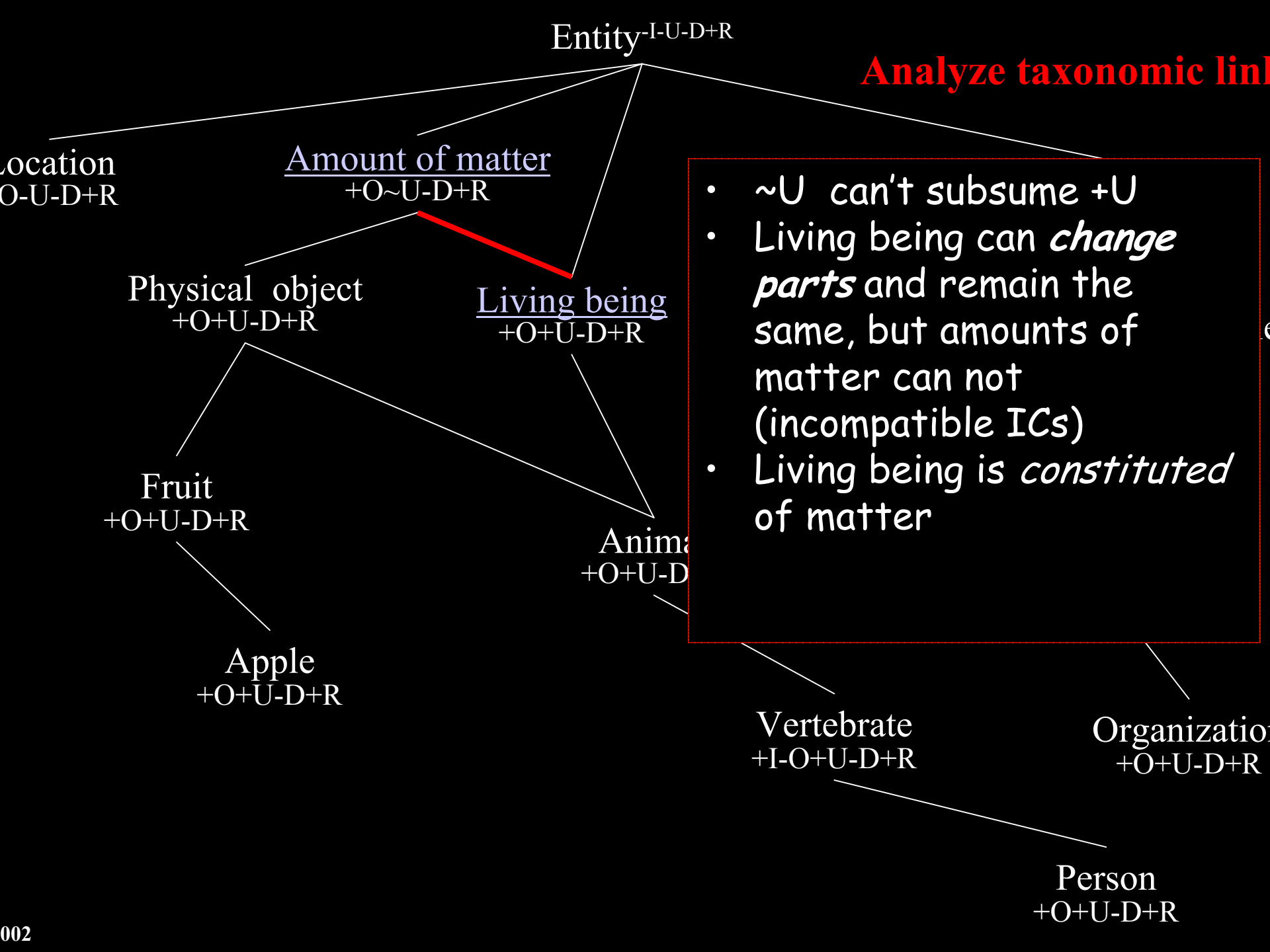
- Butterfly
  - +L: same-wing-pattern
  - +U: biological
  - -D
  - ~R: the *same entity* can be something else (a caterpillar)
  - Phased sortal
- Caterpillar
  - +L: spots, legs, color
  - +U: biological
  - -D
  - ~R: caterpillars become butterflies and change their IC
  - Phased sortal

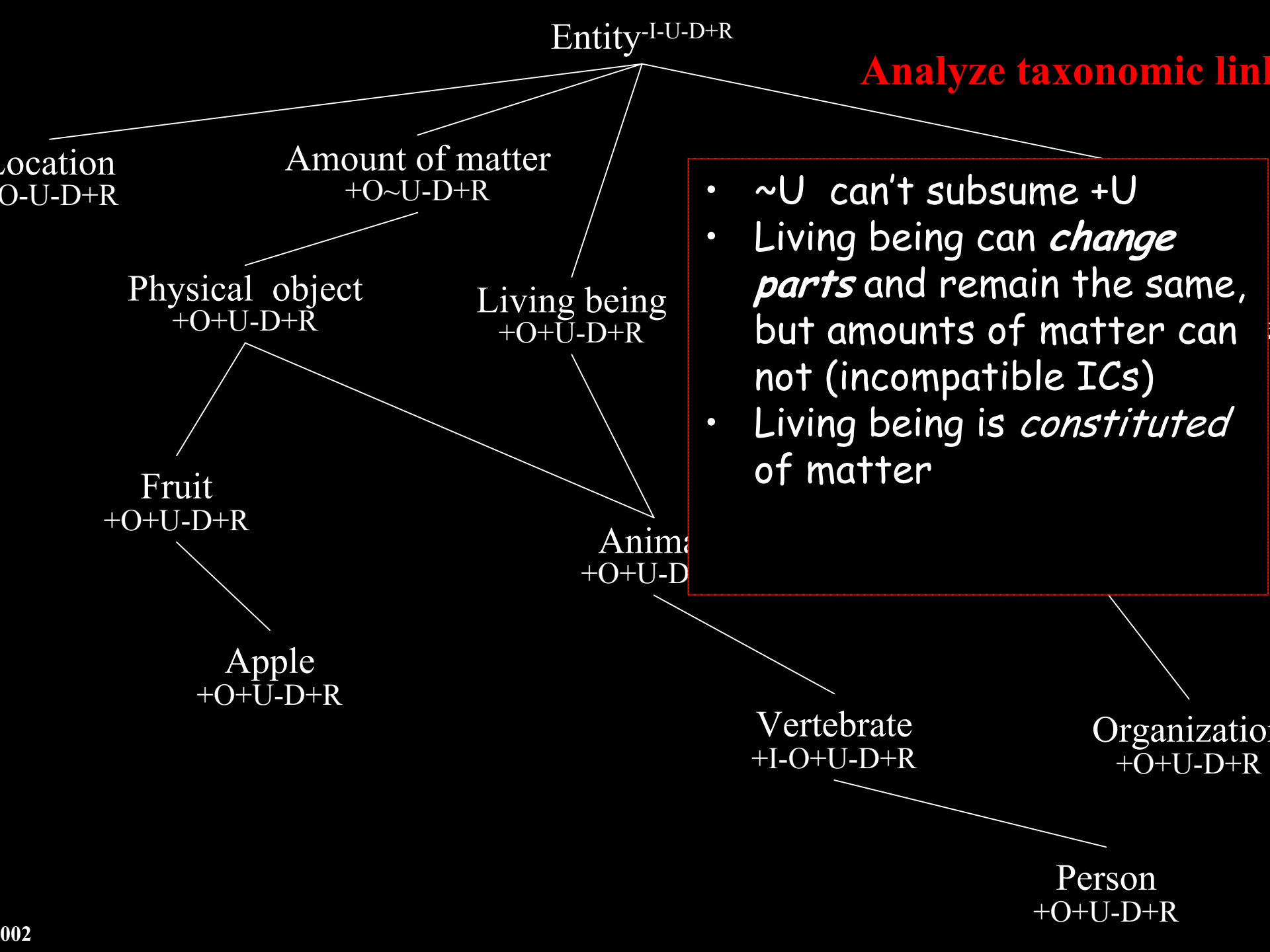
Property Analysis
Country

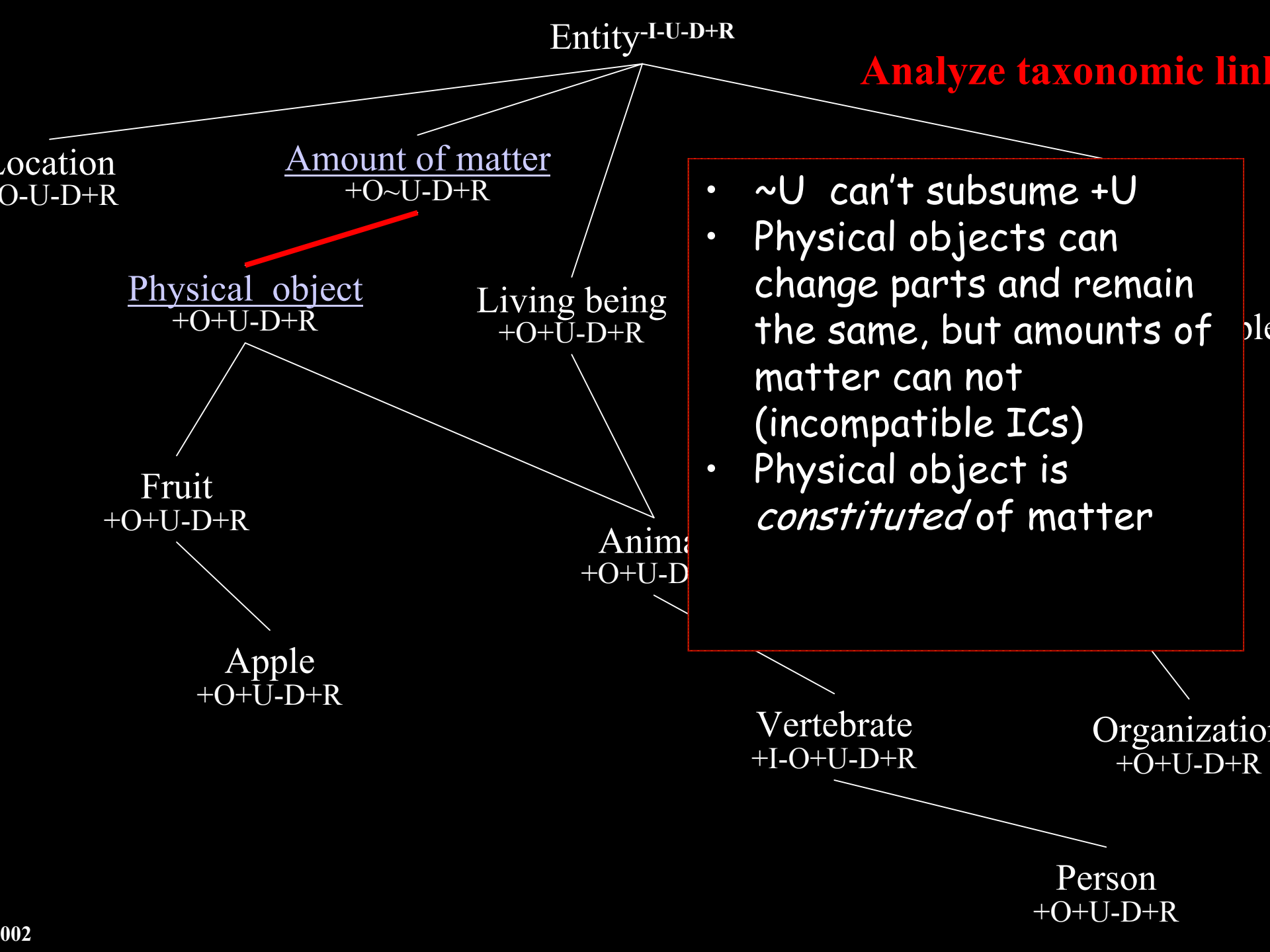
- Country
  - A place recognized by convention as autonomous
  - +L: government, sub-regions
  - +U: countries are countable (heuristic)
  - -D
  - ~R: some countries do not exist as countries any more (e.g. Prussia) but are still places
  - Phased sortal

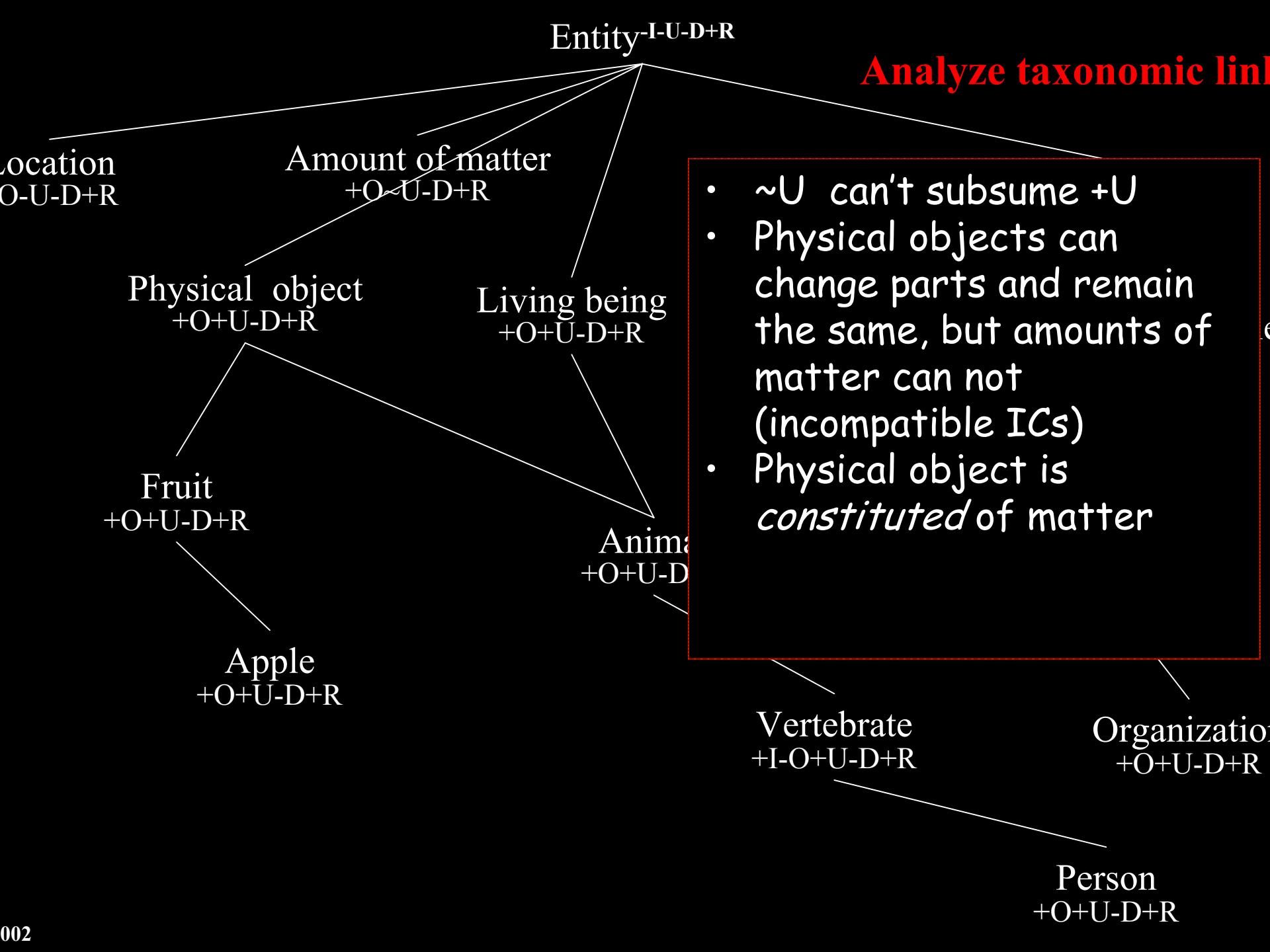

Entity
assign meta-properties
ocation
Amount of matter
Red
Agent
Group
Physical object
Living being
Group of peop
Fruit
Food
Social entity
Animal
Legal agent
Apple
Vertebrate
Organizatio
Caterpillar
ountry
Red apple
Butterfly
Person

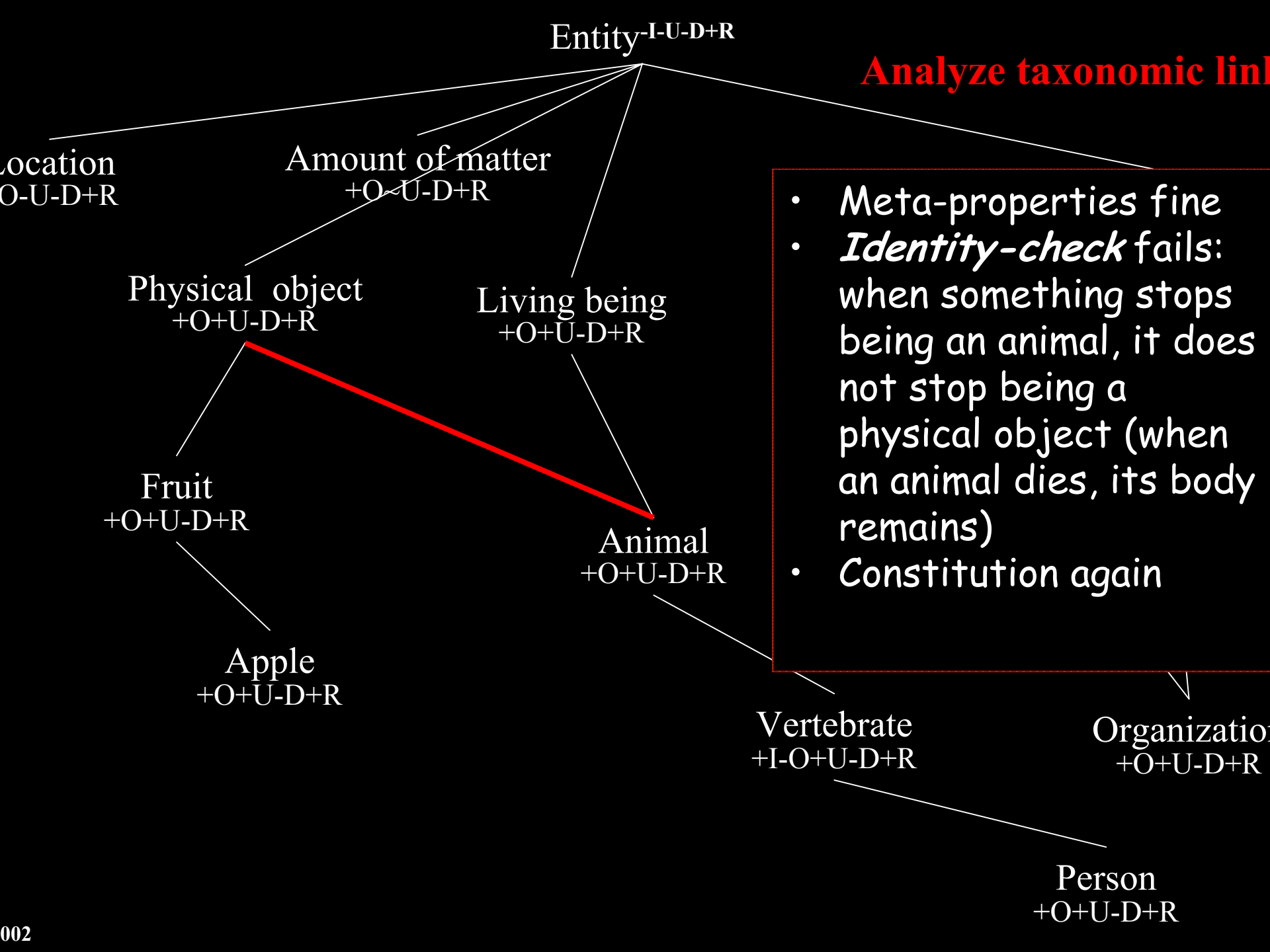

Entity -I-U-D+R
Remove non-rigid properti
Location
O-U-D+R
Amount of matter
+O~U-D+R
Red
-I-U-D-R
Agent
-I-U+D~R
Group
+O~U-D+R
Physical object
+O+U-D+R
Living being
+O+U-D+R
Group of people
+I-O~U-D+R
Social entity
-I+U-D+R
Fruit
+O+U-D+R
Food
+I-O~U+D~R
Animal
+O+U-D+R
Legal agent
+L-U+D~R
Apple
+O+U-D+R
Vertebrate
+I-O+U-D+R
Organizatio
+O+U-D+R
Caterpillar
+L+U-D~R
Butterfly
+L+U-D~R
Red apple
+I-O+U-D~R
Country
L+U-D~R
Person
+O+U-D+R
002

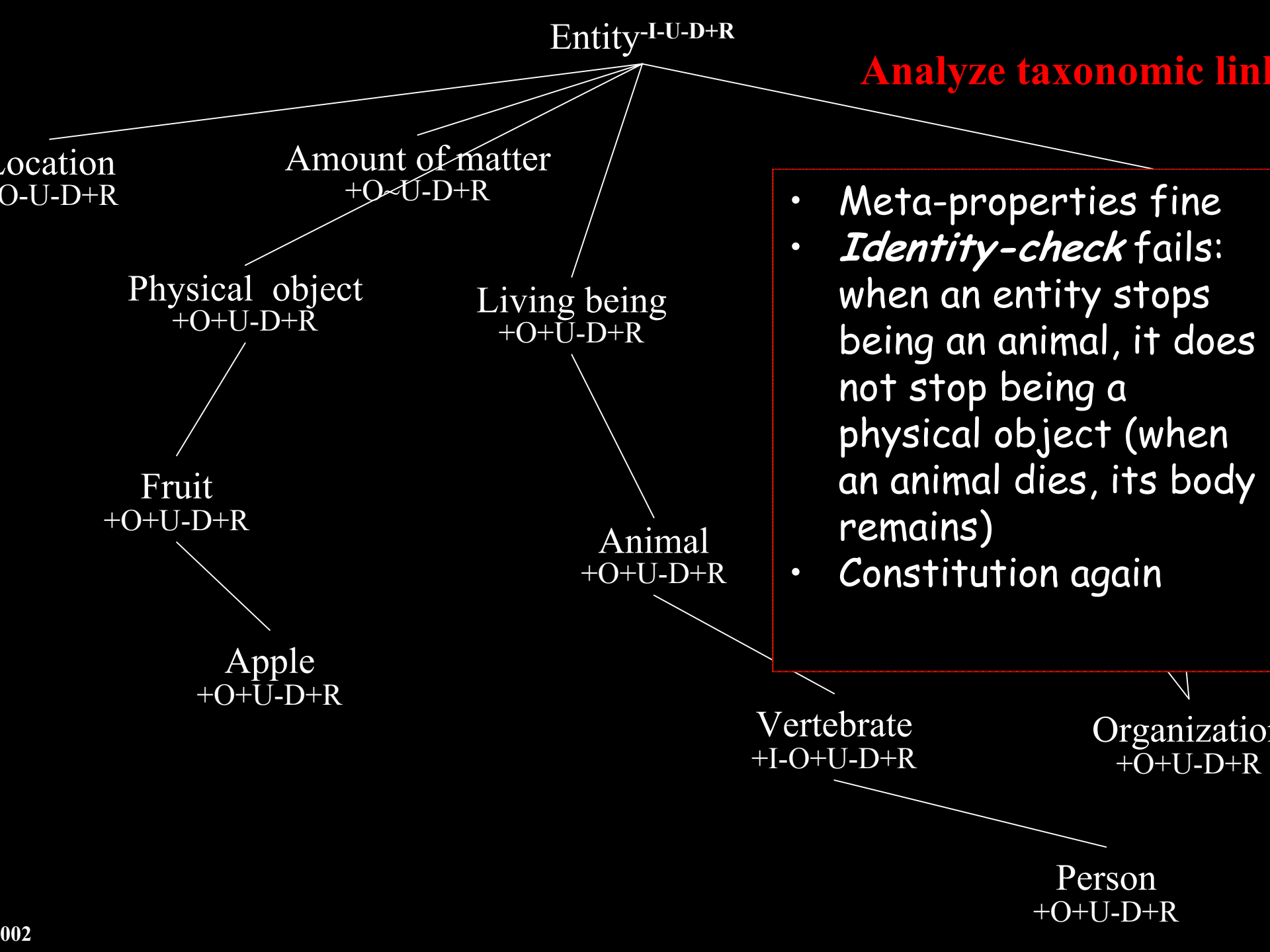

Entity-I-U-D+R
Analyze taxonomic link
Location
O-U-D+R
Amount of matter
+O~U-D+R
Physical object
+O+U-D+R
Living being
+O+U-D+R
Fruit
+O+U-D+R
Anima
+O+U-D
Apple
+O+U-D+R
Vertebrate
+I-O+U-D+R
Organizatio
+O+U-D+R
Person
+O+U-D+R
• ~U can't subsume +U
• Living being can *change parts* and remain the same, but amounts of matter can not (incompatible ICs)
• Living being is *constituted* of matter
002

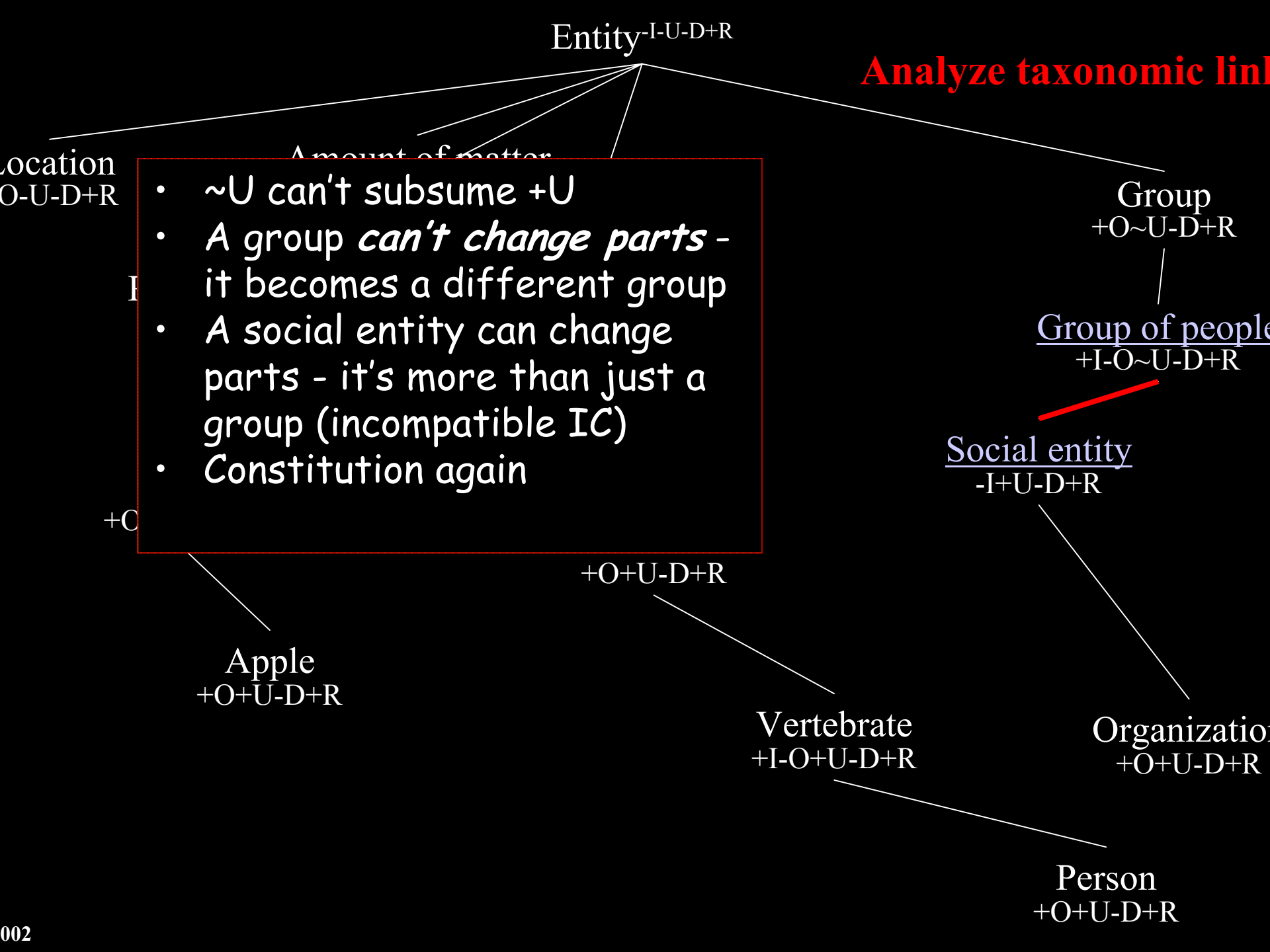

Entity-I-U-D+R
Analyze taxonomic link
ocation
O-U-D+R
Amount of matter
+O~U-D+R
Physical object
+O+U-D+R
Living being
+O+U-D+R
Fruit
+O+U-D+R
Anima
+O+U-D
Apple
+O+U-D+R
Vertebrate
+I-O+U-D+R
Organizatio
+O+U-D+R
Person
+O+U-D+R
• ~U can't subsume +U
• Living being can *change parts* and remain the same, but amounts of matter can not (incompatible ICs)
• Living being is *constituted* of matter
002

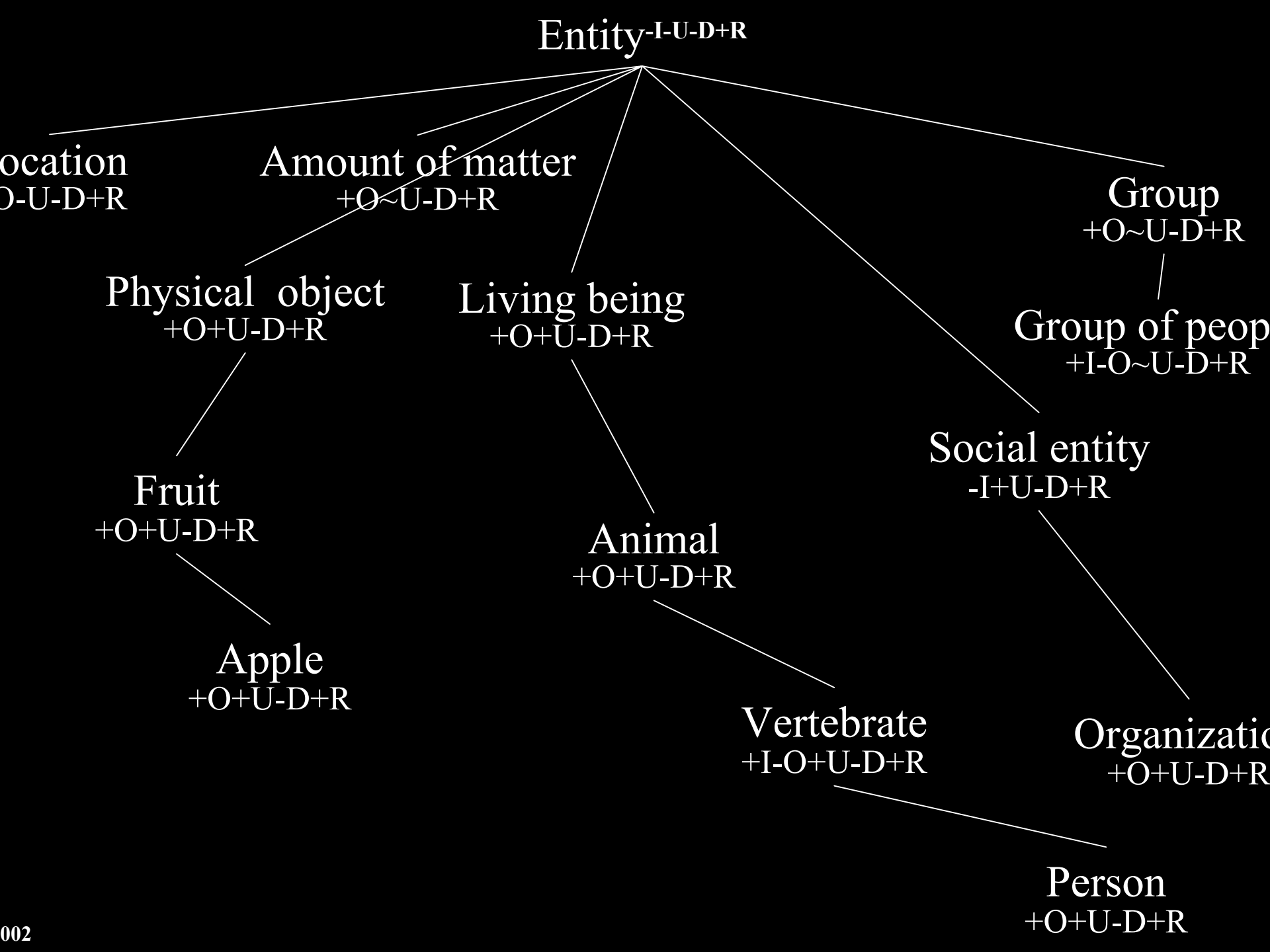

Entity-I-U-D+R
Analyze taxonomic link
Location
O-U-D+R
Amount of matter
+O~U-D+R
Physical object
+O+U-D+R
Living being
+O+U-D+R
Fruit
+O+U-D+R
Anima
+O+U-D
Apple
+O+U-D+R
Vertebrate
+I-O+U-D+R
Organizatio
+O+U-D+R
Person
+O+U-D+R
• ~U can't subsume +U
• Physical objects can change parts and remain the same, but amounts of matter can not (incompatible ICs)
• Physical object is *constituted* of matter
002

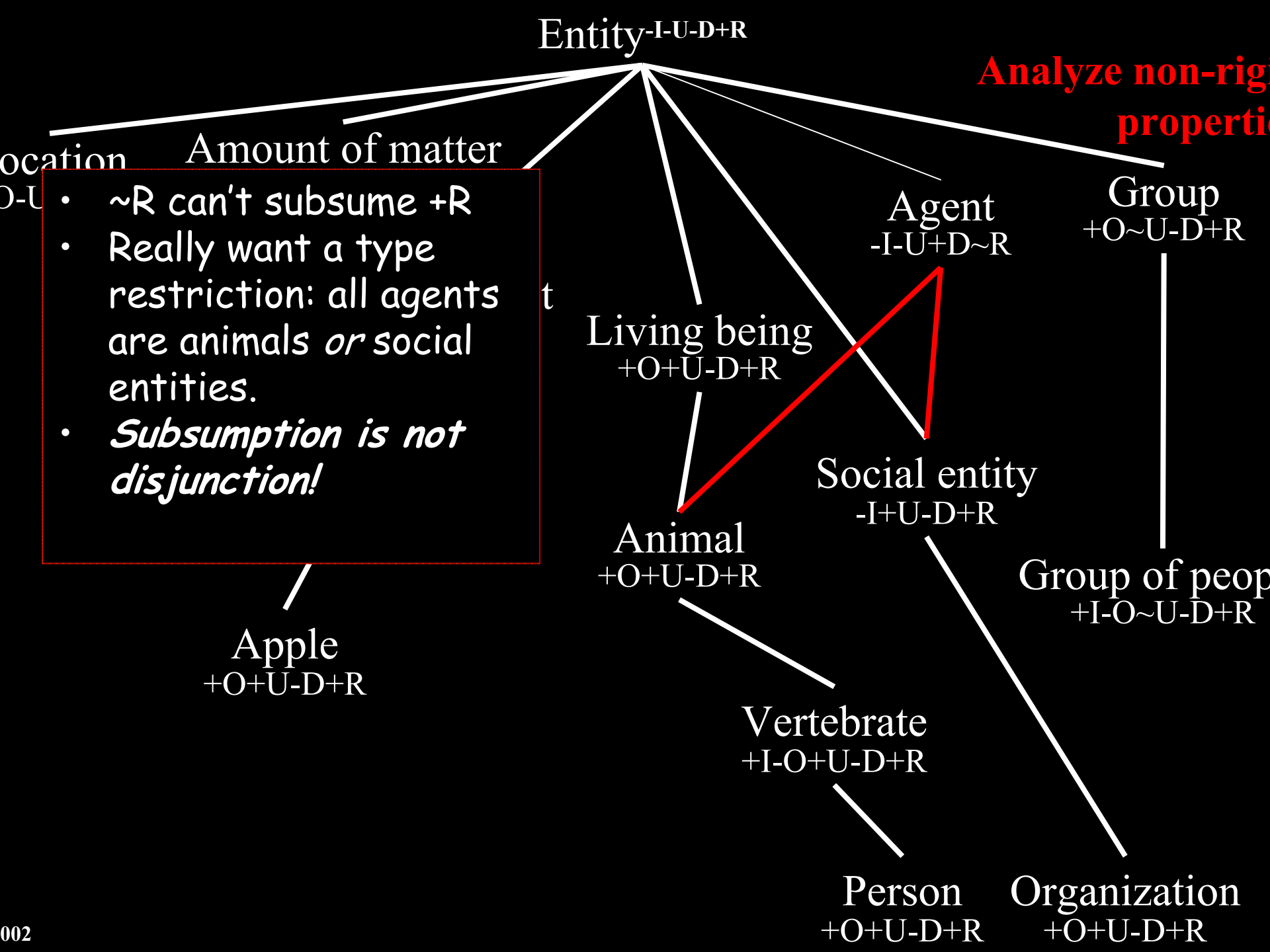

Entity-I-U-D+R
Analyze taxonomic link
ocation
O-U-D+R
Amount of matter
+O-U-D+R
Physical object
+O+U-D+R
Living being
+O+U-D+R
Fruit
+O+U-D+R
Anima
+O+U-D
Apple
+O+U-D+R
Vertebrate
+I-O+U-D+R
Organizatio
+O+U-D+R
Person
+O+U-D+R
• ~U can't subsume +U
• Physical objects can change parts and remain the same, but amounts of matter can not (incompatible ICs)
• Physical object is *constituted* of matter
002

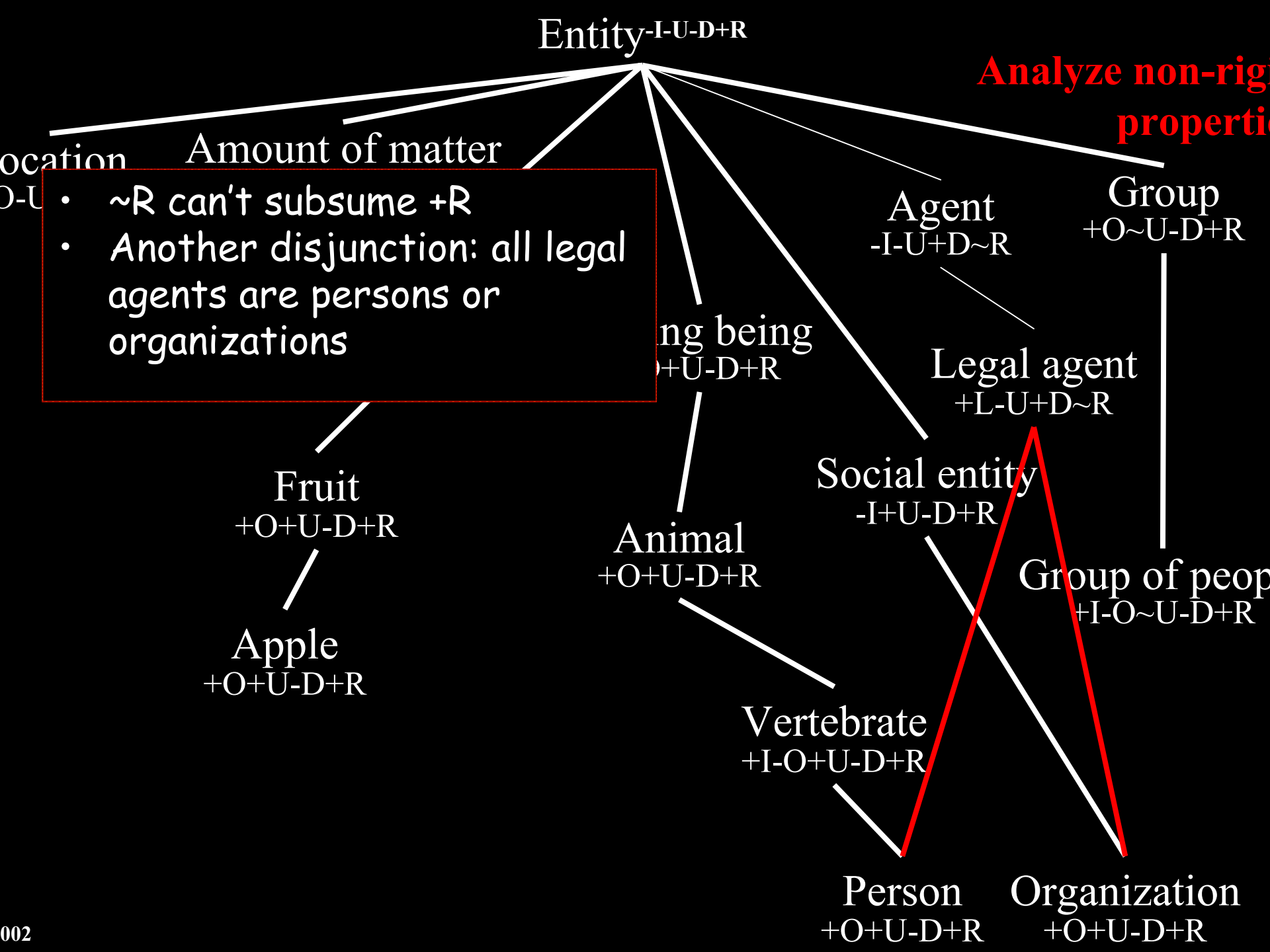

Entity-I-U-D+R
Analyze taxonomic link
ocation
O-U-D+R
Amount of matter
+O-U-D+R
Physical object
+O+U-D+R
Living being
+O+U-D+R
Fruit
+O+U-D+R
Animal
+O+U-D+R
Apple
+O+U-D+R
Vertebrate
+I-O+U-D+R
Organizatio
+O+U-D+R
Person
+O+U-D+R
• Meta-properties fine
• Identity-check fails: when something stops being an animal, it does not stop being a physical object (when an animal dies, its body remains)
• Constitution again
002

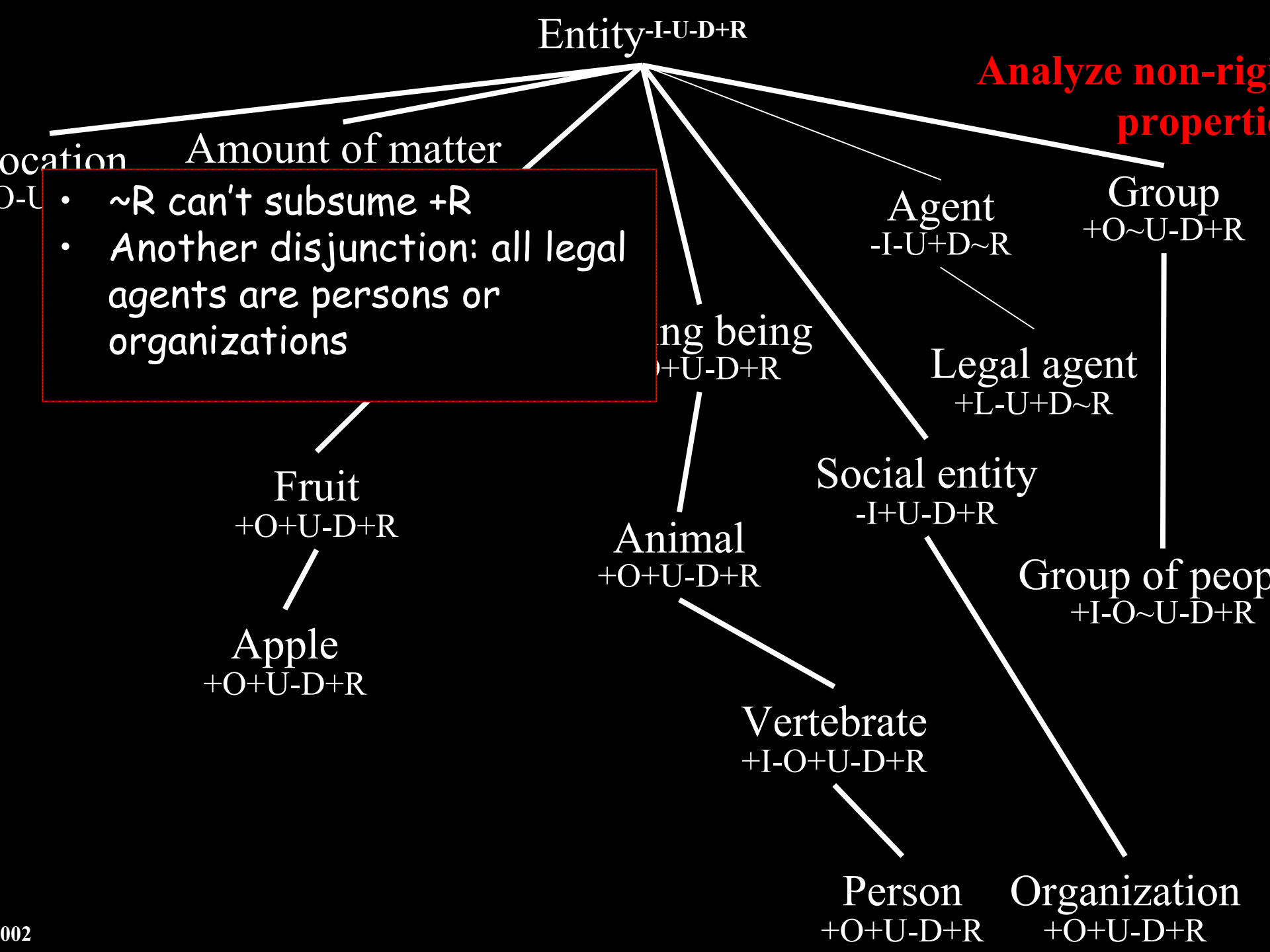

Entity-I-U-D+R
Analyze taxonomic link
ocation
O-U-D+R
Amount of matter
+O-U-D+R
Physical object
+O+U-D+R
Living being
+O+U-D+R
Fruit
+O+U-D+R
Animal
+O+U-D+R
Apple
+O+U-D+R
Vertebrate
+I-O+U-D+R
Organizatio
+O+U-D+R
Person
+O+U-D+R
• Meta-properties fine
• Identity-check fails: when an entity stops being an animal, it does not stop being a physical object (when an animal dies, its body remains)
• Constitution again
002

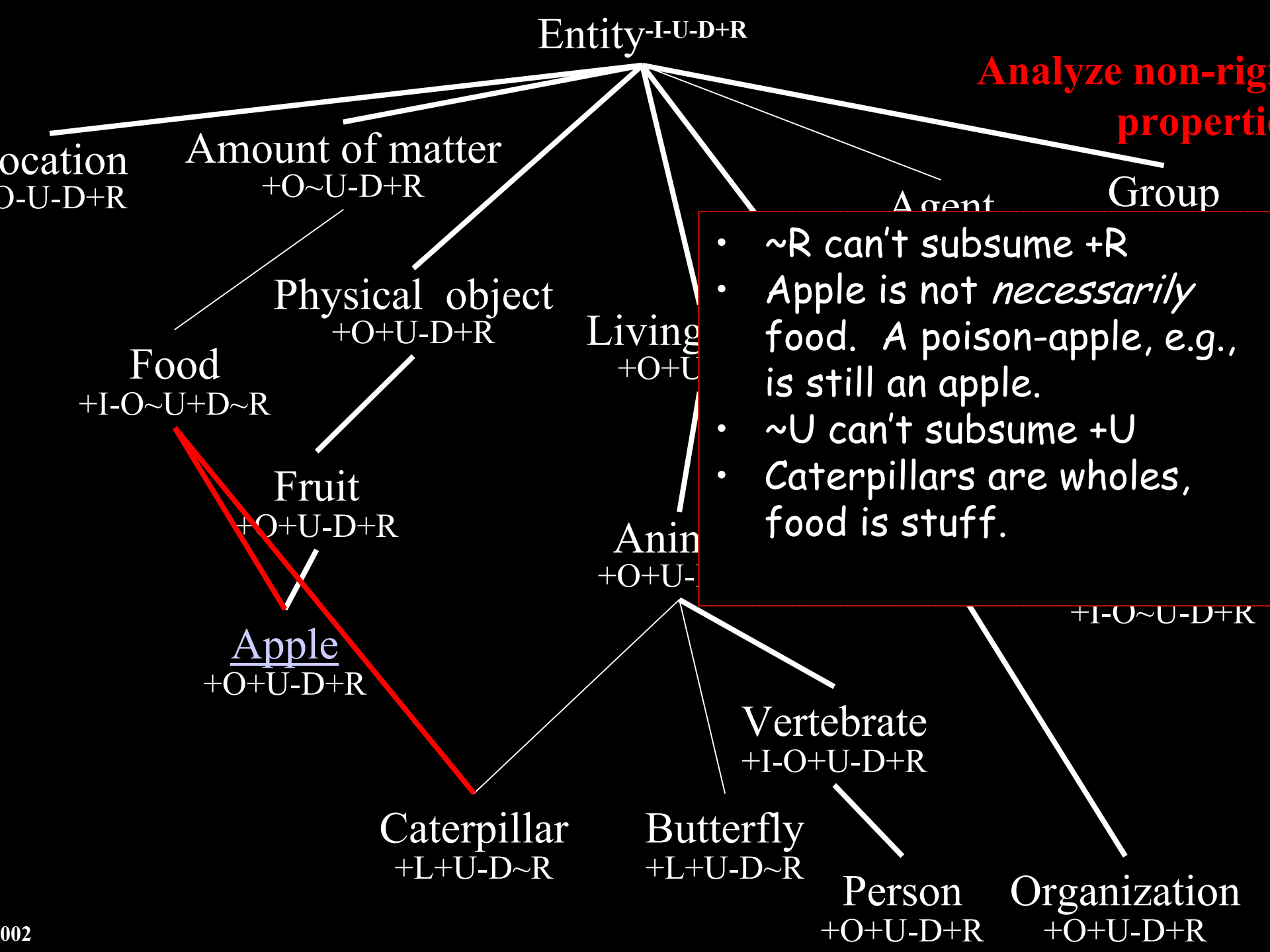

Entity -I-U-D+R
Analyze taxonomic link
Location
O-U-D+R
Group
+O~U-D+R
Group of people
+I-O~U-D+R
Social entity
-I+U-D+R
• ~U can't subsume +U
• A group can't change parts - it becomes a different group
• A social entity can change parts - it's more than just a group (incompatible IC)
• Constitution again
+O+U-D+R
Apple
+O+U-D+R
Vertebrate
+I-O+U-D+R
Organizatio
+O+U-D+R
Person
+O+U-D+R
002

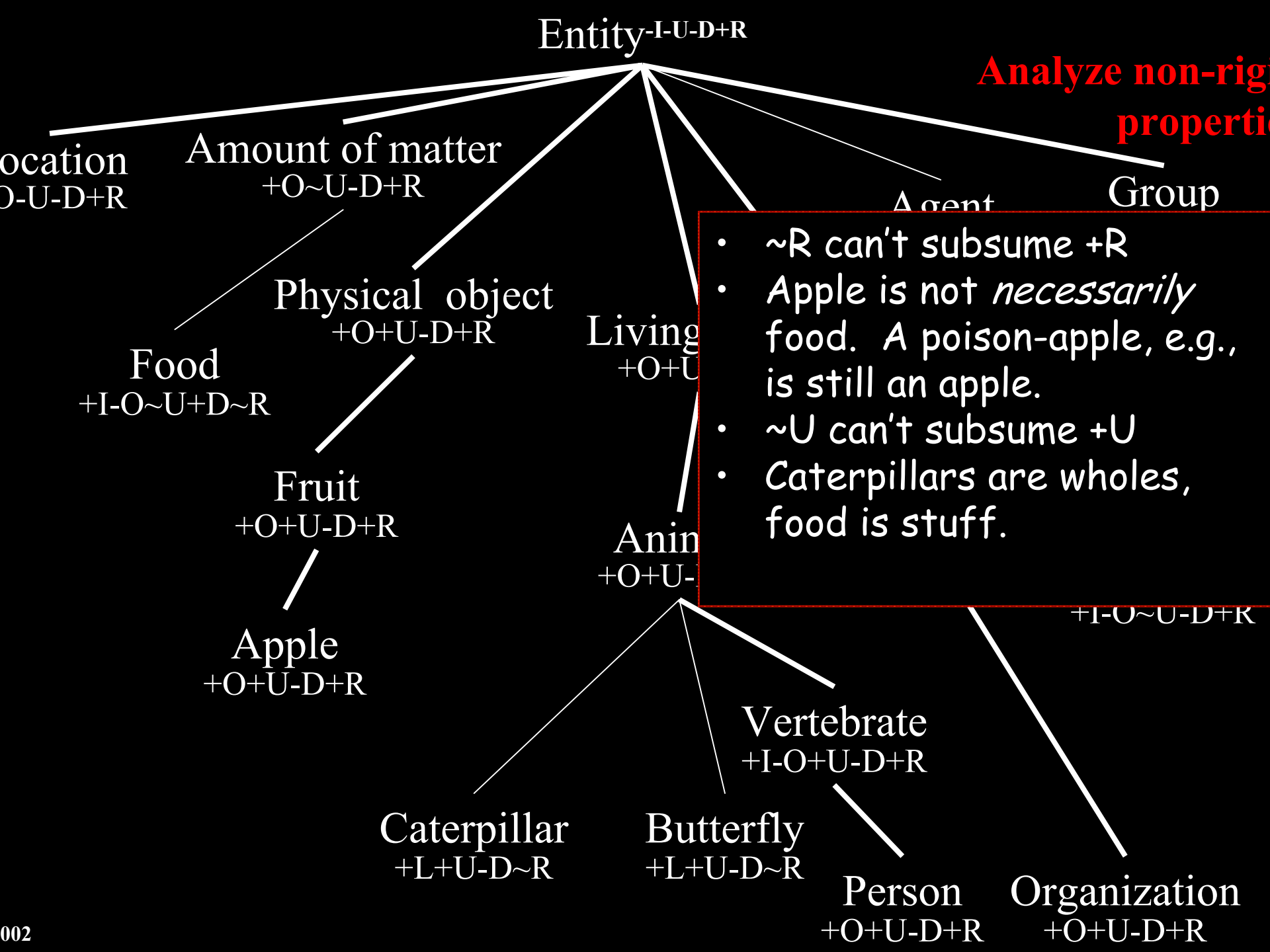

Entity-I-U-D+R
ocation
O-U-D+R
Amount of matter
+O~U-D+R
Group
+O~U-D+R
Physical object
+O+U-D+R
Living being
+O+U-D+R
Group of peop
+I-O~U-D+R
Social entity
-I+U-D+R
Fruit
+O+U-D+R
Animal
+O+U-D+R
Apple
+O+U-D+R
Vertebrate
+I-O+U-D+R
Organizatio
+O+U-D+R
Person
+O+U-D+R

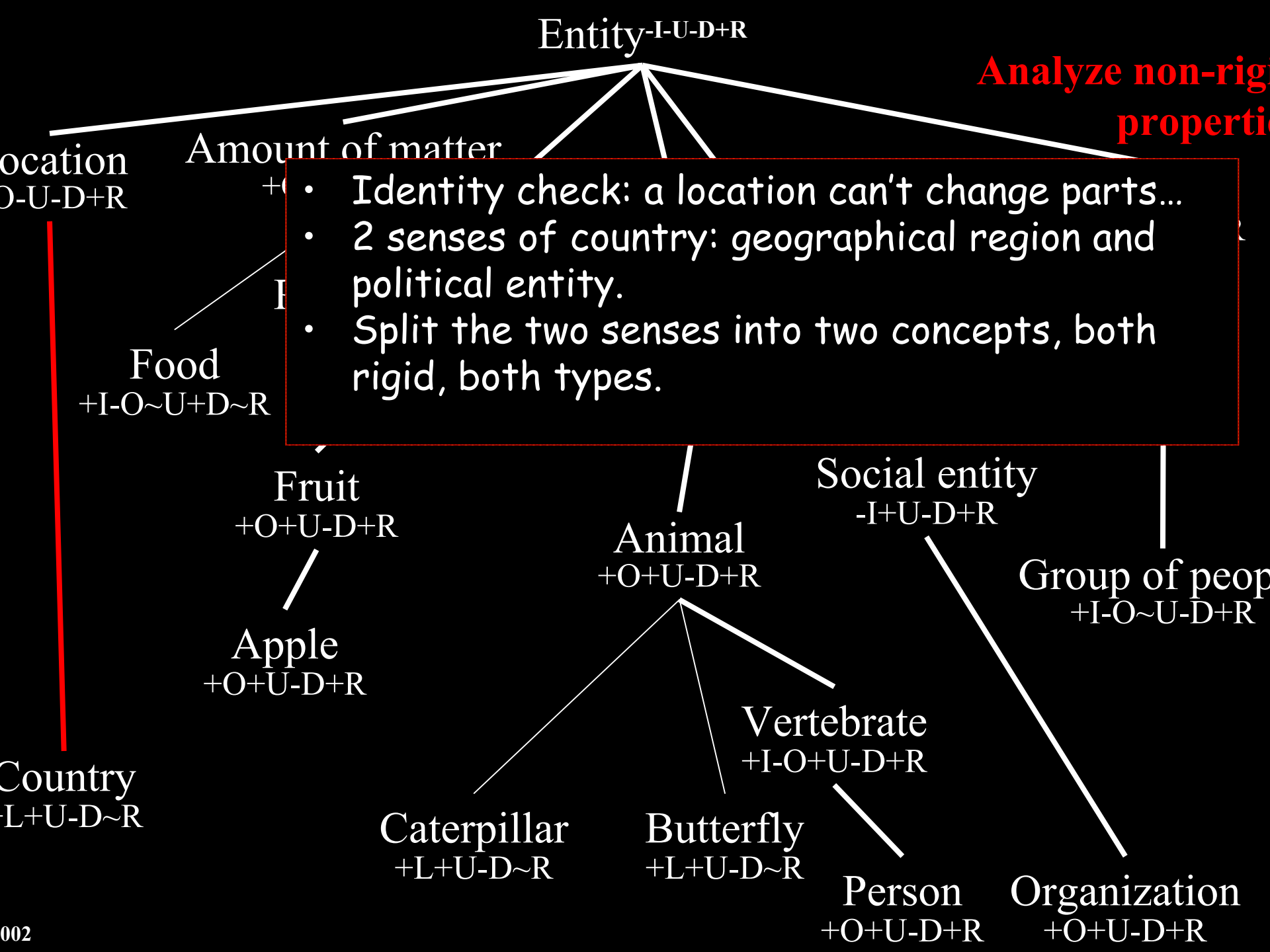

Entity-I-U-D+R
Analyze non-rig
properti
ocation
O-U
Amount of matter
• ~R can't subsume +R
• Really want a type restriction: all agents are animals *or* social entities.
• ***Subsumption is not disjunction!***
t
Living being
+O+U-D+R
Agent
-I-U+D~R
Group
+O~U-D+R
Social entity
-I+U-D+R
Animal
+O+U-D+R
Group of peop
+I-O~U-D+R
Apple
+O+U-D+R
Vertebrate
+I-O+U-D+R
Person
+O+U-D+R
Organization
+O+U-D+R

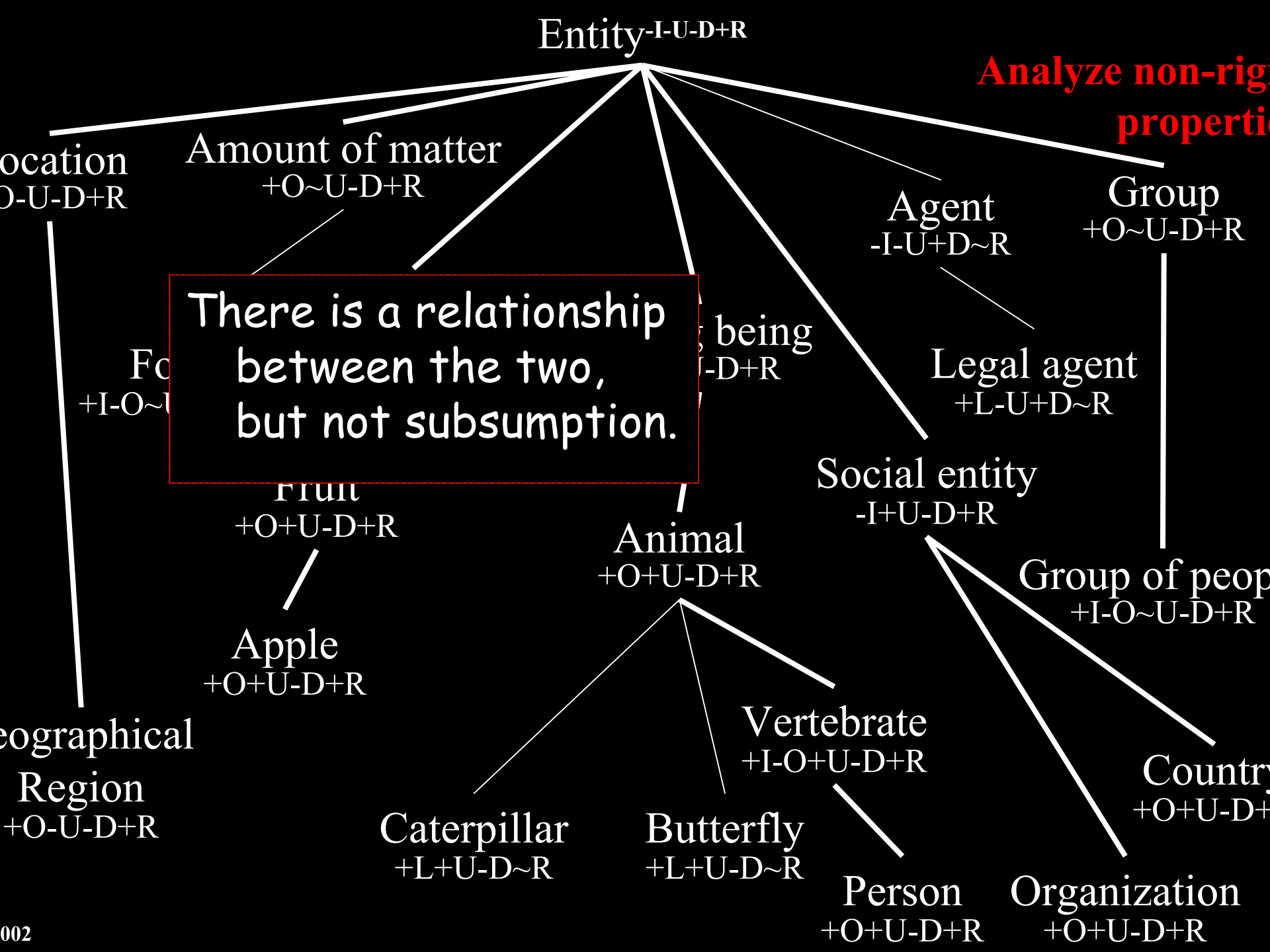

Entity-I-U-D+R
Analyze non-rig
properti
ocation
O-U
Amount of matter
• ~R can't subsume +R
• Another disjunction: all legal agents are persons or organizations
Agent
-I-U+D~R
Group
+O~U-D+R
ng being
)+U-D+R
Legal agent
+L-U+D~R
Fruit
+O+U-D+R
Social entity
-I+U-D+R
Animal
+O+U-D+R
Group of peop
+I-O~U-D+R
Apple
+O+U-D+R
Vertebrate
+I-O+U-D+R
Person
+O+U-D+R
Organization
+O+U-D+R
002

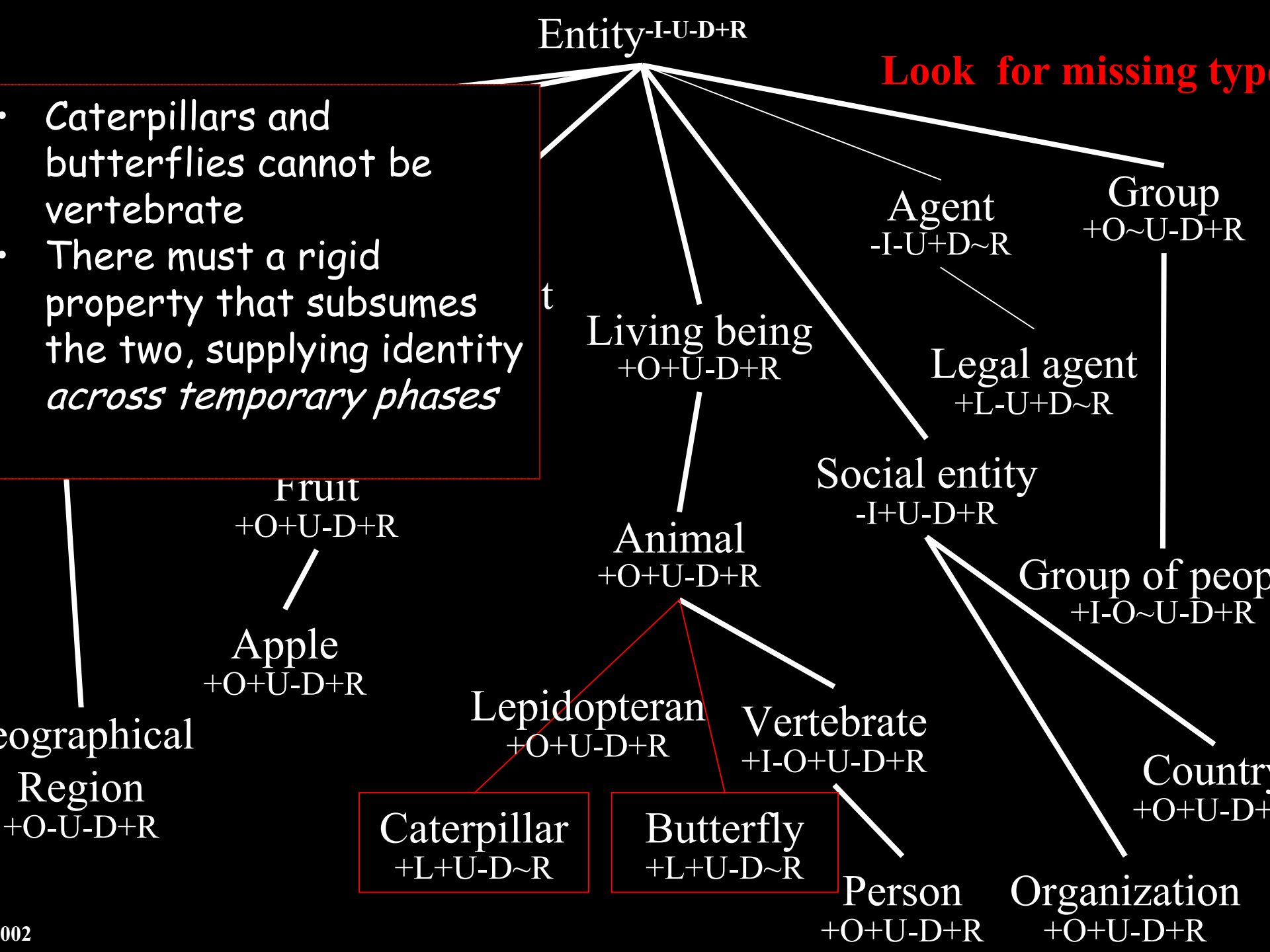

Entity-I-U-D+R
Analyze non-rig
properti
ocation
O-U
Amount of matter
• ~R can't subsume +R
• Another disjunction: all legal agents are persons or organizations
Agent
-I-U+D~R
Group
+O~U-D+R
ng being
)+U-D+R
Legal agent
+L-U+D~R
Fruit
+O+U-D+R
Social entity
-I+U-D+R
Animal
+O+U-D+R
Group of peop
+I-O~U-D+R
Apple
+O+U-D+R
Vertebrate
+I-O+U-D+R
Person
+O+U-D+R
Organization
+O+U-D+R
002

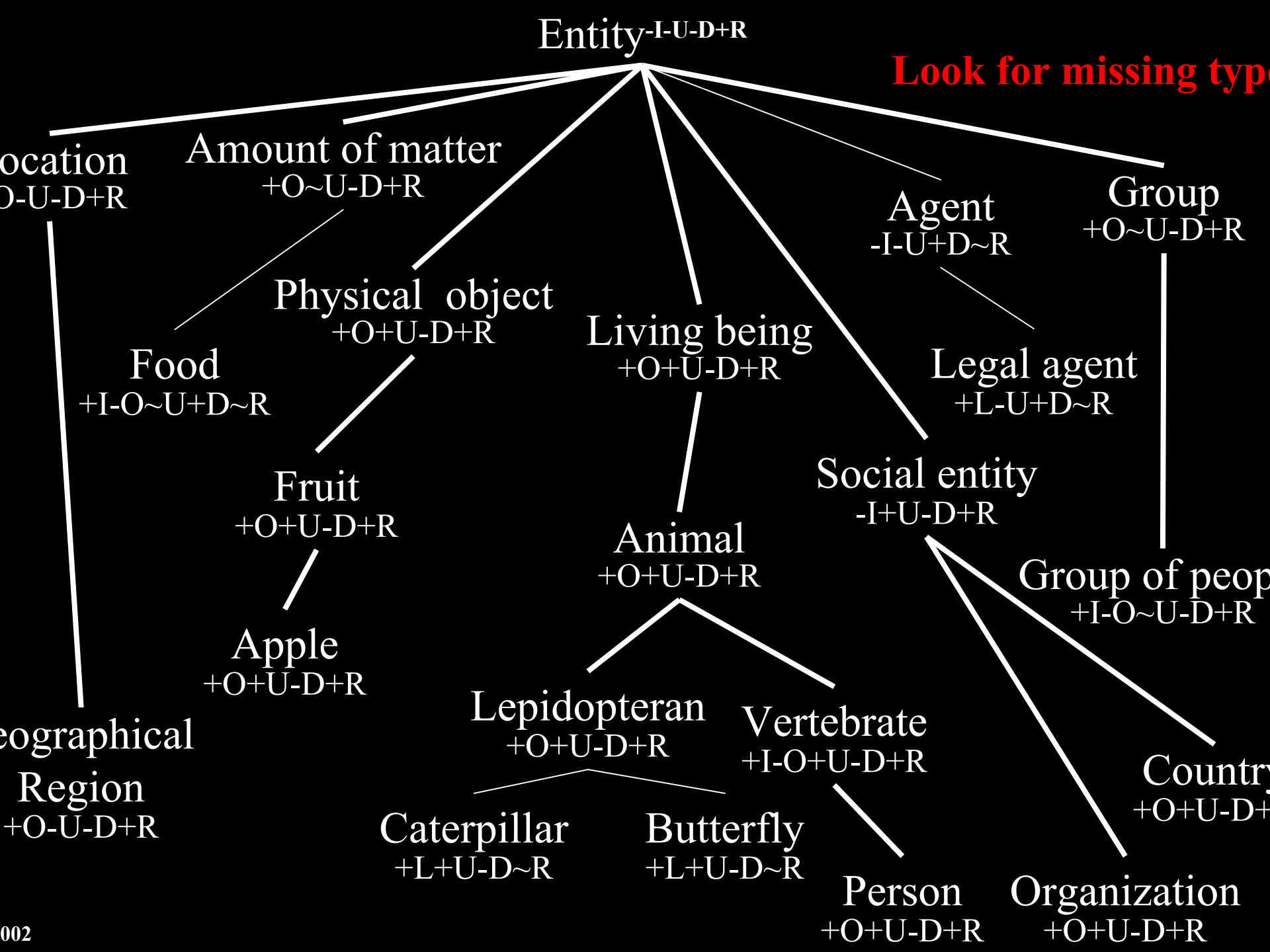

Entity-I-U-D+R
Analyze non-rig
properti
ocation
O-U-D+R
Amount of matter
+O~U-D+R
Group
Physical object
+O+U-D+R
Living
+O+U
Food
+I-O~U+D~R
Fruit
+O+U-D+R
Anin
+O+U-
+I-O~U-D+R
Apple
+O+U-D+R
Vertebrate
+I-O+U-D+R
Caterpillar
+L+U-D~R
Butterfly
+L+U-D~R
Person
+O+U-D+R
Organization
+O+U-D+R
~R can't subsume +R
Apple is not necessarily food. A poison-apple, e.g., is still an apple.
~U can't subsume +U
Caterpillars are wholes, food is stuff.
002

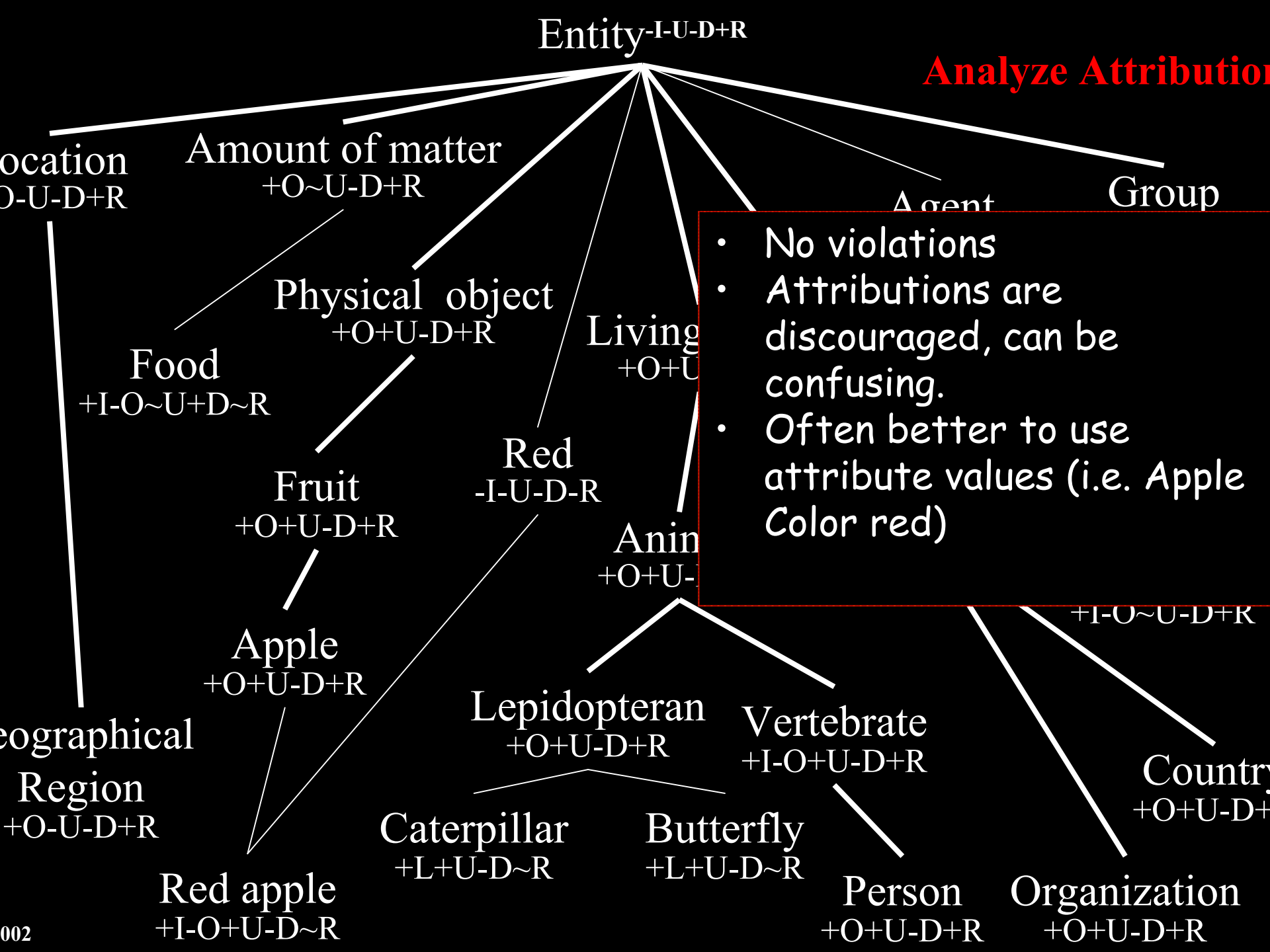

Entity-I-U-D+R
Analyze non-rig
properti
ocation
O-U-D+R
Amount of matter
+O~U-D+R
Physical object
+O+U-D+R
Food
+I-O~U+D~R
Fruit
+O+U-D+R
Apple
+O+U-D+R
Living
+O+U
Agent
Group
+I-O~U-D+R
Anin
+O+U-
Vertebrate
+I-O+U-D+R
Caterpillar
+L+U-D~R
Butterfly
+L+U-D~R
Person
+O+U-D+R
Organization
+O+U-D+R
~R can't subsume +R
Apple is not necessarily food. A poison-apple, e.g., is still an apple.
~U can't subsume +U
Caterpillars are wholes, food is stuff.
002

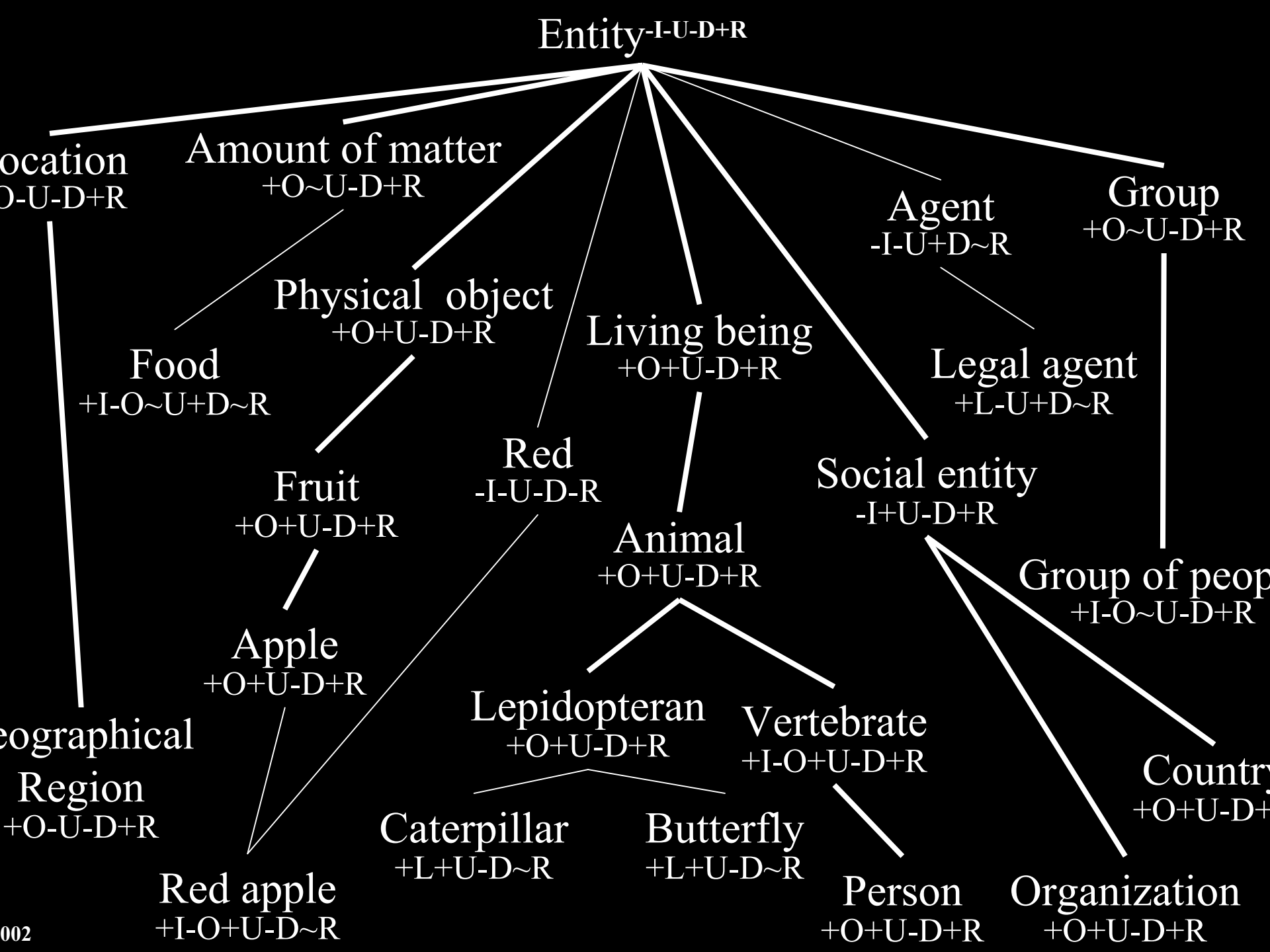

Entity-I-U-D+R
Analyze non-rig
properti
ocation
O-U-D+R
Amount of matter
+
• Identity check: a location can't change parts…
• 2 senses of country: geographical region and political entity.
• Split the two senses into two concepts, both rigid, both types.
Food
+I-O~U+D~R
Fruit
+O+U-D+R
Apple
+O+U-D+R
Animal
+O+U-D+R
Social entity
-I+U-D+R
Group of peop
+I-O~U-D+R
Vertebrate
+I-O+U-D+R
Country
-L+U-D~R
Caterpillar
+L+U-D~R
Butterfly
+L+U-D~R
Person
+O+U-D+R
Organization
+O+U-D+R
002

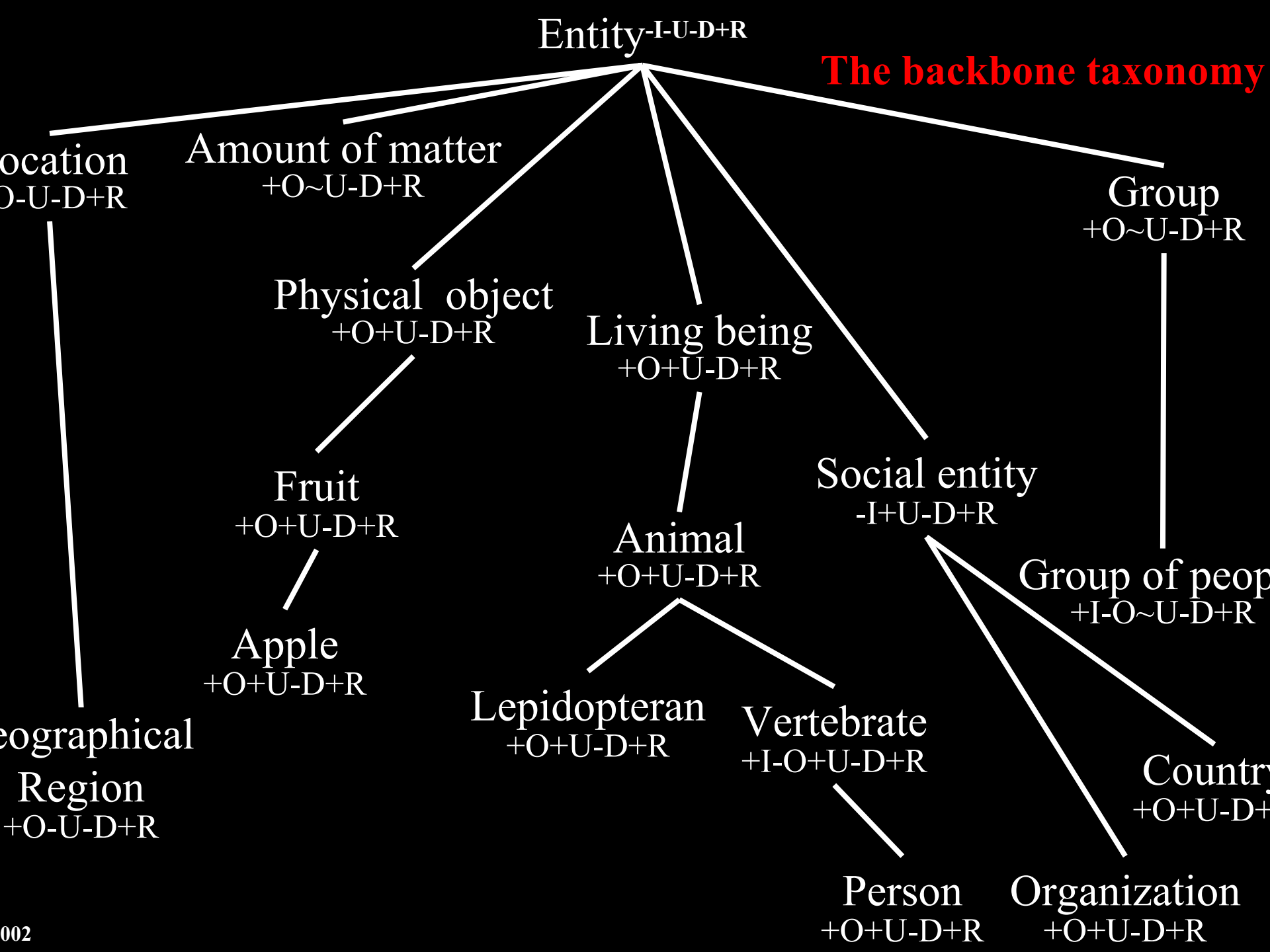

Entity-I-U-D+R
Analyze non-rig
properti
ocation
O-U-D+R
Amount of matter
+O~U-D+R
Agent
-I-U+D~R
Group
+O~U-D+R
There is a relationship between the two, but not subsumption.
Fc
+I-O~
being
-D+R
Legal agent
+L-U+D~R
Fruit
+O+U-D+R
Social entity
-I+U-D+R
Animal
+O+U-D+R
Group of peop
+I-O~U-D+R
Apple
+O+U-D+R
eographical
Region
+O-U-D+R
Vertebrate
+I-O+U-D+R
Countr
+O+U-D+
Caterpillar
+L+U-D~R
Butterfly
+L+U-D~R
Person
+O+U-D+R
Organization
+O+U-D+R
002

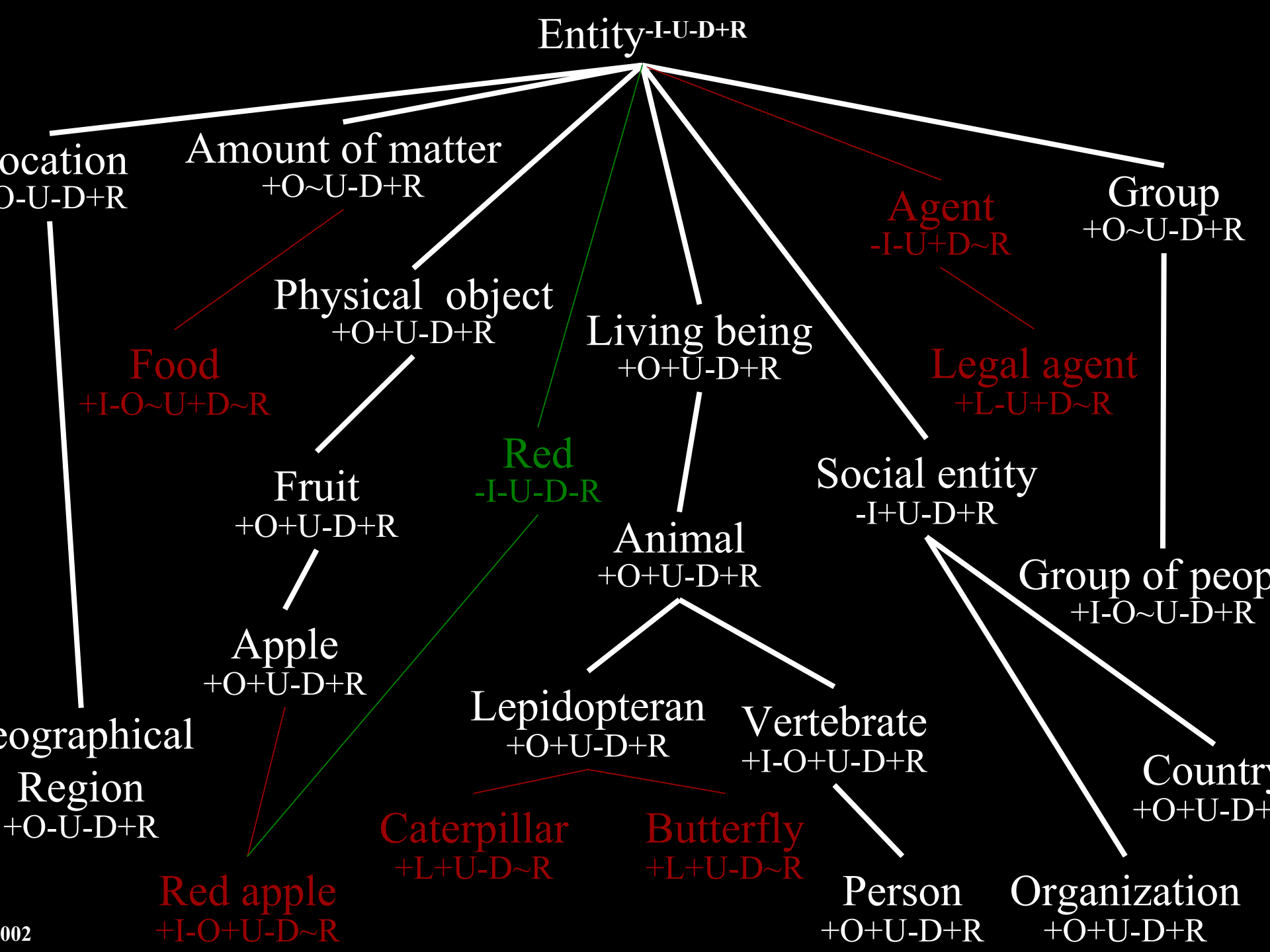

Entity-I-U-D+R
Look for missing typ
• Caterpillars and butterflies cannot be vertebrate
• There must a rigid property that subsumes the two, supplying identity *across temporary phases*
Agent
-I-U+D~R
Group
+O~U-D+R
Living being
+O+U-D+R
Legal agent
+L-U+D~R
Social entity
-I+U-D+R
Fruit
+O+U-D+R
Animal
+O+U-D+R
Group of peop
+I-O~U-D+R
Apple
+O+U-D+R
Lepidopteran
+O+U-D+R
Vertebrate
+I-O+U-D+R
eographical
Region
+O-U-D+R
Caterpillar
+L+U-D~R
Butterfly
+L+U-D~R
Country
+O+U-D+
Person
+O+U-D+R
Organization
+O+U-D+R
002

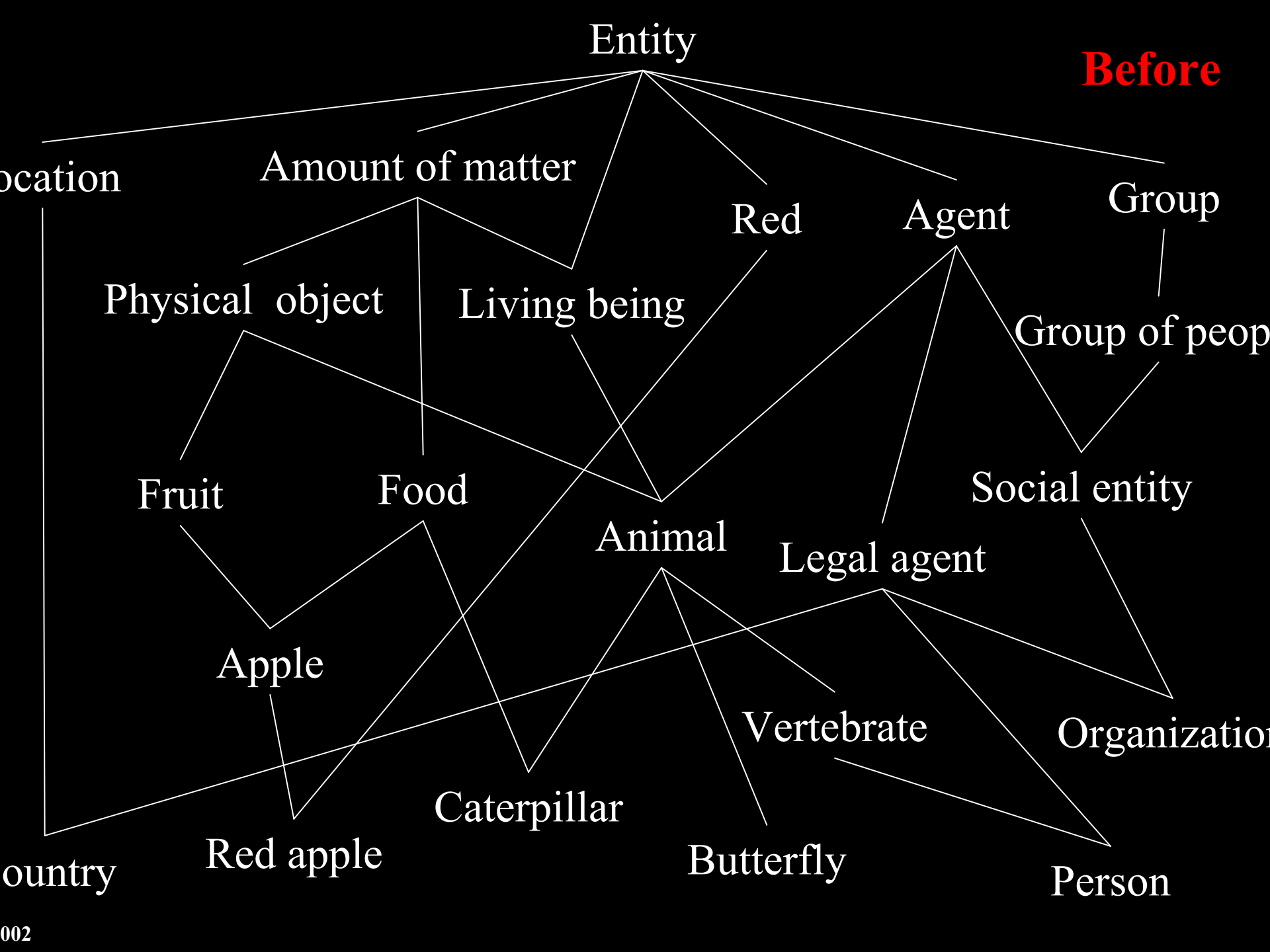

Entity-I-U-D+R
Look for missing type
ocation
O-U-D+R
Amount of matter
+O~U-D+R
Agent
-I-U+D~R
Group
+O~U-D+R
Physical object
+O+U-D+R
Living being
+O+U-D+R
Food
+I-O~U+D~R
Legal agent
+L-U+D~R
Fruit
+O+U-D+R
Social entity
-I+U-D+R
Animal
+O+U-D+R
Group of peop
+I-O~U-D+R
Apple
+O+U-D+R
eographical
Region
+O-U-D+R
Lepidopteran
+O+U-D+R
Vertebrate
+I-O+U-D+R
Country
+O+U-D+
Caterpillar
+L+U-D~R
Butterfly
+L+U-D~R
Person
+O+U-D+R
Organization
+O+U-D+R
002

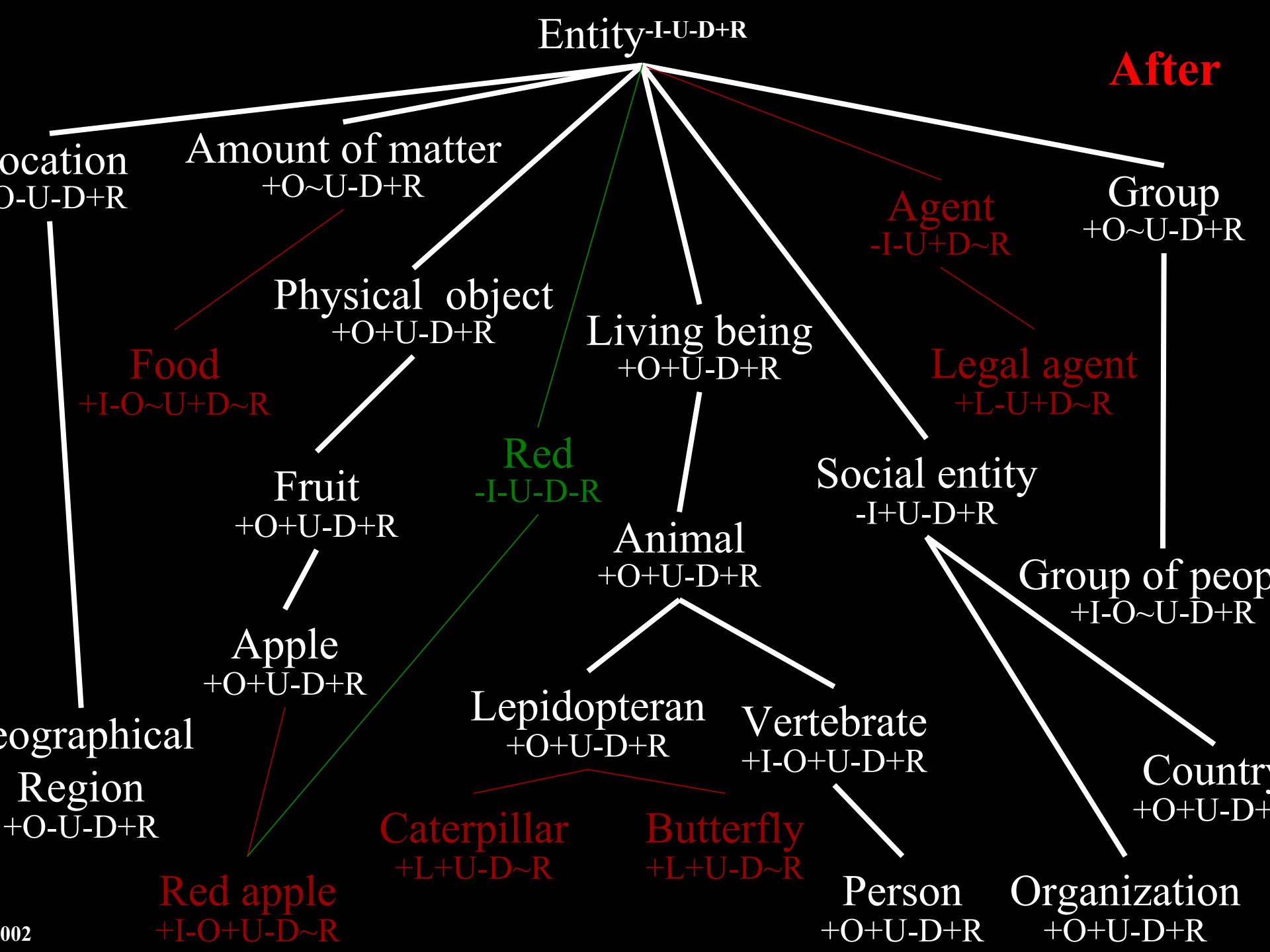

Entity-I-U-D+R
Analyze Attributio
ocation
O-U-D+R
Amount of matter
+O~U-D+R
Physical object
+O+U-D+R
Food
+I-O~U+D~R
Fruit
+O+U-D+R
Apple
+O+U-D+R
Red
-I-U-D-R
Living
+O+U
Anin
+O+U-
Group
+I-O~U-D+R
No violations
Attributions are discouraged, can be confusing.
Often better to use attribute values (i.e. Apple Color red)
eographical
Region
+O-U-D+R
Red apple
+I-O+U-D~R
Lepidopteran
+O+U-D+R
Caterpillar
+L+U-D~R
Butterfly
+L+U-D~R
Vertebrate
+I-O+U-D+R
Person
+O+U-D+R
Organization
+O+U-D+R
Country
+O+U-D+
002


Entity-I-U-D+R
ocation
O-U-D+R
Amount of matter
+O~U-D+R
Physical object
+O+U-D+R
Food
+I-O~U+D~R
Fruit
+O+U-D+R
Apple
+O+U-D+R
eographical
Region
+O-U-D+R
Red
-I-U-D-R
Red apple
+I-O+U-D~R
Living being
+O+U-D+R
Animal
+O+U-D+R
Lepidopteran
+O+U-D+R
Caterpillar
+L+U-D~R
Butterfly
+L+U-D~R
Vertebrate
+I-O+U-D+R
Agent
-I-U+D~R
Legal agent
+L-U+D~R
Social entity
-I+U-D+R
Person
+O+U-D+R
Group
+O~U-D+R
Group of peop
+I-O~U-D+R
Country
+O+U-D+
Organization
+O+U-D+R
002


Entity-I-U-D+R
The backbone taxonomy
ocation
O-U-D+R
Amount of matter
+O~U-D+R
Physical object
+O+U-D+R
Living being
+O+U-D+R
Group
+O~U-D+R
Fruit
+O+U-D+R
Social entity
-I+U-D+R
Animal
+O+U-D+R
Group of peop
+I-O~U-D+R
Apple
+O+U-D+R
eographical
Region
+O-U-D+R
Lepidopteran
+O+U-D+R
Vertebrate
+I-O+U-D+R
Country
+O+U-D+
Person
+O+U-D+R
Organization
+O+U-D+R
002


Entity -I-U-D+R
ocation
O-U-D+R
Amount of matter
+O~U-D+R
Physical object
+O+U-D+R
Food
+I-O~U+D~R
Fruit
+O+U-D+R
Apple
+O+U-D+R
eographical
Region
+O-U-D+R
Red apple
+I-O+U-D~R
Red
-I-U-D-R
Living being
+O+U-D+R
Animal
+O+U-D+R
Lepidopteran
+O+U-D+R
Caterpillar
+L+U-D~R
Butterfly
+L+U-D~R
Vertebrate
+I-O+U-D+R
Person
+O+U-D+R
Agent
-I-U+D~R
Legal agent
+L-U+D~R
Social entity
-I+U-D+R
Organization
+O+U-D+R
Group
+O~U-D+R
Group of peop
+I-O~U-D+R
Country
+O+U-D+
002


Before
Entity
ocation
Amount of matter
Red
Agent
Group
Physical object
Living being
Group of peop
Fruit
Food
Social entity
Animal
Legal agent
Apple
Vertebrate
Organizatio
Caterpillar
ountry
Red apple
Butterfly
Person
002


Entity-I-U-D+R
After
ocation
O-U-D+R
Amount of matter
+O~U-D+R
Physical object
+O+U-D+R
Food
+I-O~U+D~R
Fruit
+O+U-D+R
Apple
+O+U-D+R
eographical
Region
+O-U-D+R
Red apple
+I-O+U-D~R
Red
-I-U-D-R
Living being
+O+U-D+R
Animal
+O+U-D+R
Lepidopteran
+O+U-D+R
Caterpillar
+L+U-D~R
Butterfly
+L+U-D~R
Vertebrate
+I-O+U-D+R
Person
+O+U-D+R
Agent
-I-U+D~R
Legal agent
+L-U+D~R
Social entity
-I+U-D+R
Group
+O~U-D+R
Group of peop
+I-O~U-D+R
Country
+O+U-D+
Organization
+O+U-D+R
002

Use OntoClean for all your ontology cleaning needs!