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# *BFO Deep Dive Part 2*

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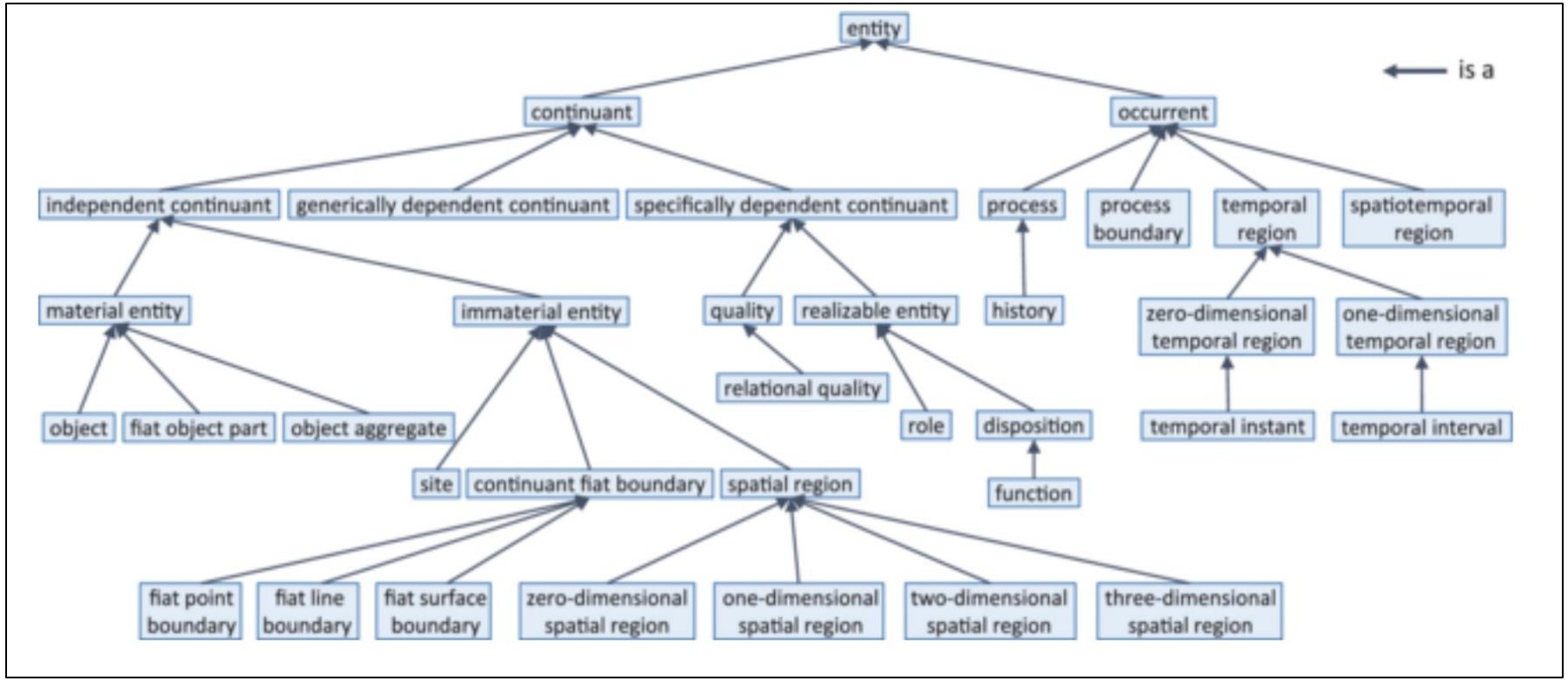
Affiliate Faculty, *Institute of Artificial Intelligence and Data Science*

# ***Basic Formal Ontology***

Created by **Barry Smith**, BFO is that top-level architecture, used by over 700 open-source projects, including various ontology Foundry efforts

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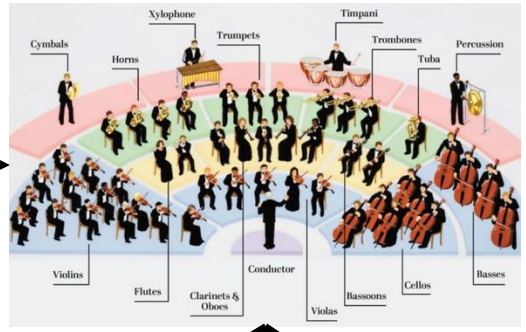
# *Beethoven's #9th Symphony*

**Beethoven's #9**

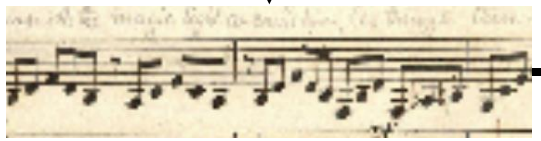
*is about*



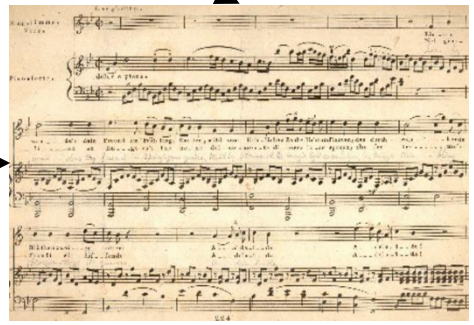

*generically depends on*

*concretized in*

*concretized in*



*inheres in*



*has realization*

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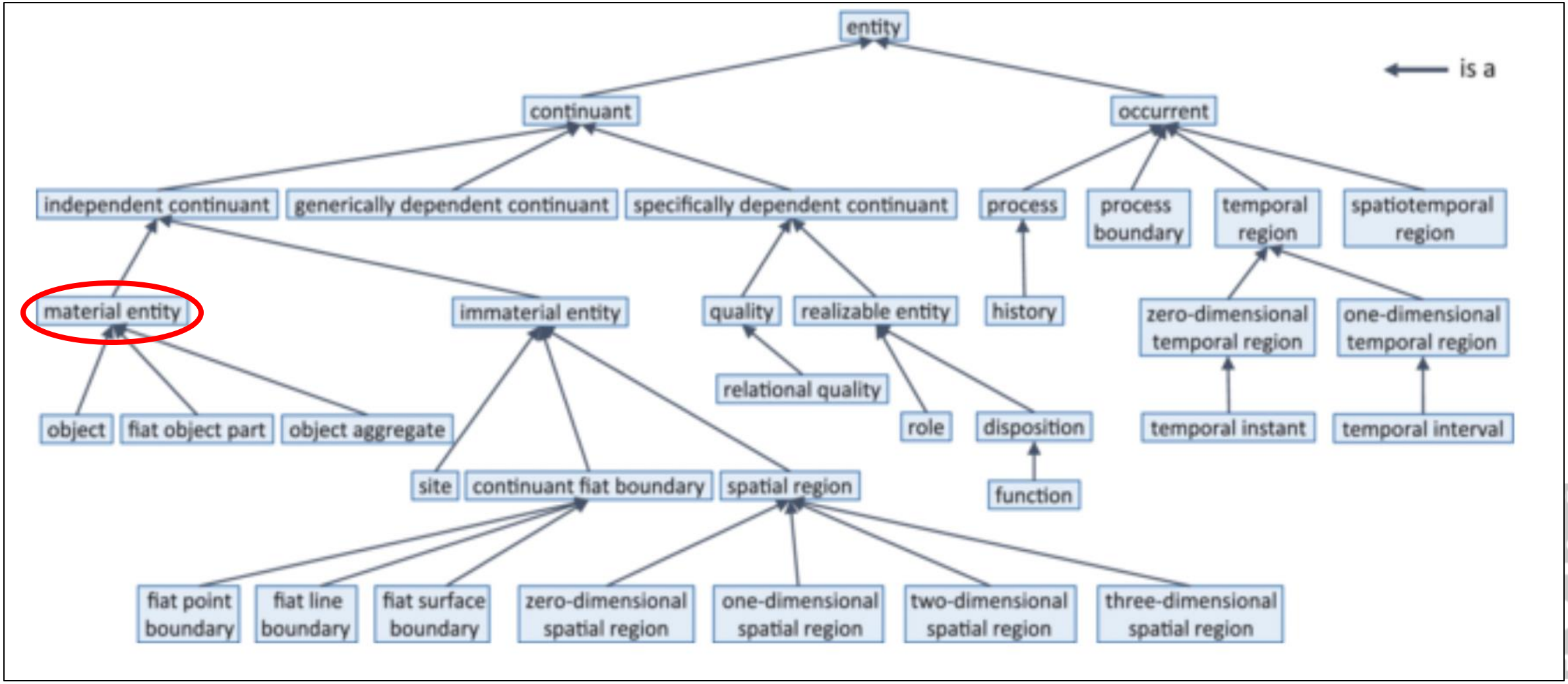
# *Material Entity*



# *Material Entity*

- Many independent continuants discussed thus far depend on instances falling under the class **Material Entity**, which includes all independent continuants having matter as part

- Apples, people, cars, blankets, viruses, tanks, etc. thus fall

- Subclasses include objects, object aggregates, and fiat object parts

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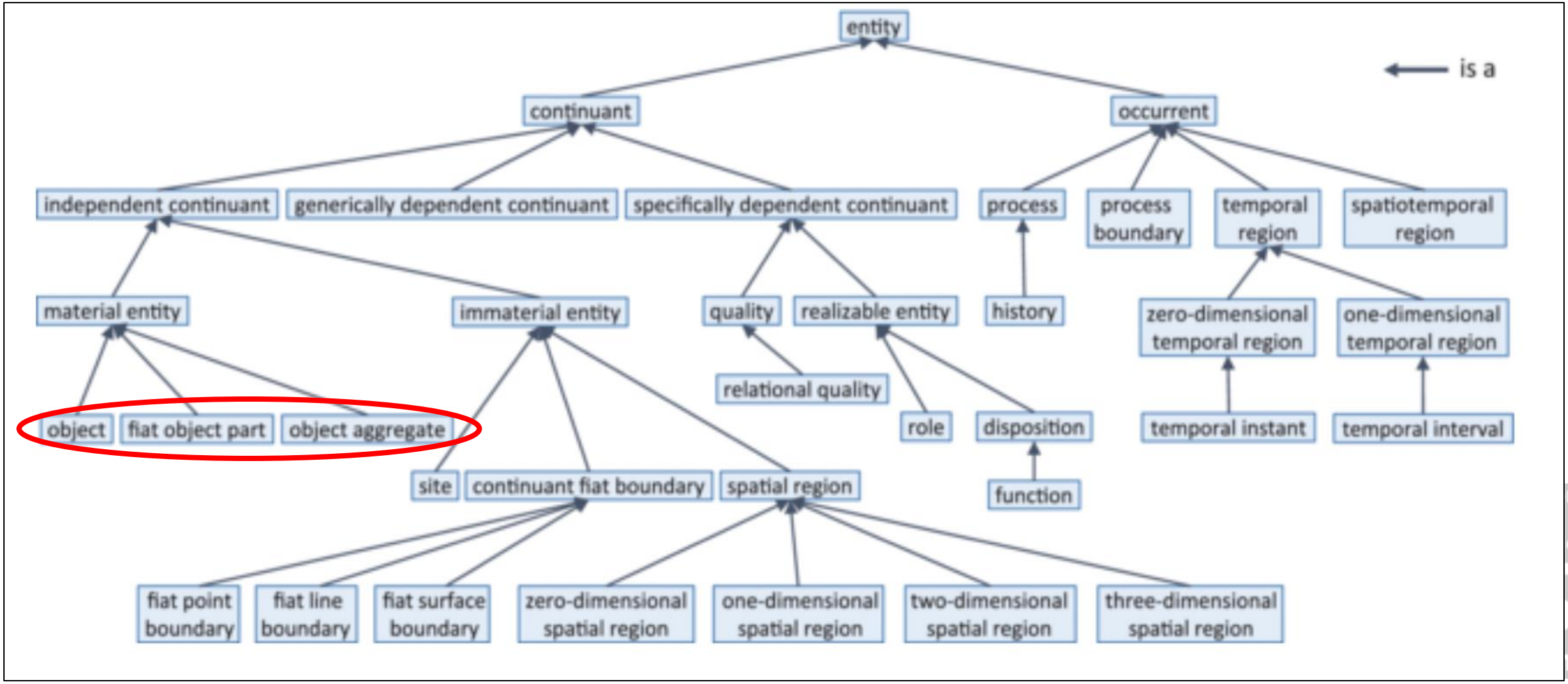
# *Subclasses of Material Entity*



# *Object*

- An object is a material entity that manifests causal unity, where its instances are maximal with respect to that causal unity

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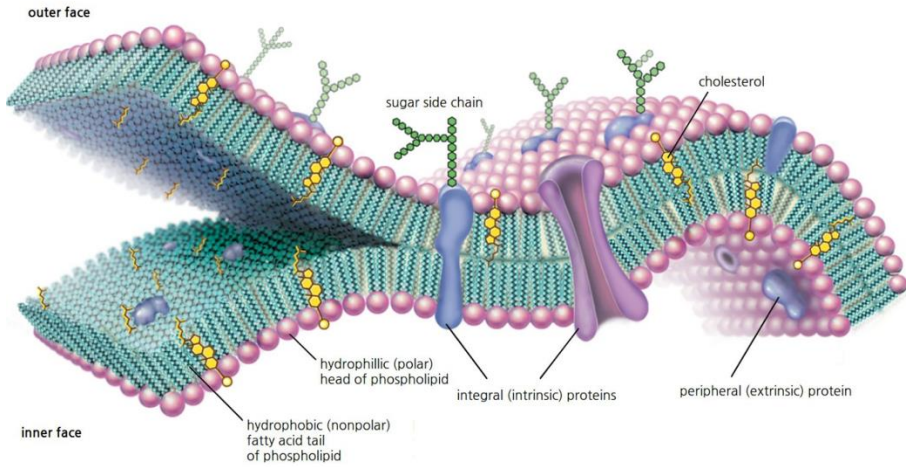
  - Physical covering, e.g. interior of the object are covered by a connected membrane

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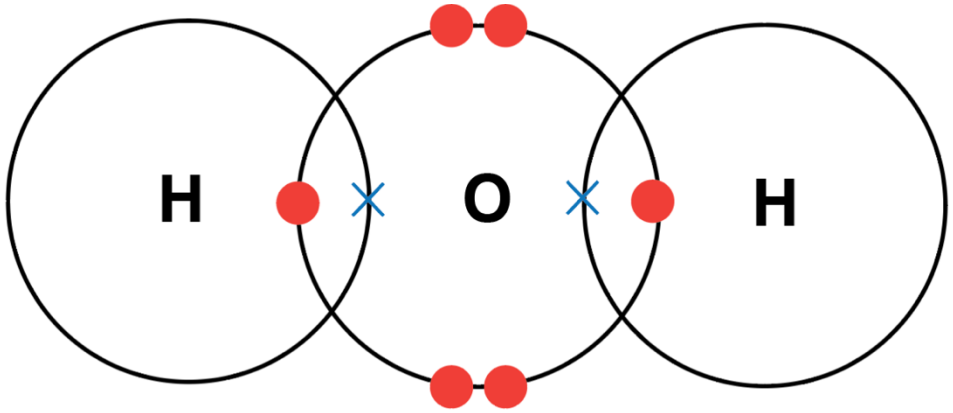


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# *Object*

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- Examples of causal unity:
  - Physical covering, e.g. interior of the object are covered by a connected membrane
  - Internal forces, e.g. ionic bonds holding together molecules
  - Engineered assembly, e.g. mechanical assembly through screws or fasteners

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# *Rule of Thumb*

**If moving a proper part of some material entity requires moving other material parts of that entity, there is likely causal unity between them**

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- To say x is maximal with respect to causal unity is to say x is:
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- For example, relative to causal unity by covering, your torso is not maximal, but the whole of you as an organism is maximal

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# *Object Aggregate*

- Defined such that any and all members of the aggregate are objects which do not share any parts in common, i.e. are pairwise disjoint

- For example, one can define the object aggregate that is all instruments in an orchestra, or all members of a band

- More generally, the "X aggregate" is intended to be a recipe that may be applied to other classes, e.g. "aggregate of roles"

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# *Fiat Object Part*

- Certain parts of objects that are not themselves objects, warrant catergorization beyond merely being identified as parts

- For example, a so-called **bona fide** object part of the Earth, which would be an object, such as an island, may be divided into northern and southern **fiat** object parts

- Northern and southern portions of a given island exist regardless of whether we delineate them so

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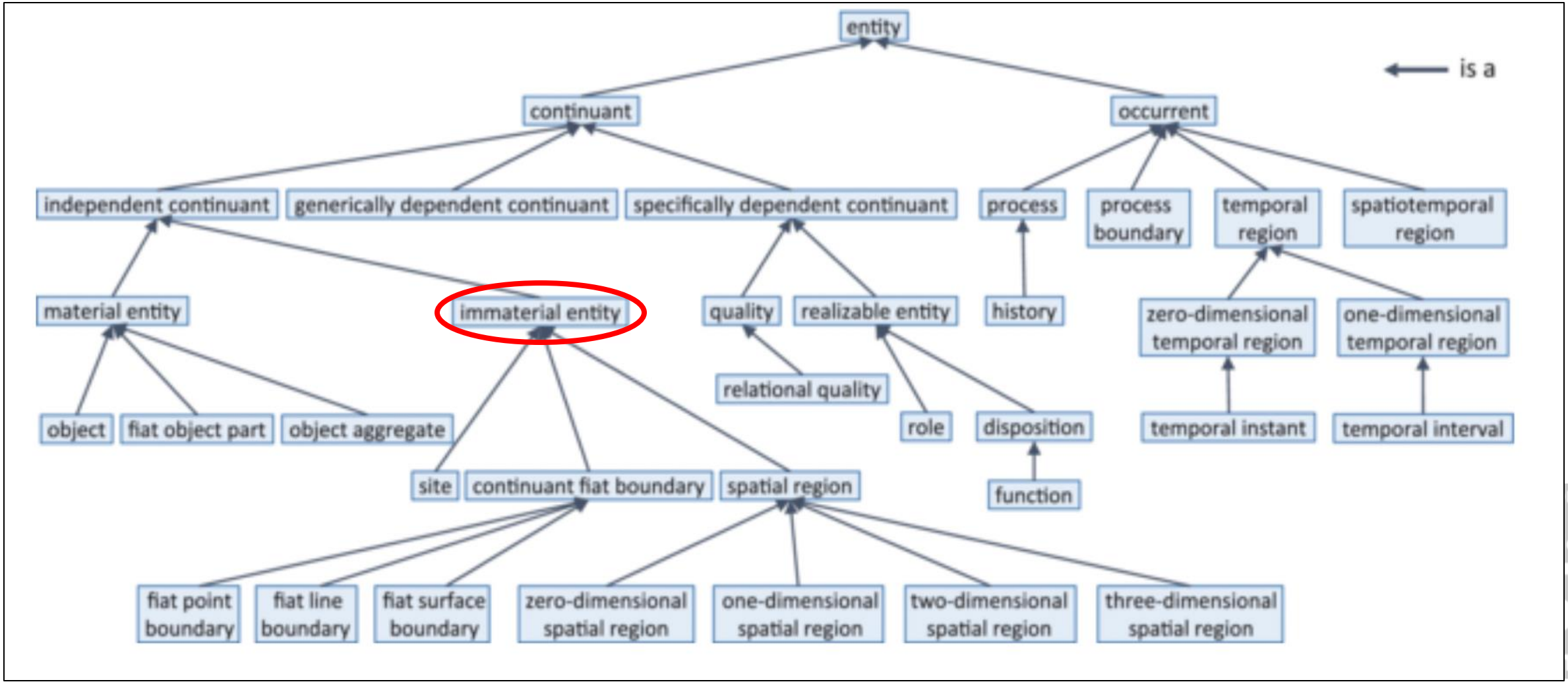
# *Immaterial Entity*



Any entity that has a material entity as part is a material entity

But material entities may have immaterial entities as parts

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# *Immaterial Entity*

- Not all independent continuants have matter as parts

- Territorial boundaries, internal hulls of ships, interiors of capsules, etc. are not identical to whatever material is often associated with them

- For example, an archaeologist seeking the site through which a contemporary river used to flow, is not looking for the material the river used to flow through, for that is lost to time

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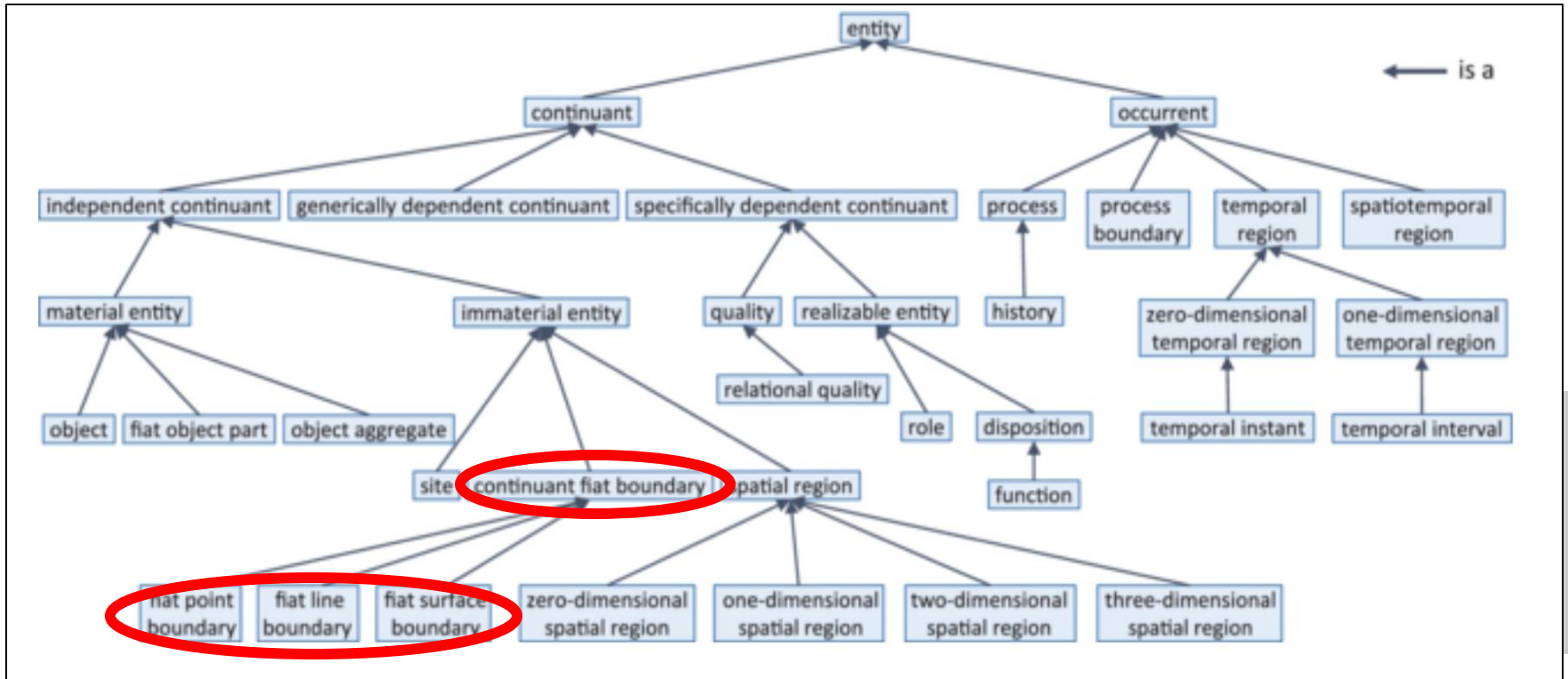
# *Continuant Fiat Boundary*

- *Continuant Fiat Boundary* $=_{\text{def}}$ An immaterial entity such that there is no time t when it has a spatial region as continuant part & whose location is determined in relation to some material entity

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- In BFO, **objects** are three-dimensional and have two-dimensional boundaries, e.g. surfaces

- There are no three-dimensional boundaries, because boundaries are always entities of some lower dimension

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# *Dimension Constraint*

- *x* has a lower dimension than *y*
  - irreflexive
  - asymmetric
  - transitive

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# *Dimension Constraint*

- *x* has a lower dimension than *y*
  - irreflexive
  - asymmetric
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**If *x* is boundary of *y* then *x* has lower dimension than *y***

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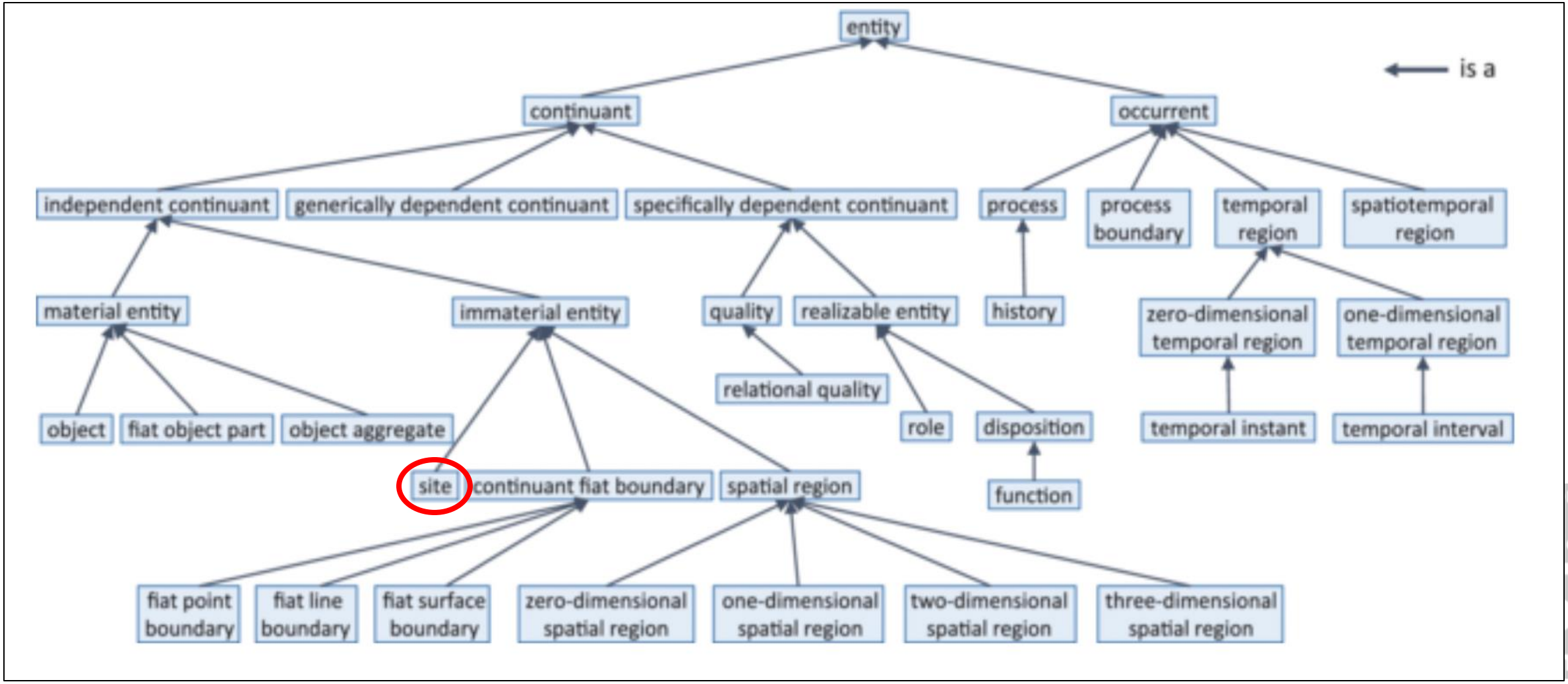
# *Site*


entity
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continuant
occurrent
independent continuant
generically dependent continuant
specifically dependent continuant
process
process boundary
temporal region
spatiotemporal region
material entity
immaterial entity
quality
realizable entity
history
zero-dimensional temporal region
one-dimensional temporal region
relational quality
object
fiat object part
object aggregate
role
disposition
temporal instant
temporal interval
site
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spatial region
function
fiat point boundary
fiat line boundary
fiat surface boundary
zero-dimensional spatial region
one-dimensional spatial region
two-dimensional spatial region
three-dimensional spatial region

# *Site*

- *Site* $=_{\text{def}}$ A three-dimensional immaterial entity whose boundaries either (partially or wholly) coincide with the boundaries of one or more material entities or have locations determined in relation to some material entity

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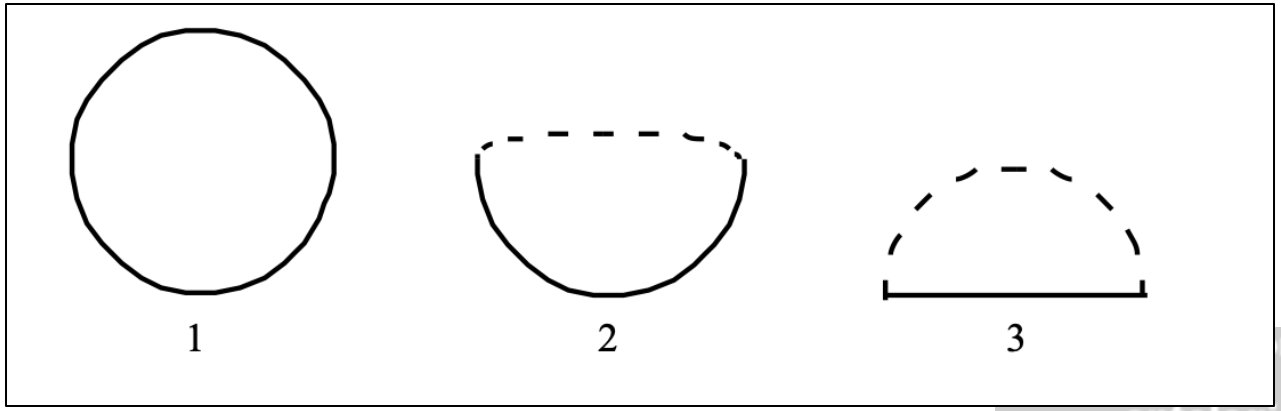
# *Site*

- *Site* $=_{\text{def}}$ A three-dimensional immaterial entity whose boundaries either (partially or wholly) coincide with the boundaries of one or more material entities or have locations determined in relation to some material entity

- Examples:
  - A rabbit hole
  - The interior of your bedroom
  - The hold of a ship
  - The cockpit of an aircraft

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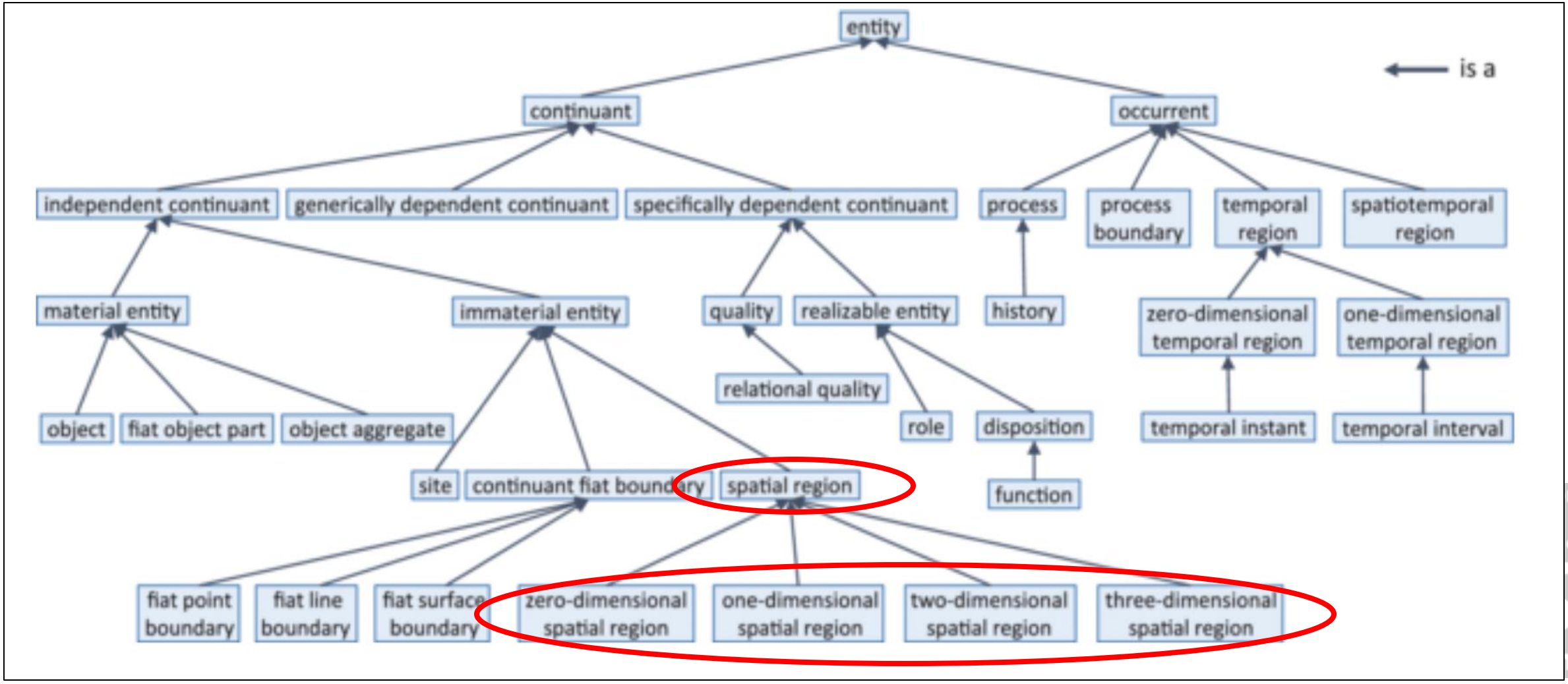
# *Spatial Region*



# *Spatial Regions*

- *Spatial Region* $=_{\text{def}}$ A continuant that is continuant part of the spatial projection of a portion of spacetime at a given time

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**Cosmological Principle: Spatial distribution of matter in the universe is uniformly isotropic and homogeneous.**

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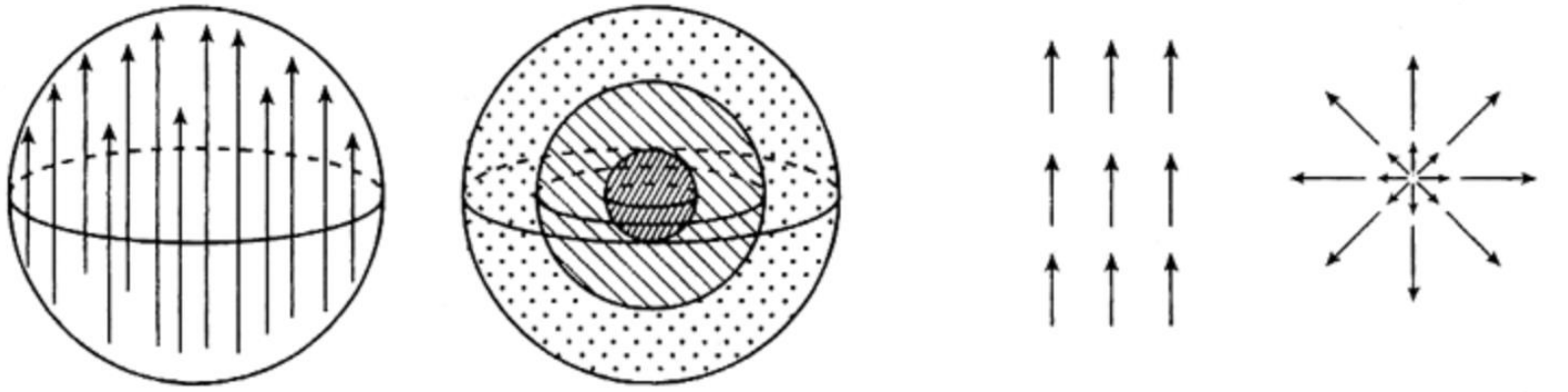


**Figure 1.5** Illustrations of how homogeneity and isotropy are not equivalent in (a) three dimensions and (b) two dimensions. In the first example of each, a unique direction is picked out but translation invariance is maintained. In the second example of each, all directions are the same (rotation invariance) but a radial gradient exists.

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- *spatially projects onto* $=_{\text{def}}$ Holds between spatiotemporal region *s* and spatial region *r* at some time *t* such that *r* is the spatial extent of *s* at *t*

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**spatial projection is exact, i.e. there is no *r'* of which *r* is proper part such that *s* spatially projects onto *r'***

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# *Dependence*

- For certain entities, their existence depends on the existence of something else
- Other entities do not depend on any other entities for their existence
- The latter are categorized in BFO as **independent continuants**
- The former include **specifically dependent** and **generically dependent entities**, as well as **processes**

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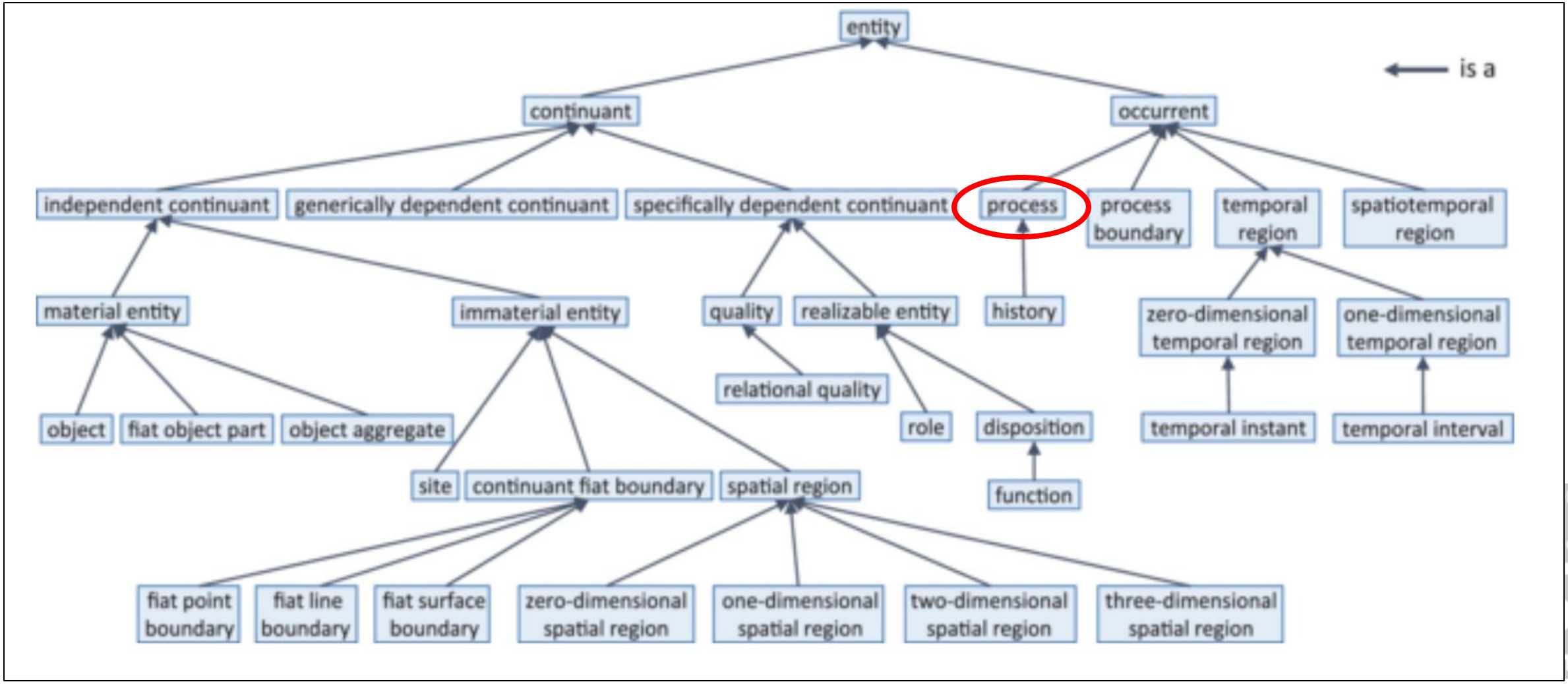
# *Process*


entity
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process boundary
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immaterial entity
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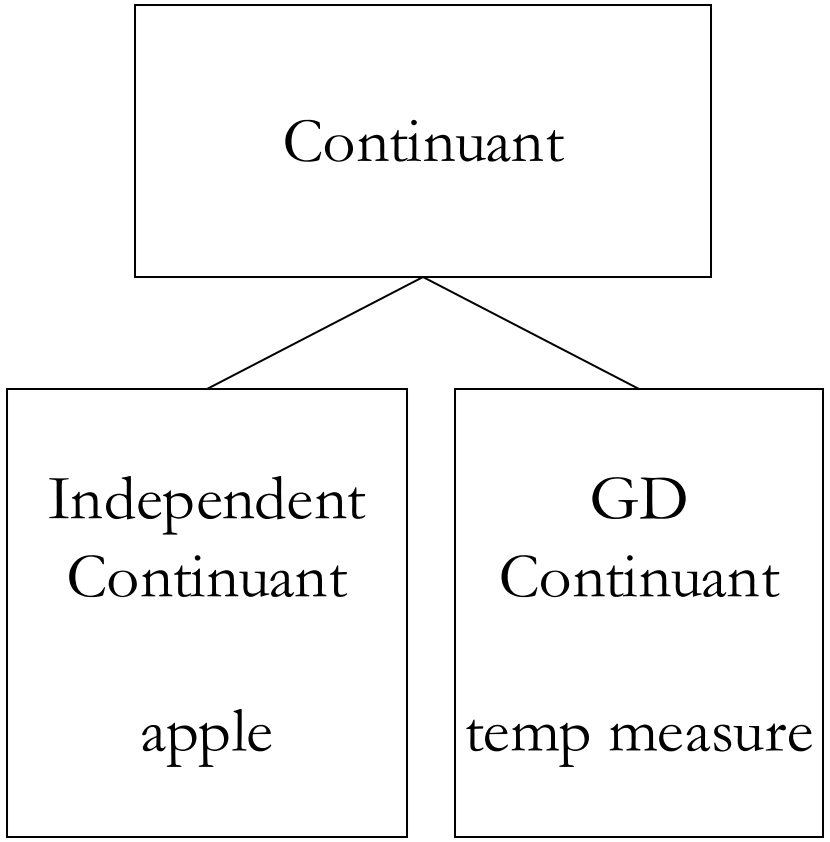
# *Process*




Occurrent

process, event

**Some occurrent entities depend on continuants**

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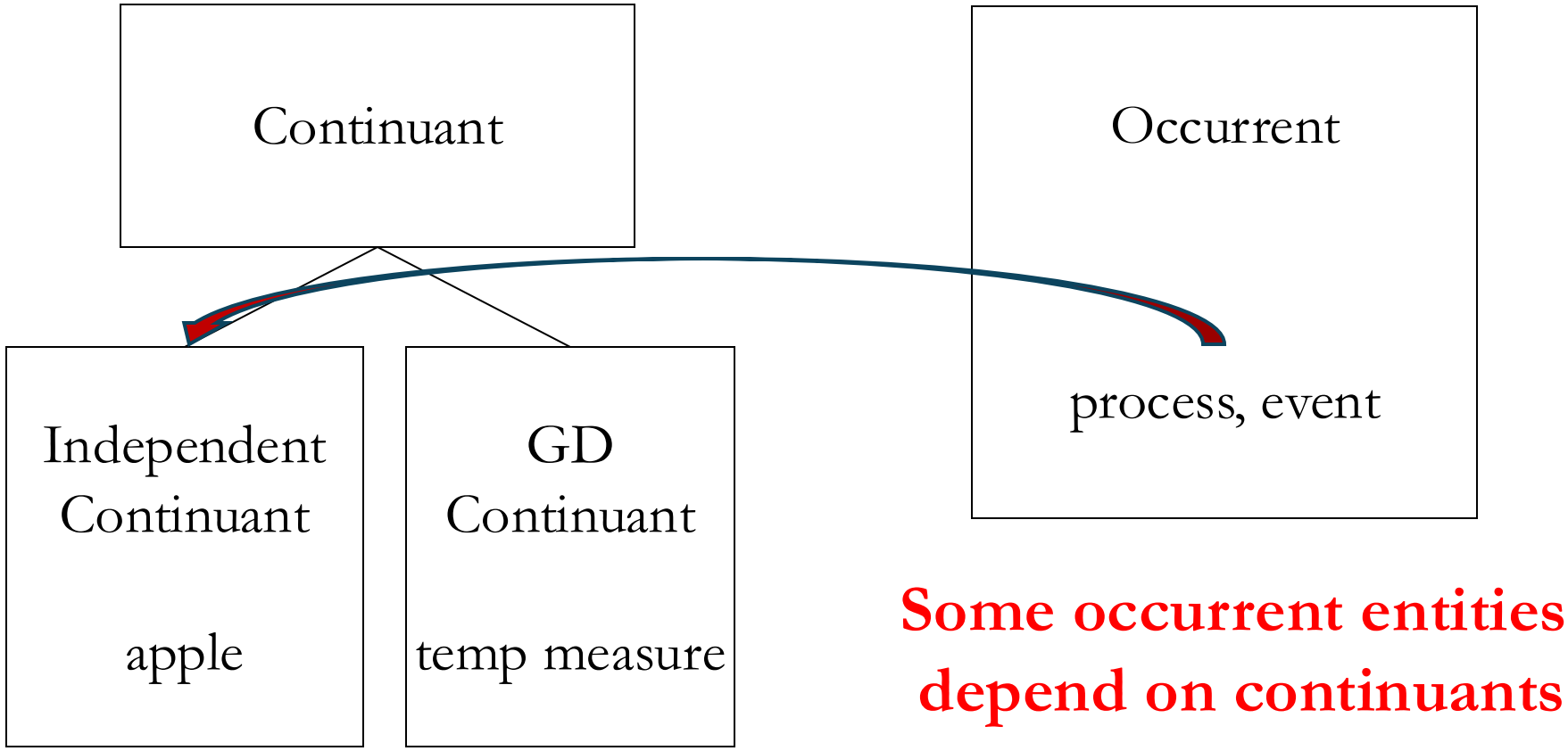
# *Process*

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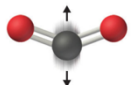
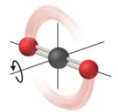

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# *Processes*

- Are where happenings live…
- All processes in BFO have at least one **temporal part** and are such that there is some **material entity** which **participates in** the process
- **participates in** is a minimal relationship connecting specifically, generically, and independent continuants to **process**

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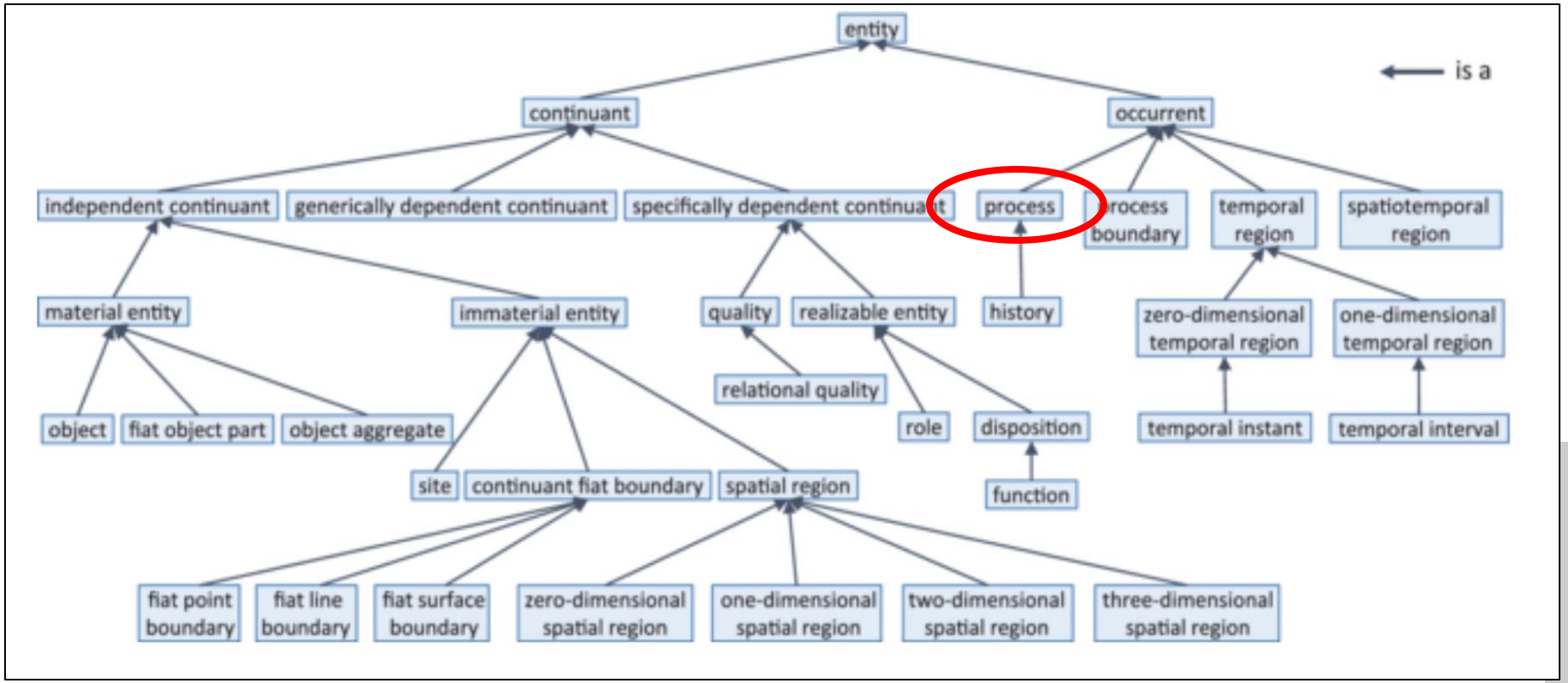
# *Dependency Chain*

- A given **process** may have realization some realizable entity, which inheres in some independent continuant

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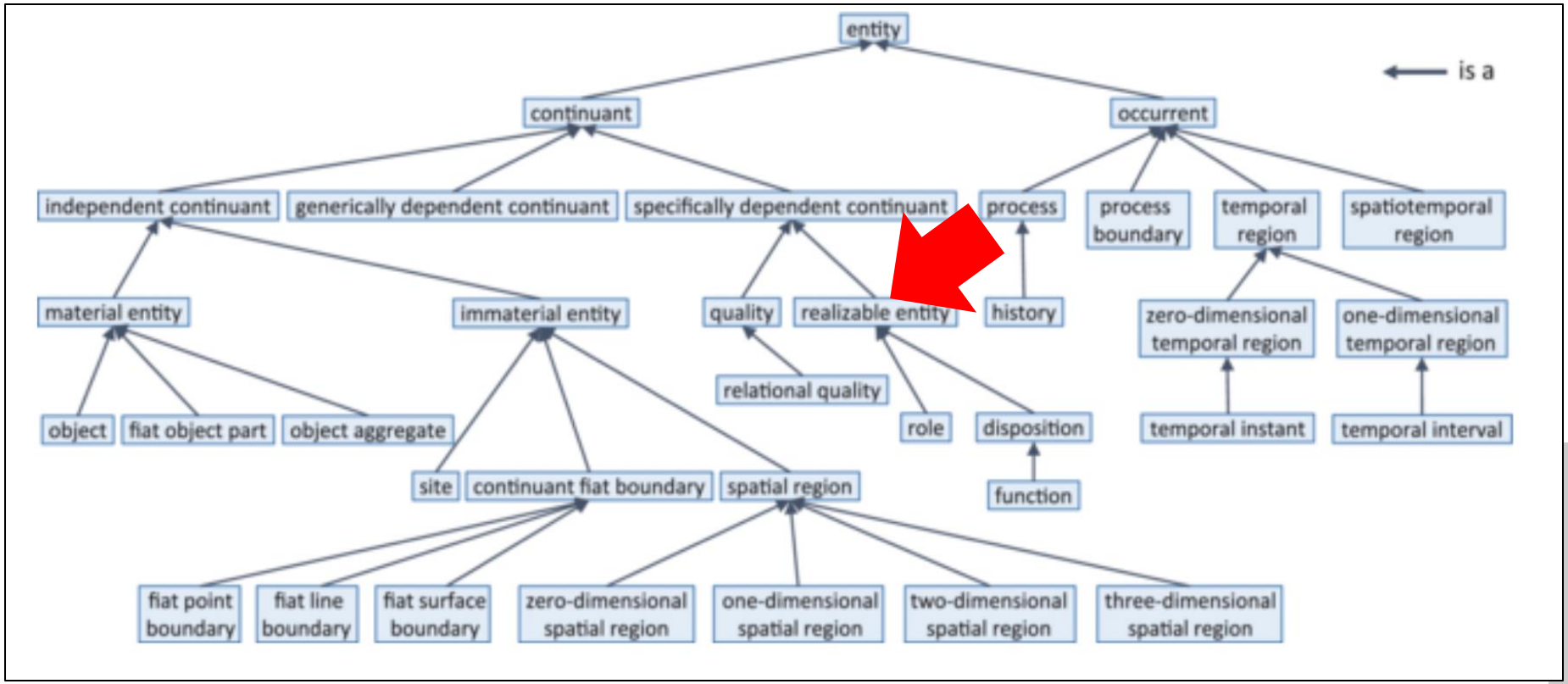


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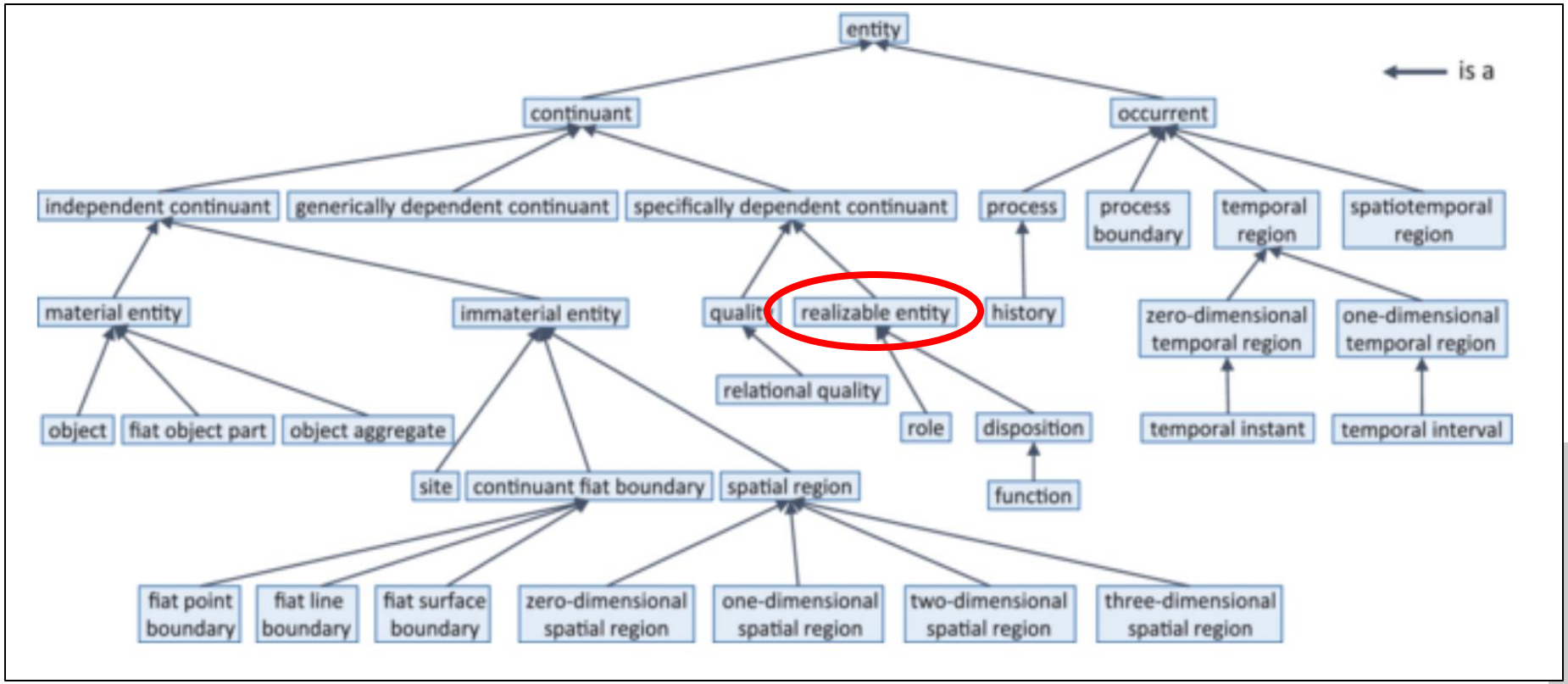


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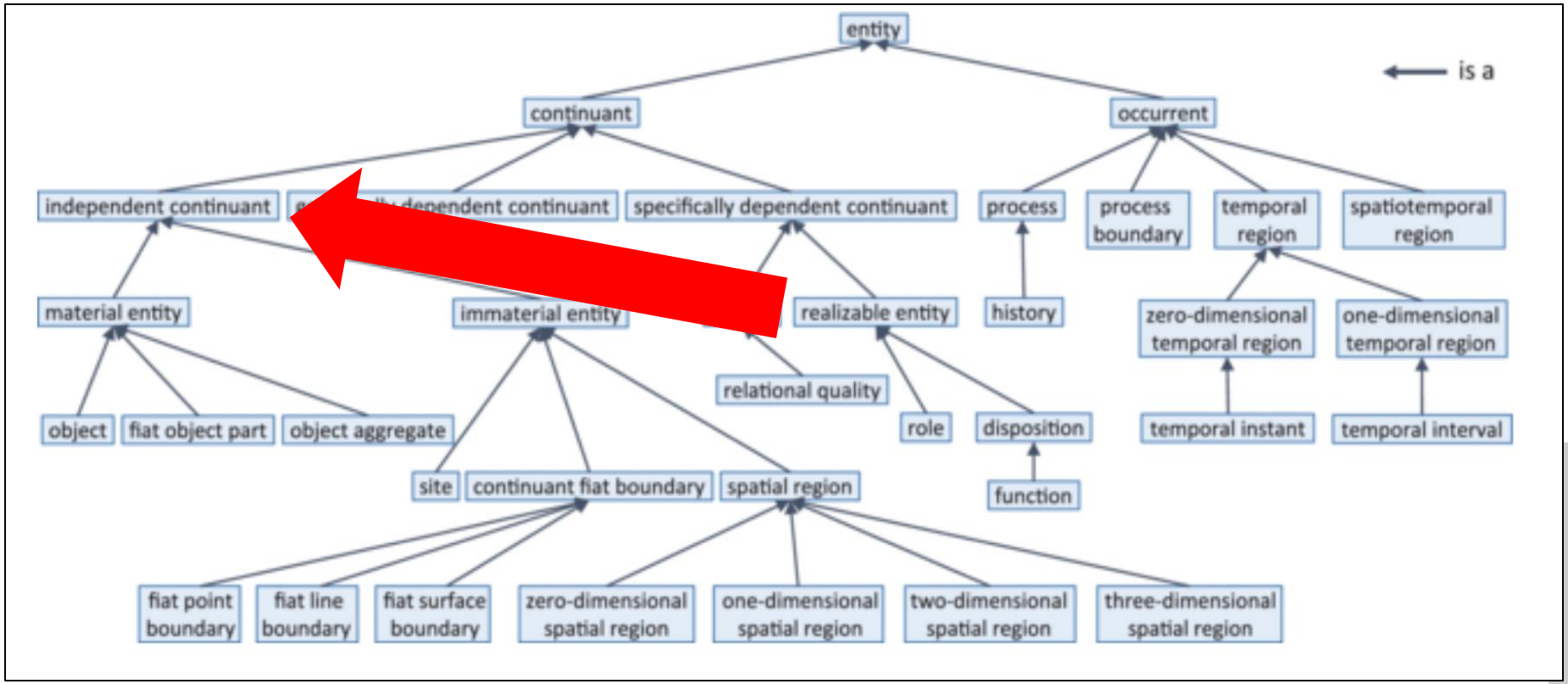


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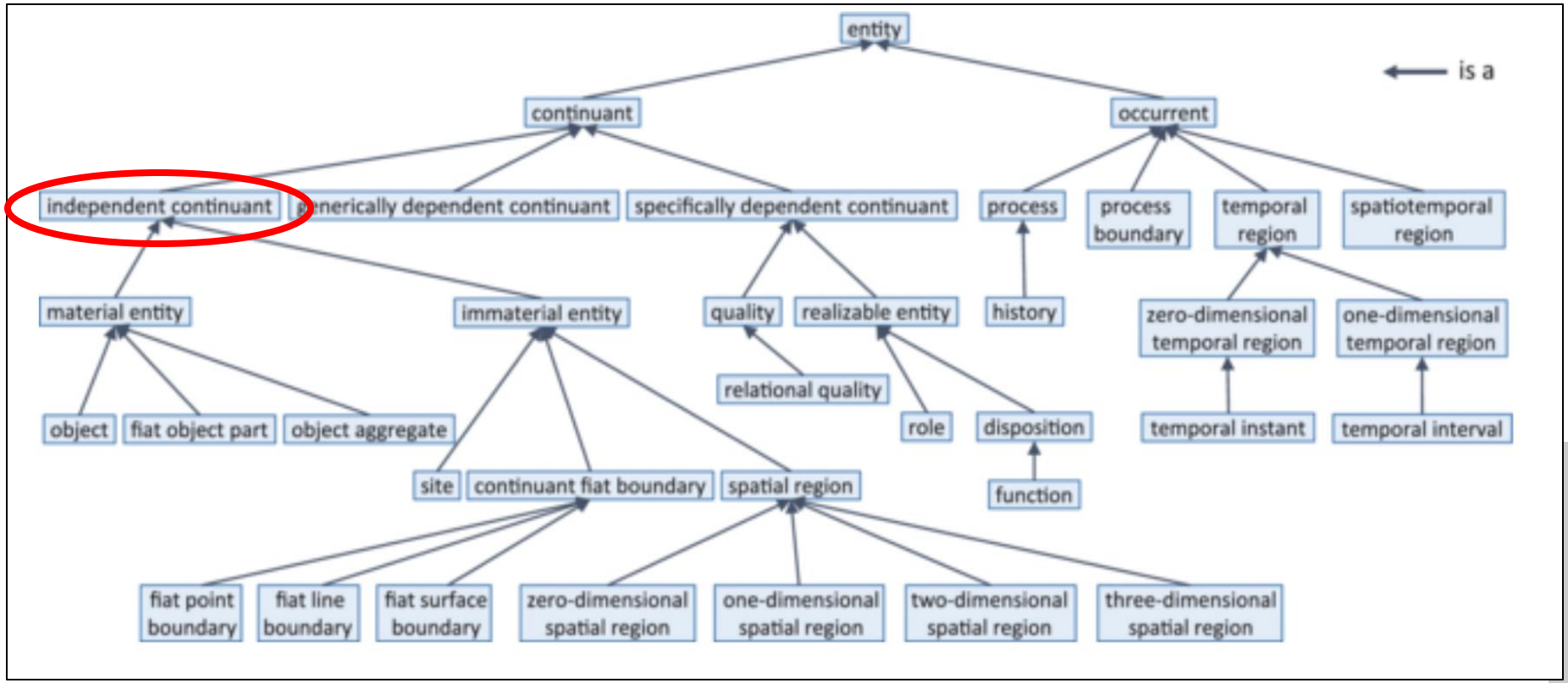


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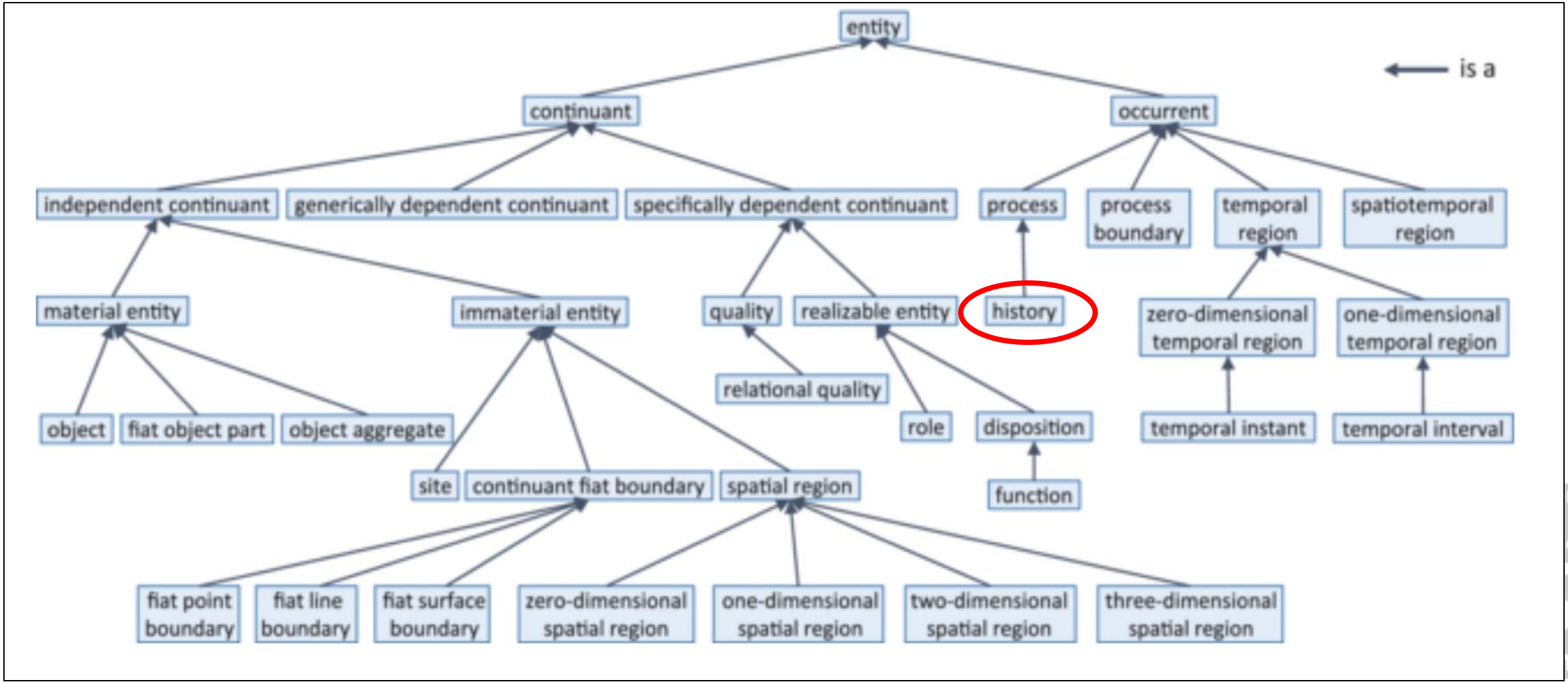
# History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three-dimensional spatial region

# *History*

- Is the sum total of all processes associated with a given material entity

- Every instance of history corresponds to one and only one instance of material entity; any instance of material entity corresponds to one and only one instance of history

- For example, the history that is my life is my history and mine alone, just as the history of the material entity that is this building belongs to the building

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# *Change over Time*

- In BFO, instances of material entities:

# *Change over Time*

- In BFO, instances of material entities:
  - Have matter as parts

# *Change over Time*

- In BFO, instances of material entities:
  - Have matter as parts
  - Gain or lose qualities,

# *Change over Time*

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# *Change over Time*

- In BFO, instances of material entities:
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  - Gain or lose qualities, parts, occupy different locations, etc.

# *Change over Time*

- In BFO, instances of material entities:
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  - Gain or lose qualities, parts, occupy different locations, etc. over the course of their history

# *Change over Time*

- In BFO, instances of material entities:
  - Have matter as parts
  - Gain or lose qualities, parts, occupy different locations, etc. over the course of their history

- An apple in an orchard ripens, reddens, and sweetens, before spoiling, developing blotches, etc. on a fruit basket

# *Processes Do Not Change*

- An intuitive understanding of change is the gain or loss of specifically dependent continuants

- In BFO, occurrents do not bear specifically dependent continuants, and so cannot – strictly speaking – gain or lose them

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# *Processes are Changes*

- As a consequence, characterizing:
  - increasing velocity of this vehicle
  - changing direction of this airplane
  - lowered volume of this alarm

- Are not understood in terms of properties of processes

- In BFO, processes do not change, they *are* changes

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# *Participants Do Change*

CASE 3: *A flower is red in the summer. As time passes, the color changes. In autumn the flower is brown.*
GOAL: *The example aims to show if and how the ontology models change in qualities/properties.*
FOCUS: *The change of the color of a flower.*

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# *Participants Do Change*

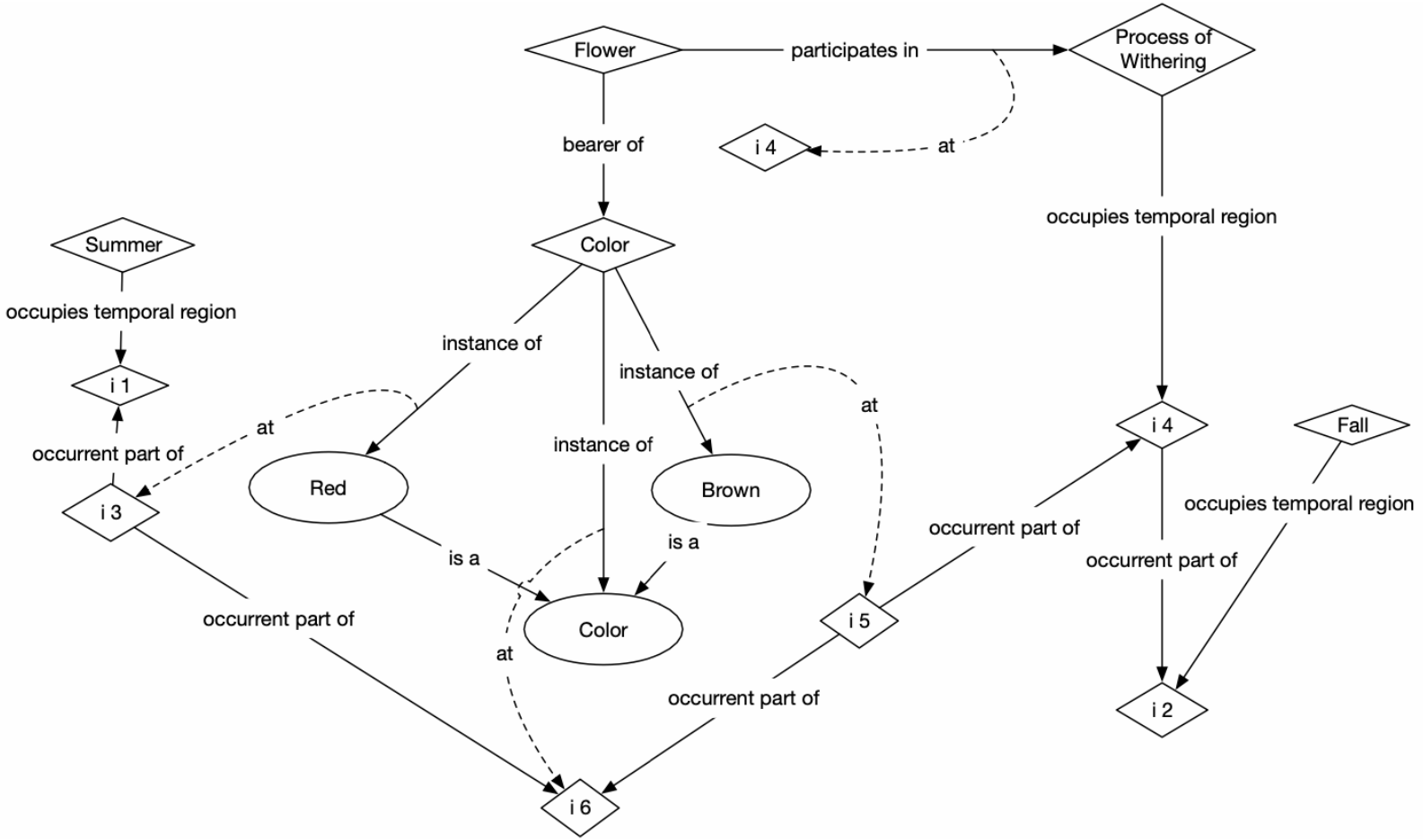


Figure 6: Petal Changing Color in Case 3

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# *Participants Do Change*

**The flower participates in a withering process**

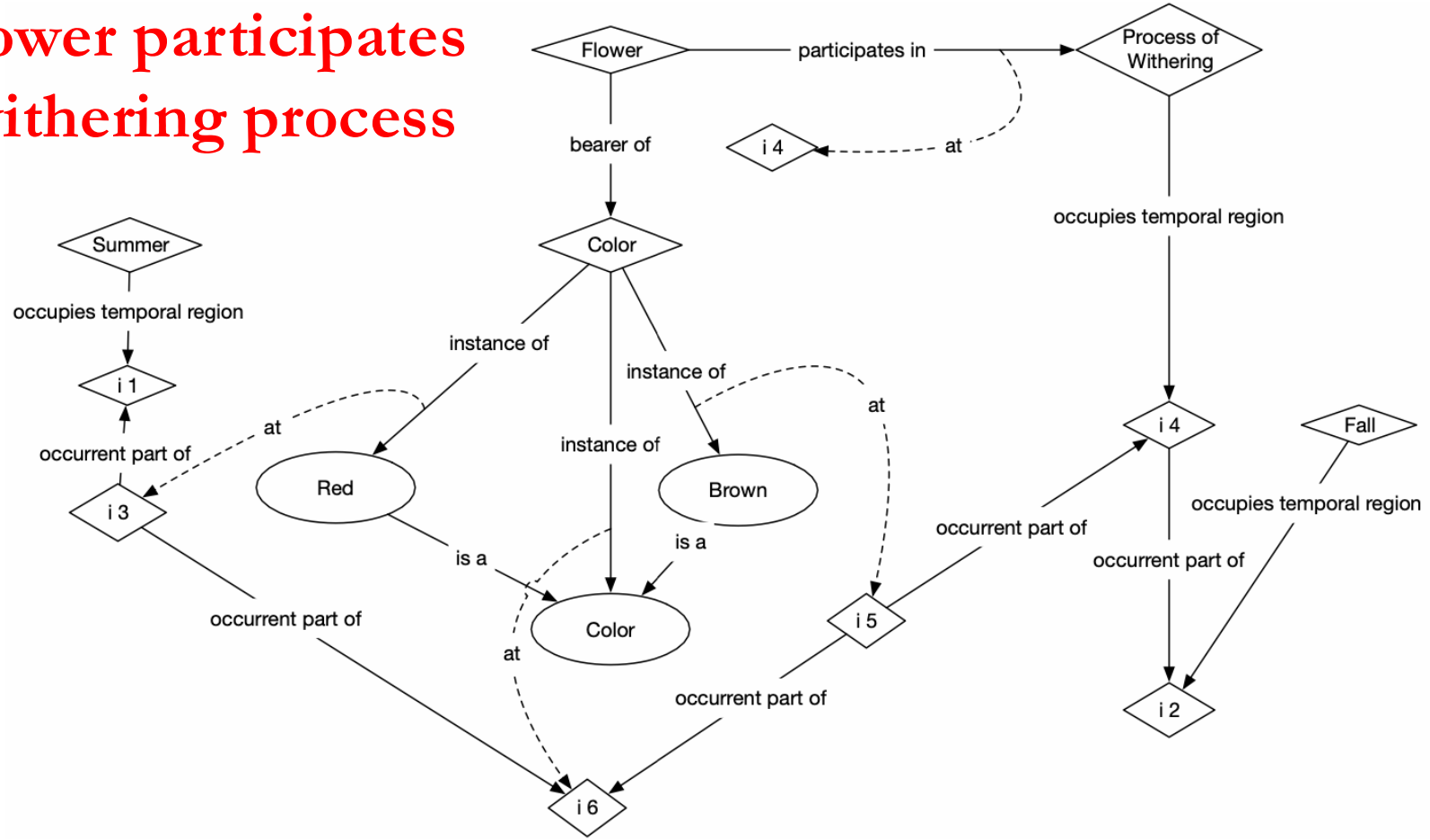


Figure 6: Petal Changing Color in Case 3

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# *Participants Do Change*

**Bearing an instance of red over one interval**

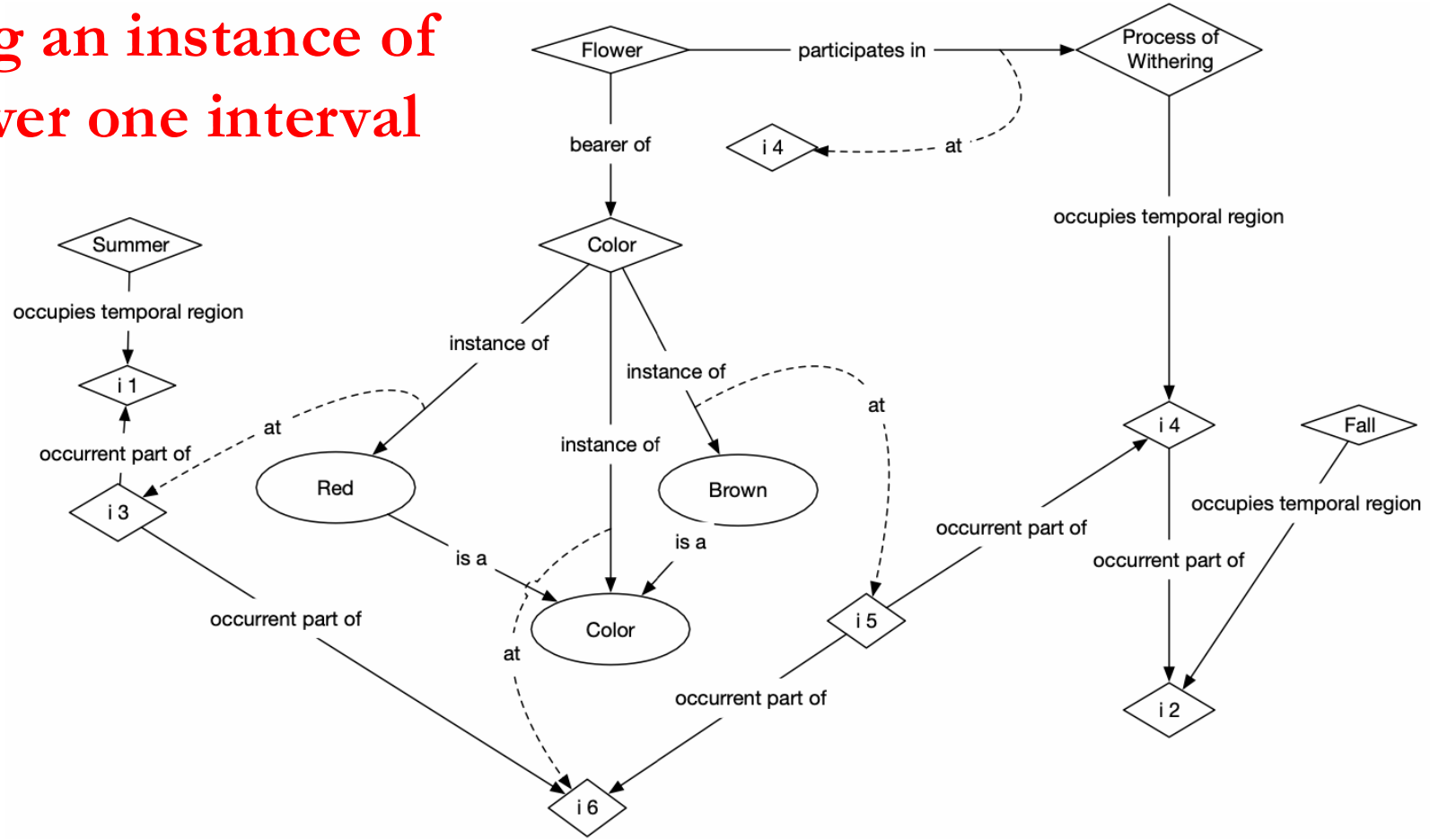


Figure 6: Petal Changing Color in Case 3

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# *Participants Do Change*

**That is later an instance of brown over another**

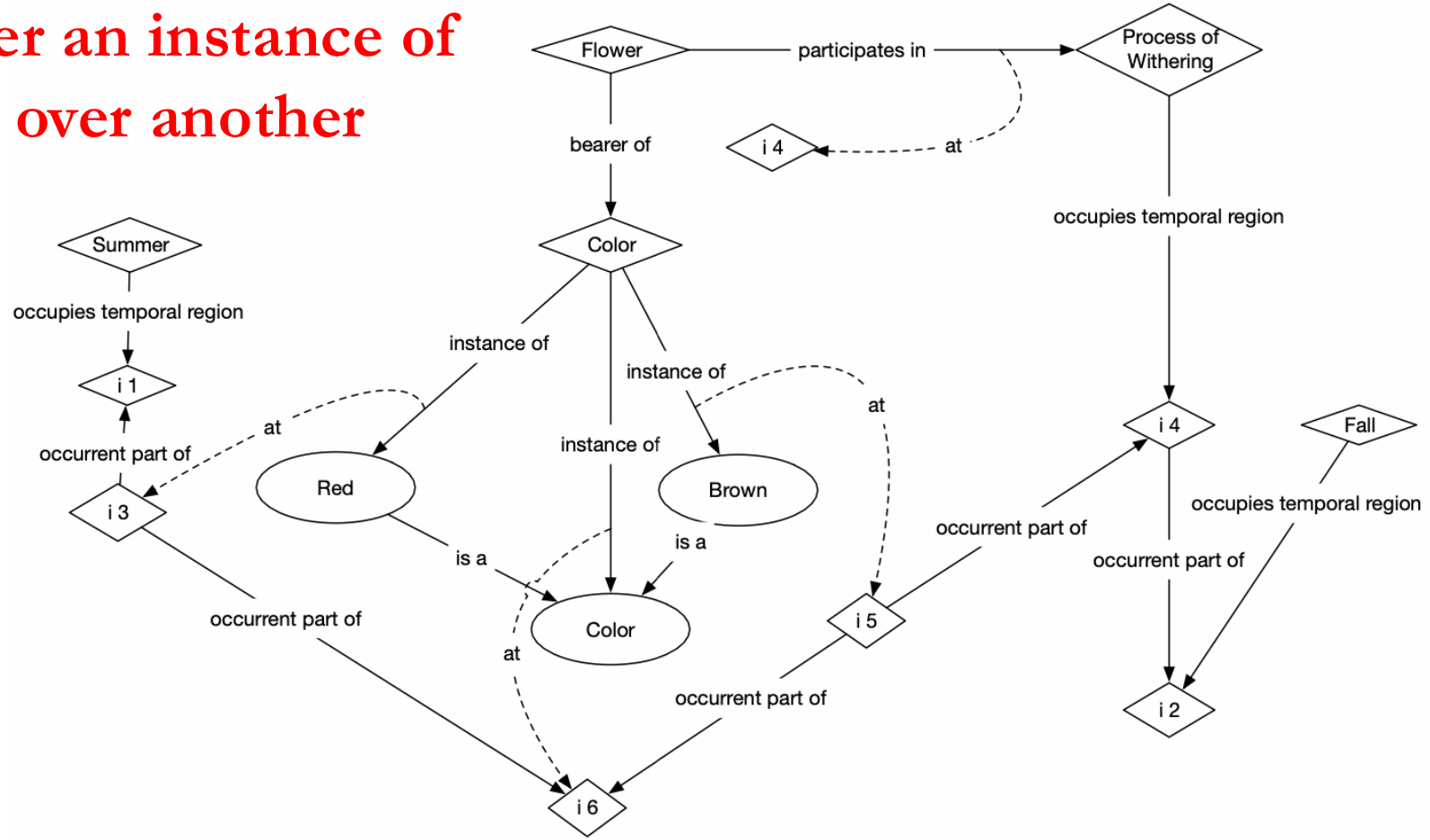


Figure 6: Petal Changing Color in Case 3

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# *Participants Do Change*

**Recall: Determinates vs Determinibles**

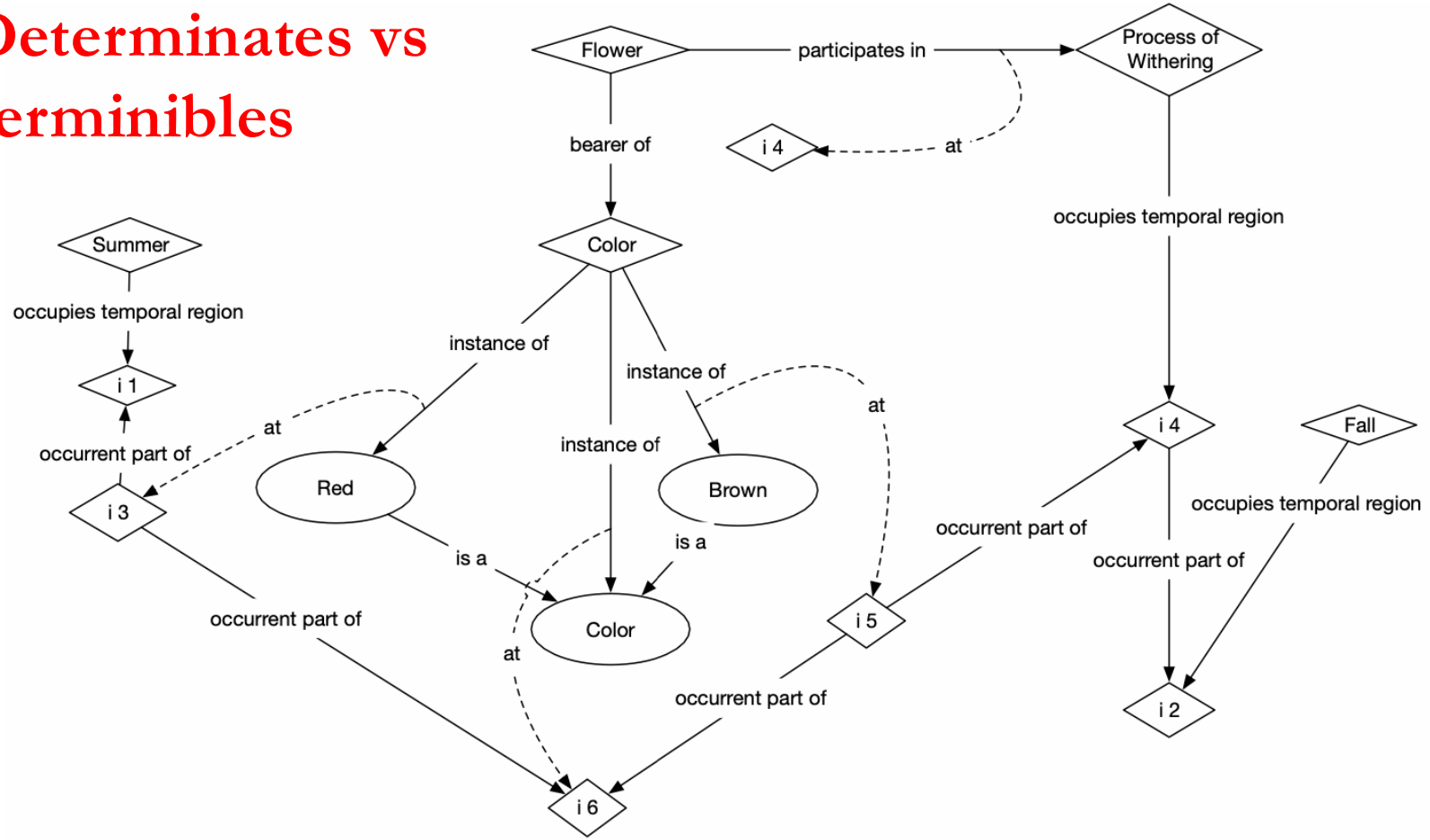


Figure 6: Petal Changing Color in Case 3

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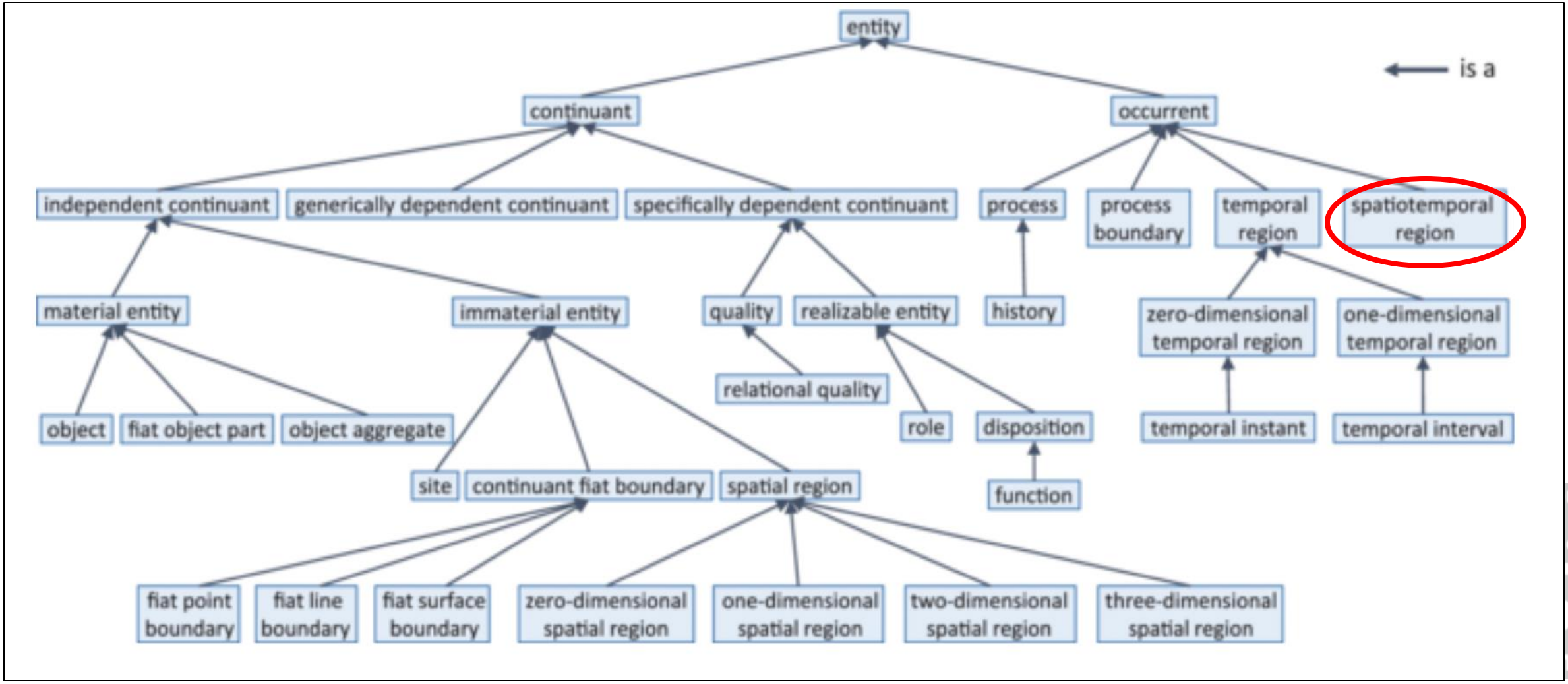
# *Spatiotemporal Region*



# *Spatiotemporal Region*

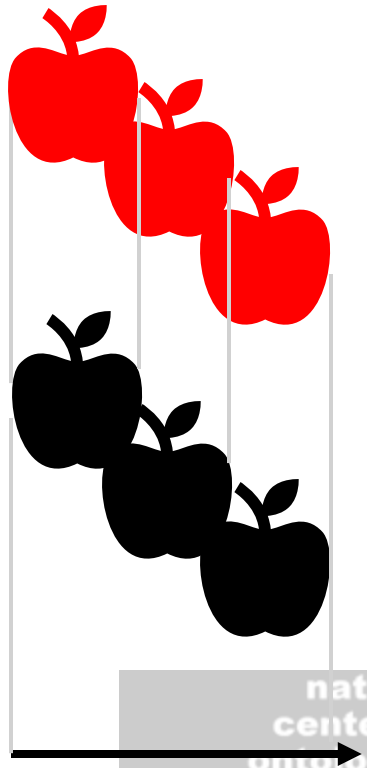
- The history of a material entity occupies some **spatiotemporal region**

- Which is an occurrent part of the instance $\text{spacetime}_R$

- Spatiotemporal regions have both **spatial** and **temporal** extents

# *Spatiotemporal Region*

- The apple occupies a spatial region *r*
- The history of that apple occupies a temporal region *t*
- The history of that apple occupies a spatiotemporal region *s*
  - *s* spatially projects onto *r*
  - *s* temporally projects onto *t*



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# *Spatial Regions*

- *Spatial Region* $=_{\text{def}}$ A continuant that is continuant part of the spatial projection of a portion of spacetime at a given time

- *spatially projects onto* $=_{\text{def}}$ Holds between spatiotemporal region *s* and spatial region *r* at some time *t* such that *r* is the spatial extent of *s* at *t*

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**Spatiotemporal regions are useful and described in terms of spatial regions, so spatial regions are useful**

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# *Information*

- Maps, geospatial coordinate systems, etc. fall under **information** in BFO

- Instances of **information** are patterns that are *about* something

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# *Information*

- Maps, geospatial coordinate systems, etc. fall under **information** in BFO

- Instances of **information** are patterns that are *about* something

**Geospatial information must be about something; spatial regions are what such information is about**

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# *Temporal Region*

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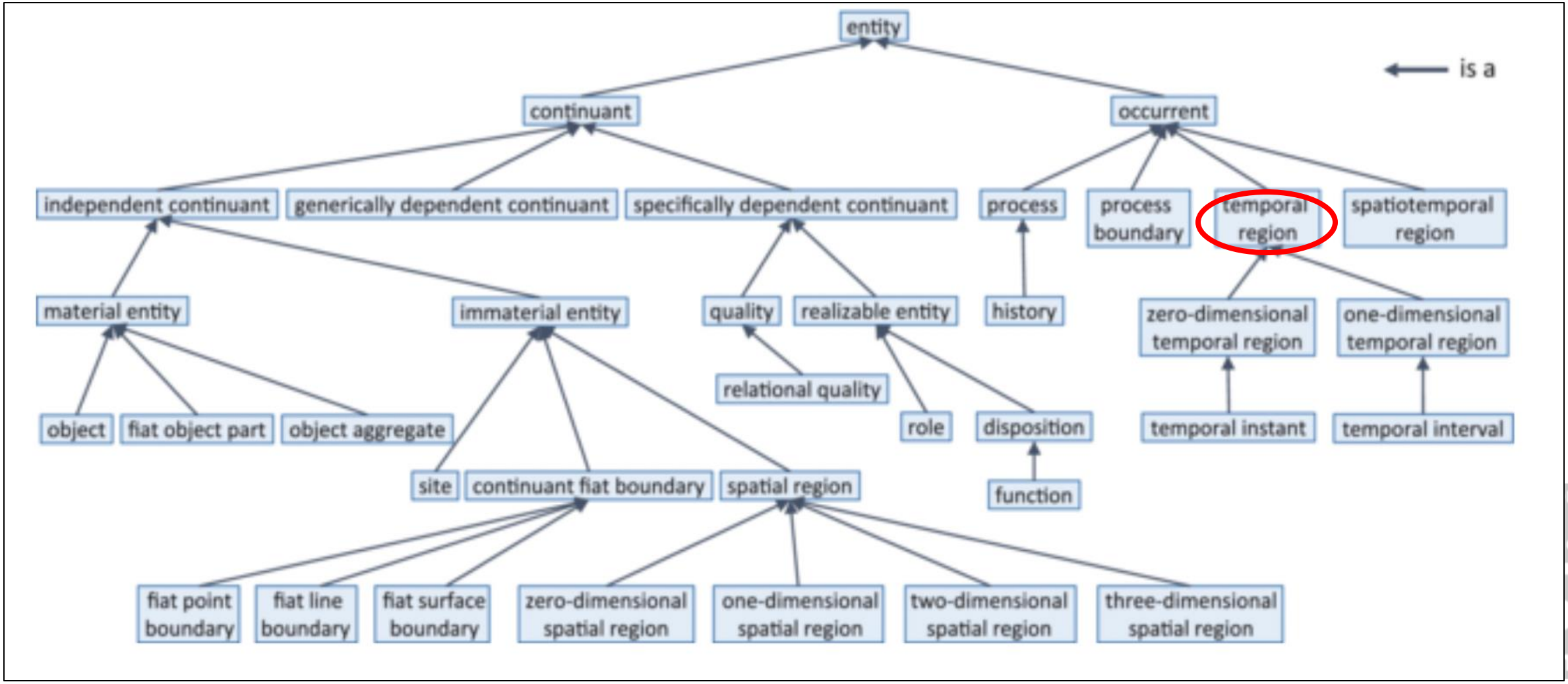
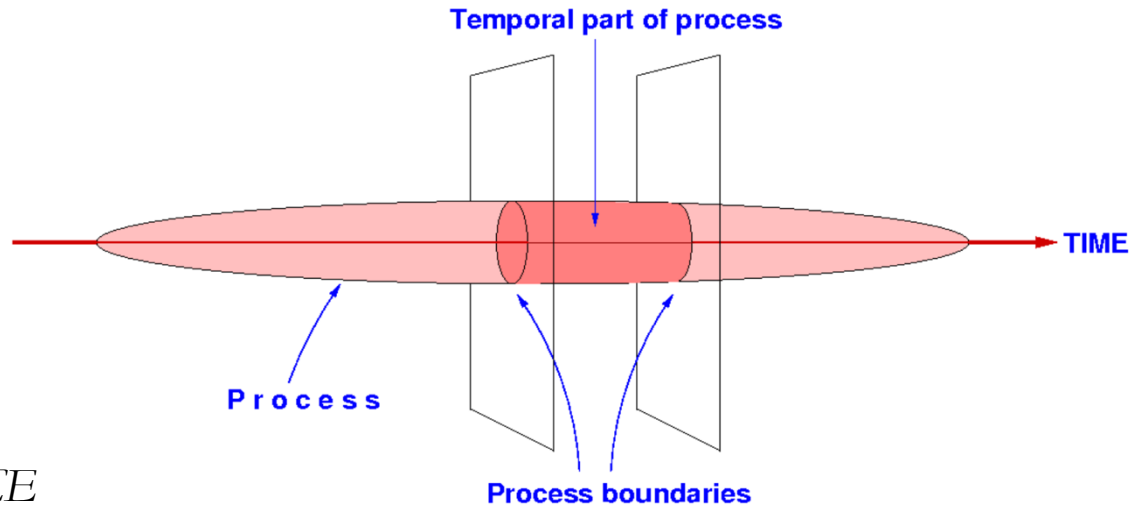
# *Temporal Region*



# *Temporal Region*

- BFO does not distinguish between processes and events
- The process of baking of an apple pie has proper parts, such as cutting apples, preparing pastry crust, etc.
- Proper process parts may be further divided, e.g. cutting of specific apples




** Image from Galton, 2016: Processes and Events in BFO and DOLCE*

# *Changing in Time*

- How might we describe something moving faster over time?

**An instance of motion process *p* has proper temporal parts *x*, *y* such that x is an instance of motion-with-speed-n at $t_1$ and *y* is an instance of motion-with-speed-m at $t_2$ where $t_1$ precedes $t_2$ and n<m**

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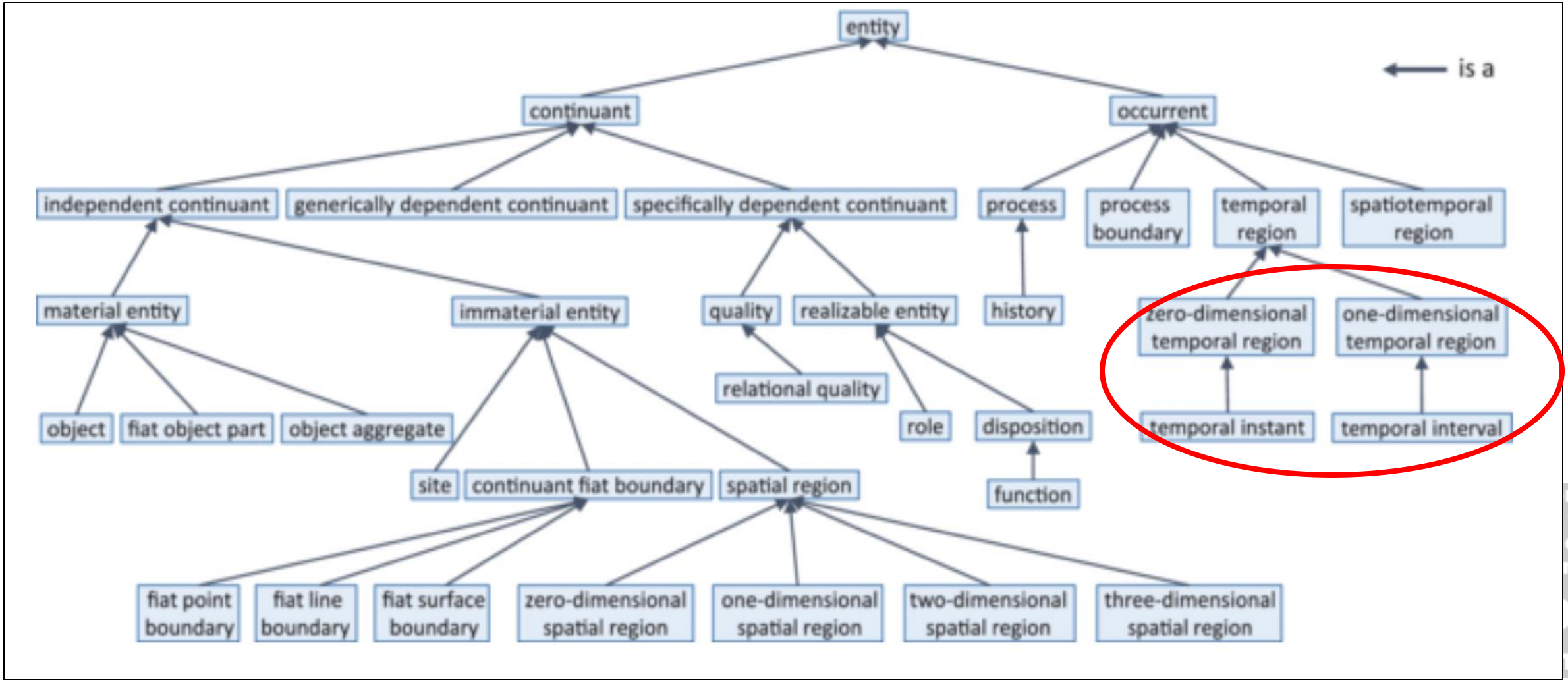
# *Dimensions of Temporal Region*



# *Spatiotemporal Relationships*

Entities are **located_at** spatial regions

Entities **exist_at** temporal regions

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# *Spatiotemporal Relationships*

Entities are **located_at** spatial regions

**Partial: If x is located at r then x is located at least at r**

Entities **exist_at** temporal regions

**Partial: If x exists at t then x exists at least at t**

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# *Spatiotemporal Relationships*

Processes **occupy** spatiotemporal regions

Spatiotemporal regions **project on** spatial and temporal regions

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# *Spatiotemporal Relationships*

Processes **occupy** spatiotemporal regions

**Exact: If p occupies temporal region t then p occupies only t**

Spatiotemporal regions **project on** spatial and temporal regions

**Exact: If s projects on temporal region t then s projects on only t**

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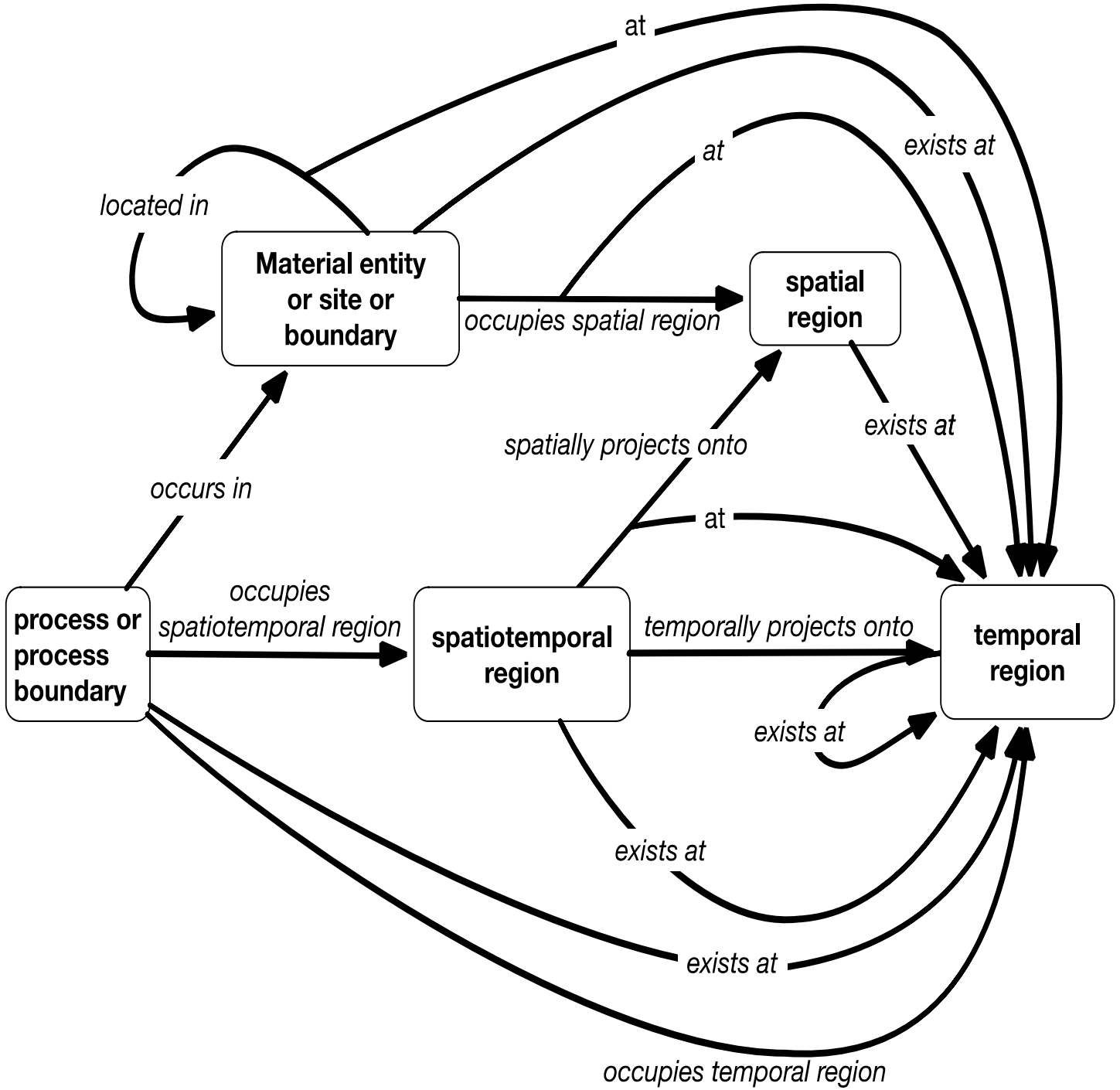


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