

# How to Distinguish Parthood from Location in Bio-Ontologies

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# Ontologies of Biological Structure ("Anatomies")

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- Foundational Model of Anatomy (FMA)
- Human Anatomy portions in OpenGalen, SNOMED CT, NCI ontology,...
- Cell Component branch in Gene Ontology
- Open Biological Ontologies (OBO):
  - Human development
  - Mouse (adult / embryo), Zebrafish, Drosophila, C. elegans,...
  - General plant, maize, cereal plant,...
  - Increasing repository of biological structure descriptions



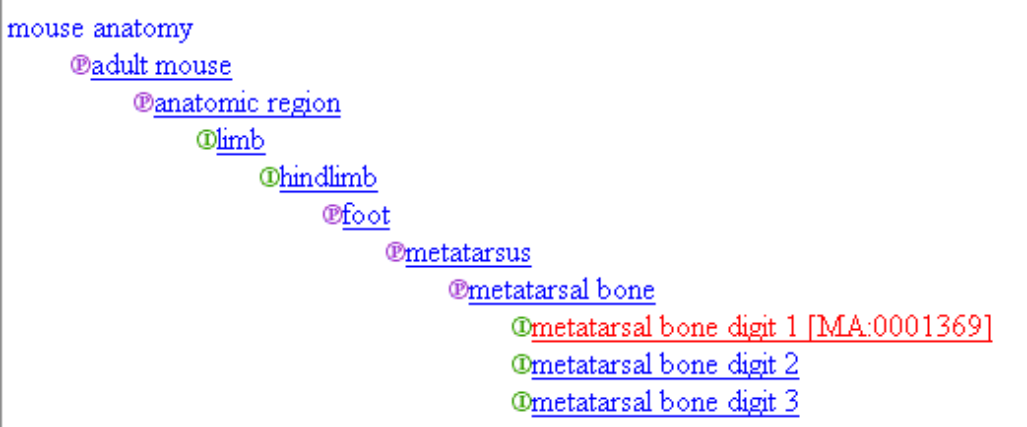
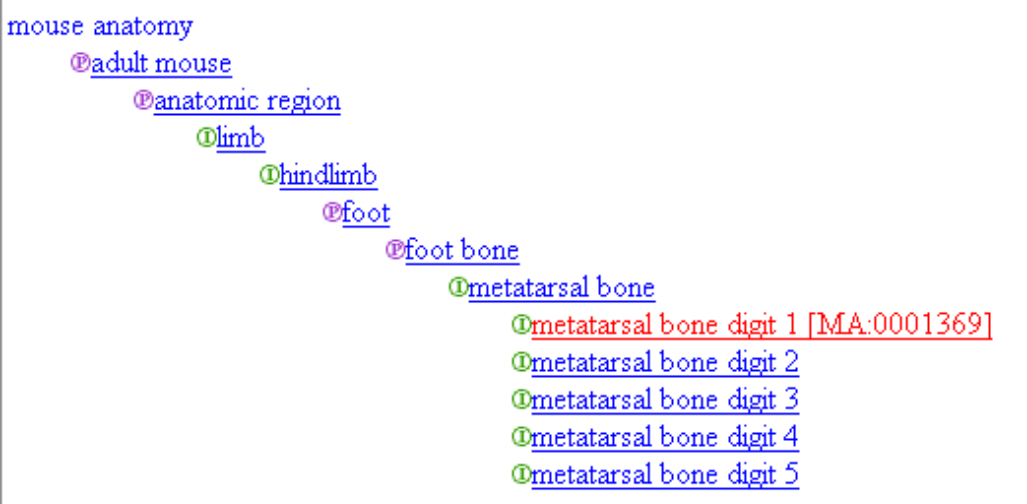
# Example:

# Adult Mouse Anatomy

Term Detail

MA term: **metatarsal bone digit 1**  
 MA id: MA:0001369  
 Number of paths to term: 9

① denotes an 'is-a' relationship  
 ② denotes a 'part-of' relationship



- Orthogonal *Part-of* and *Is-a* hierarchies are backbones of bio-ontologies
- *Part-of* and *Is-a* are generally considered “foundational relations”
- Recent standardization of the semantics of *Is-a* and *Part-of* as asserted between classes

Smith et al.: Relations in Biomedical Ontologies. Genome Biology, 2005, 6 (5)

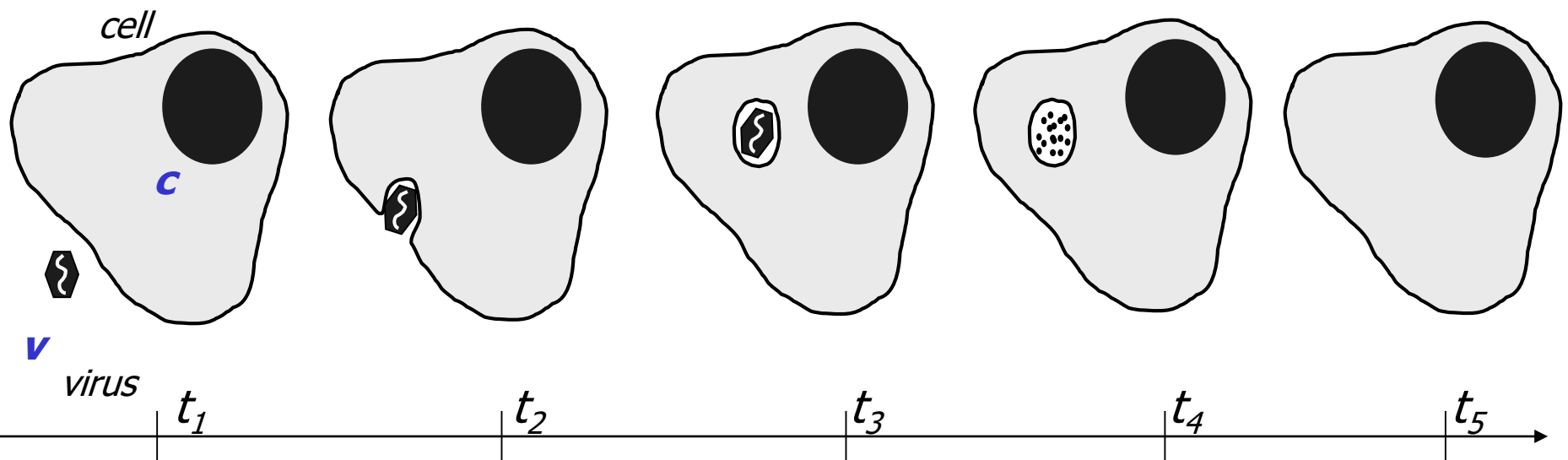
# Is *part-of* a Foundational Relation ?

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- Foundational relations are supposed to be robust with regard to individual interpretations.
- Observation: many assertions of parthood are tied to human perception and belief

# Is *part-of* a Foundational Relation ?

- Foundational relations are supposed to be robust with regard to individual interpretations.
- Many assertions of parthood are tied to human perception and belief



# *Parthood* assertions are controversial

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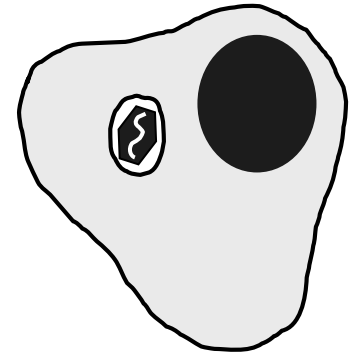
Instances of ...

<b>Part ?</b>	<b>Whole</b>	<b>Part ?</b>	<b>Whole</b>
Transplant	Organism	Thyroxin Molecule	Thyroid Gland
Mitochondrium	Cell	Alanin Molecule	Collagen Fiber
E.Coli bacterium	Intestine	Bolus of Food	Stomach
H <sub>2</sub> O molecule	Cytoplasm	Transfused Blood	Body
Glioblastoma	Brain	Zygote	Uterus
Brain metastasis	Brain	Artificial Head	Femur

# Beyond controversy: *Located-in (region-contained-in)*

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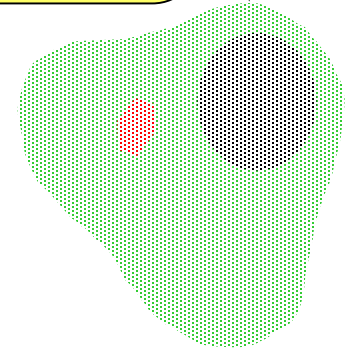
$located-in(x, y, t) =_{def}$   
 $part-of(r(x, t), r(y, t))$



# Beyond controversy:

## *Located-in (region-contained-in)*

Parthood between regions = point set inclusion

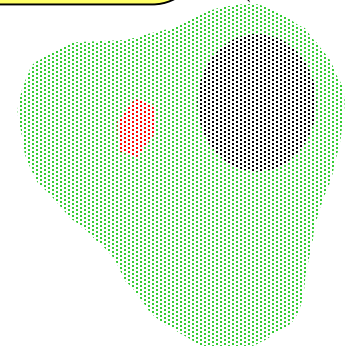
$$\textit{located-in}(x, y, t) \stackrel{\textit{def}}{=} \textit{part-of}(r(x, t), r(y, t))$$




# Relation Hierarchy

Parthood between regions = point set inclusion

$located-in(x, y, t) =_{def} part-of(r(x, t), r(y, t))$



$contained-in(x, y, t) =_{def} located-in(x, y, t) \wedge \neg part-of(x, y, t)$

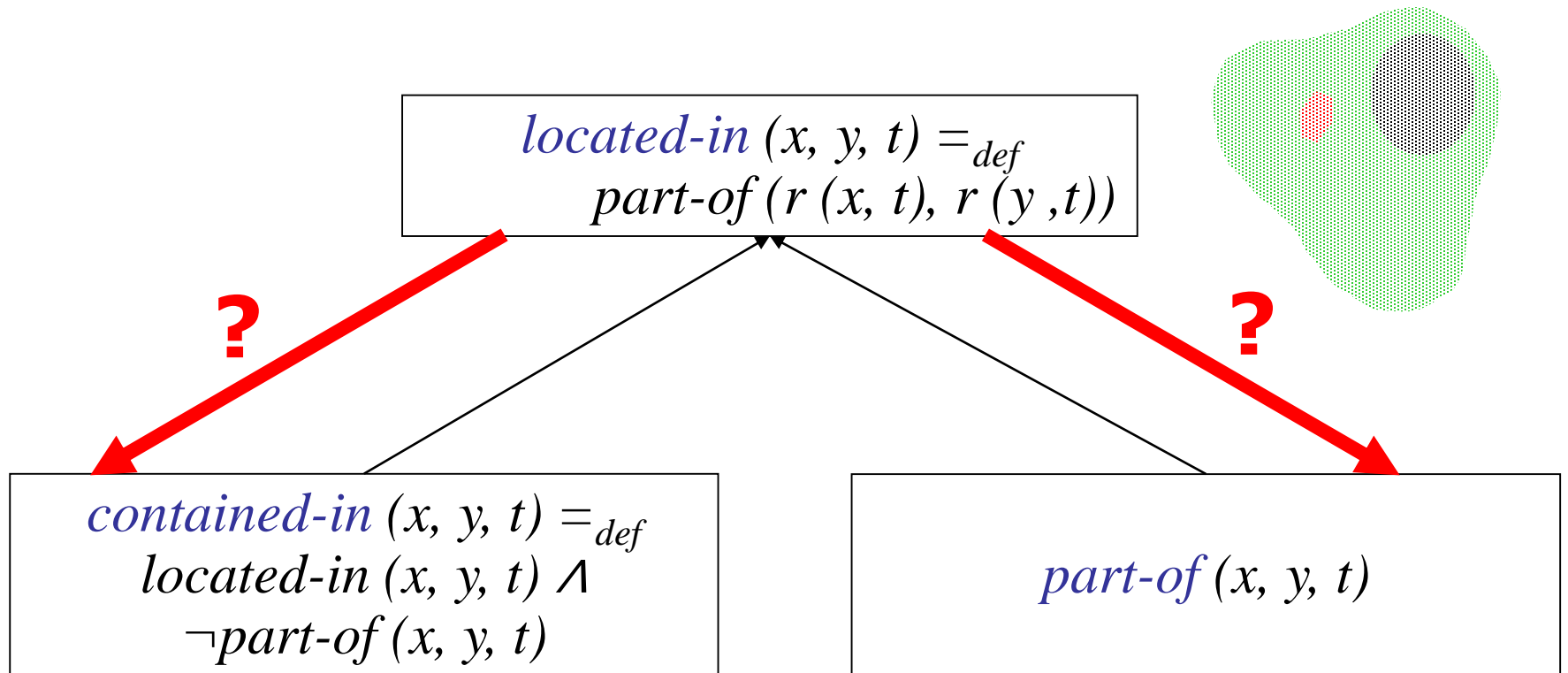
$part-of(x, y, t)$

# Problem Statement

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- Parthood always implies spatial location, but spatial location does not always imply parthood
- Under which circumstances can we infer parthood from spatial location ? When does inclusion without parthood obtain ?

# Relation Hierarchy



# Proposal: Four criteria for inferring parthood

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1. Sortality
2. Genetic identity
3. Life Cycle
4. Function / Integrity

# Inferring part from spatial inclusion: 1. Sortality

Rules out objects of certain sort as parts:

- **x is material, y is immaterial:**

$Solid(x) \wedge Hole \rightarrow (y) \wedge located-in(x, y) \rightarrow \neg part-of(x, y)$

$located-in(myBrain, myCranialCavity) \rightarrow$

$\neg part-of(myBrain, myCranialCavity)$



- **x is an non-biological artifact:**

$located-in(myPacemaker, myBody) \rightarrow$

$\neg part-of(myPacemaker, myBody)$

$located-in(myInlay, myTooth) \rightarrow$

$\neg part-of(myInlay, myTooth)$



# Inferring part from spatial inclusion: 2. Genetic Identity

Rules out objects of different genetic origin:

- Symbionts:

*located-in (anEcoliBacterium, myIntestine) →*  
*¬ part-of (anEcoliBacterium, myIntestine)*



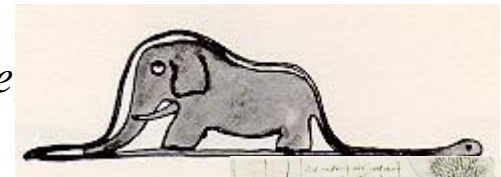
- Parasites:

*located-in (anEchinococcus, myLiver) →*  
*¬ part-of (anEchinococcus, myLiver)*



- Preys:

*located-in (anElephant, aSnake) →*  
*¬ part-of (anElephant, aSnake)*



- Zygotes, Embryos, Fetuses:

*located-in (Leonardo, Caterina) →*  
*¬ p (Leonardo, Caterina)*

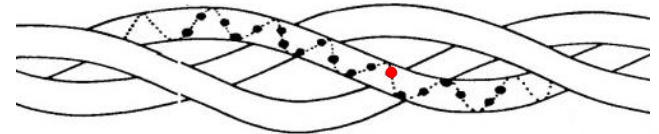


# Inferring part from spatial inclusion: 3. Life Cycle

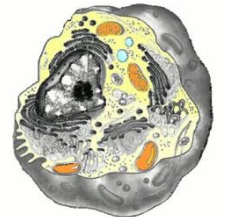
## 3. Life Cycle patterns which allow to assert parthood:

*located-in* holds for any instant of simultaneous existence

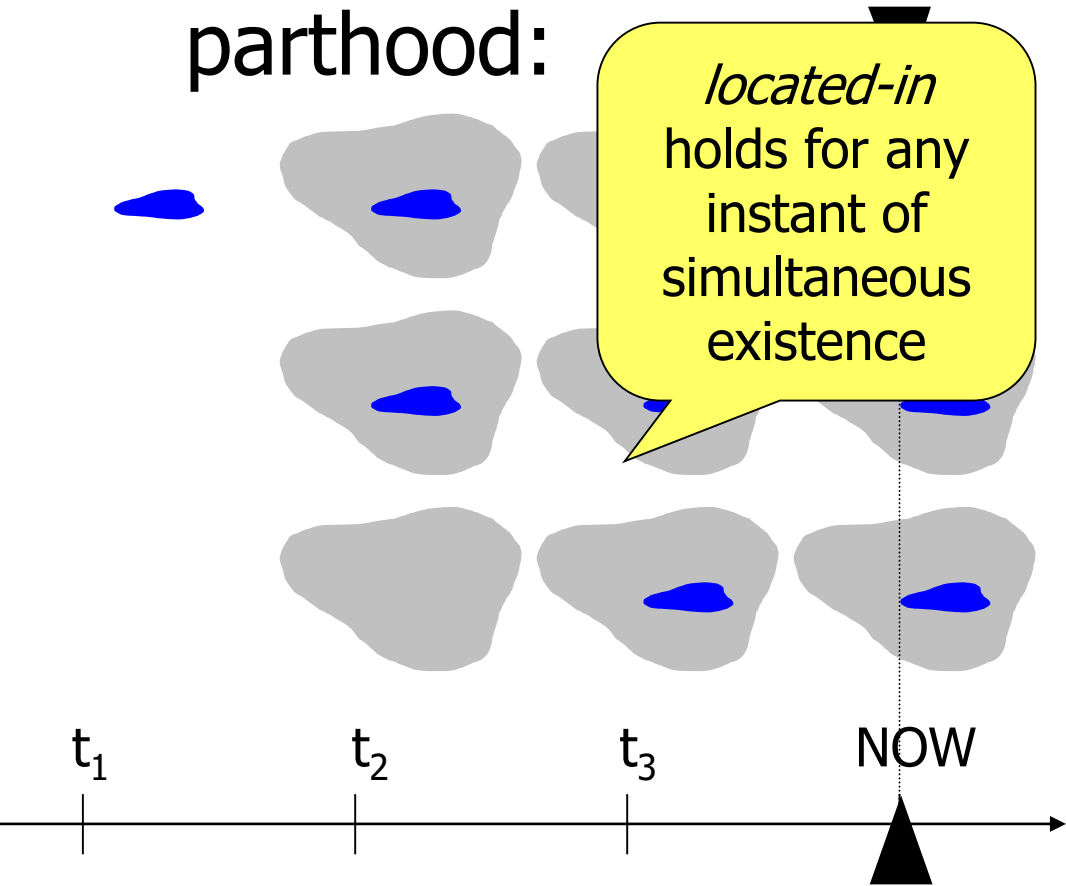
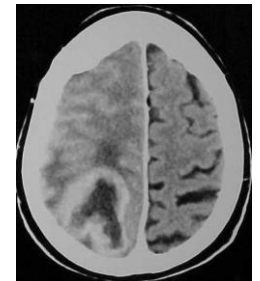
*aGlycinMolecule, aCollagenFiber*



*aCytoplasm, aCell*

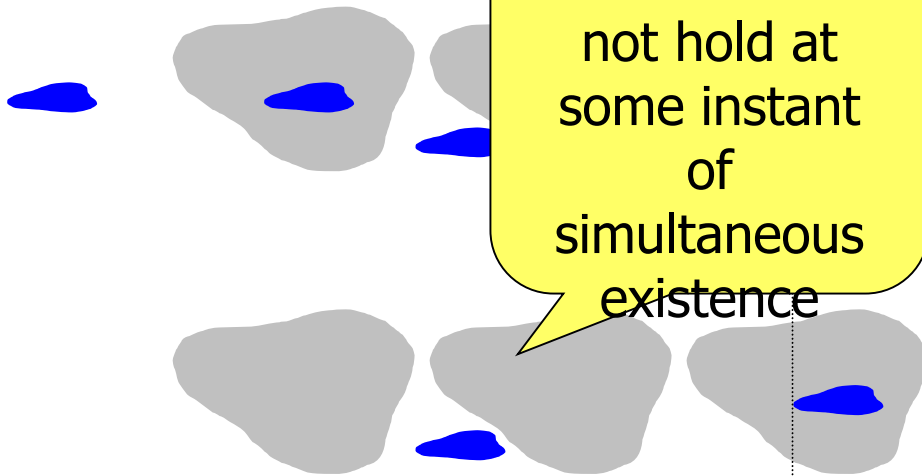


*aGlioblastoma, aBrain*



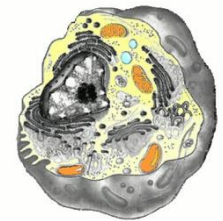
# Inferring part from spatial inclusion: 3. Life Cycle

## 3. Life Cycle patterns which allow to rule out parthood:

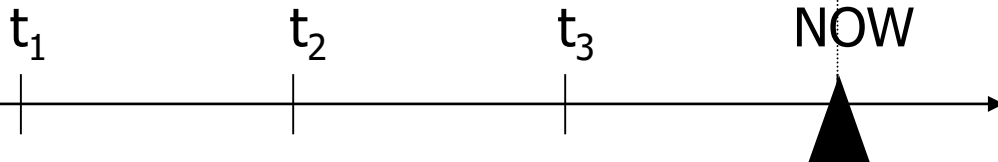
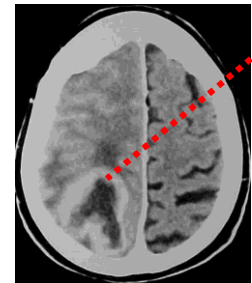


*located-in* does not hold at some instant of simultaneous existence

*aWaterMolecule, aCell*



*aBrainMetastasis, aBrain*





# Inferring part from spatial inclusion: 4. Function / Integrity

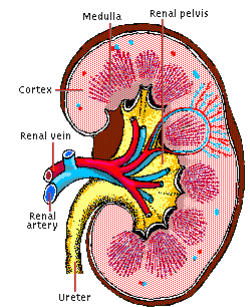
## 4. Related to function or integrity

### ■ Transplants

*functionally\_related (aTransplant, anOrganism)*

*∧ located-in (aTransplant, anOrganism) →*

*part-of (aTransplant, anOrganism)*



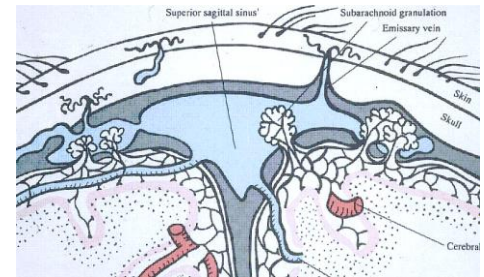
Microsoft Illustration

### ■ Body Substances:

*functionally\_related (myCSF, myCNS)*

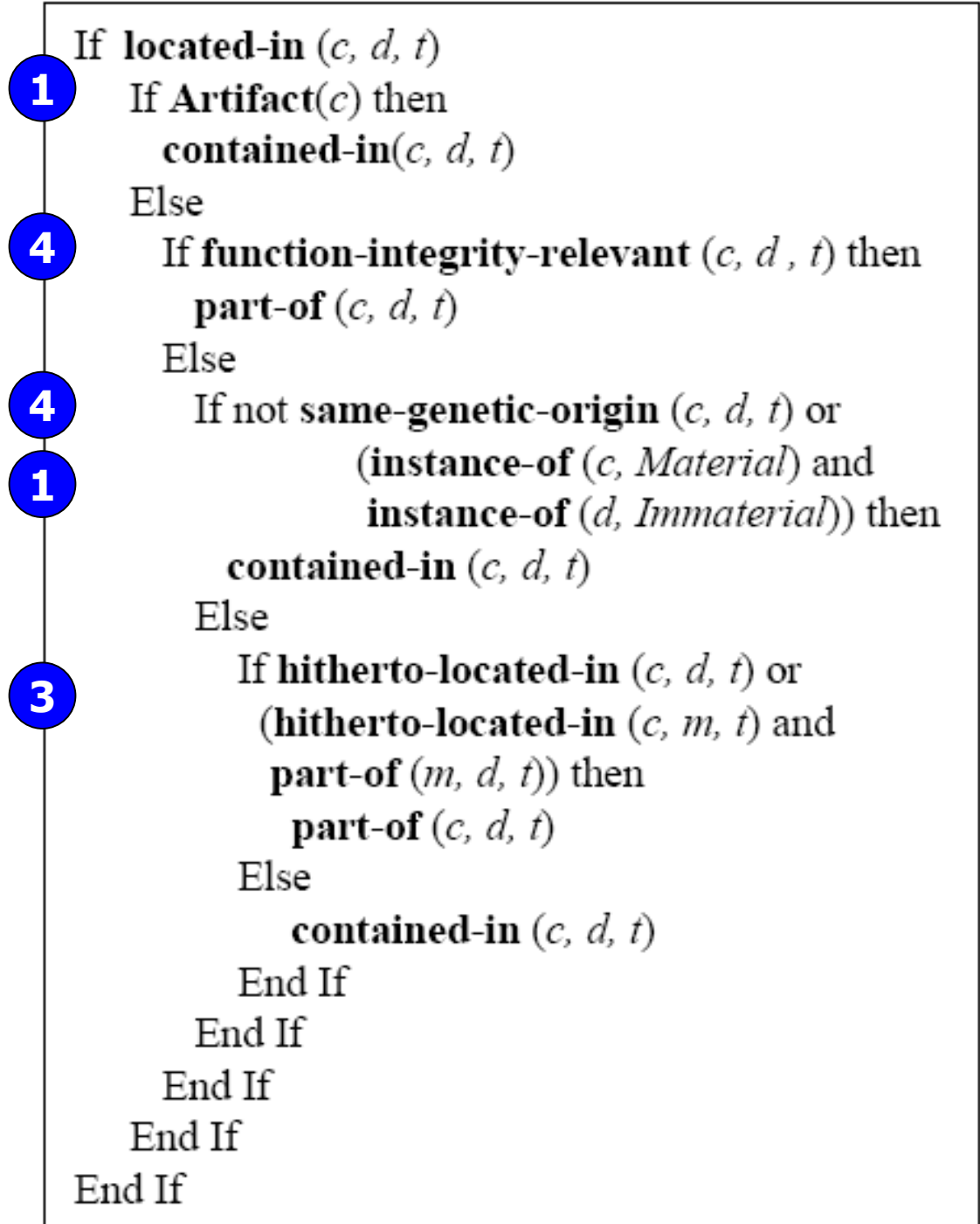
*∧ located-in (myCSF, myCNS) →*

*part-of (myCSF, myCNS)*



... but not: *part-of (thisVolumeOfUrine, myBladder)*, because not essential for function

# Inferring part from spatial inclusion: Decision algorithm

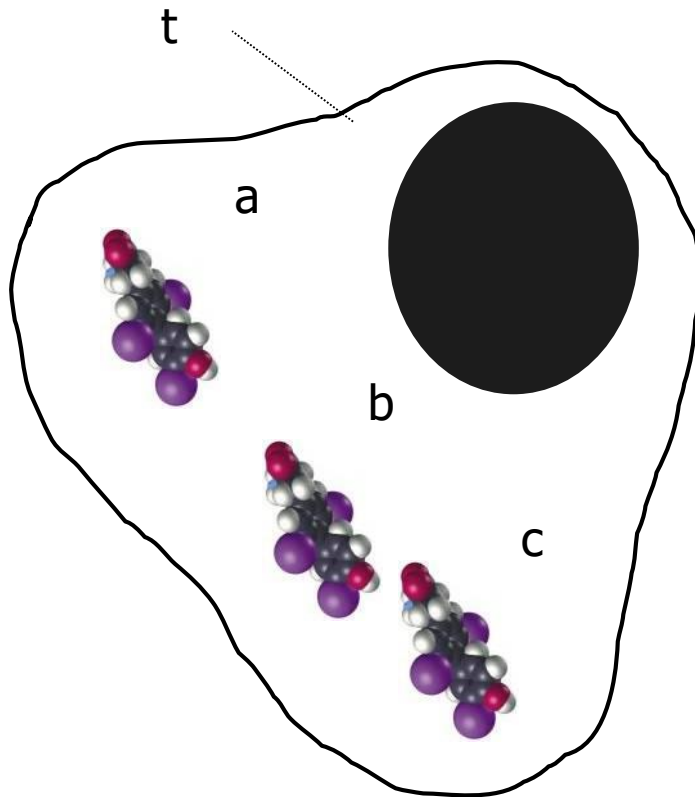


# Borderline cases

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- Fuzzy notion of “artifact”: engineered tissue, genetically modified cells
- Unclear identity: e.g., tumors, metastases (where does their existence begin ?)
- “Sameness” of masses defined by their containers (air in the lung, blood in the heart, urine in the bladder)

# Counter-intuitive consequences



- a: Thyroxine molecule synthesized by c  
-> *part-of (a, t)*
- b: Thyroxine molecule synthesized by other cell  
-> *contained-in (b, t)*
- c: Thyroxine molecule ingested as drug  
-> *contained-in (c, t)*

# Conclusion

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- Spatial location (topological) inclusion: non-controversial foundational relation for bio-ontologies
- *part-of* more useful exhibits human-dependent semantic bias
- Algorithmic approach for specializing location to either parthood or containment
- Problems persist: borderline cases, unintuitive cases, ill-defined notion of functionality / integrity

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