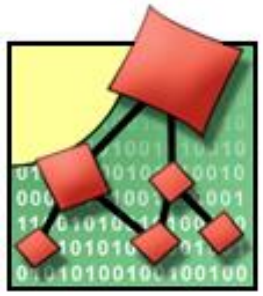
Ontology and Biomedical Informatics
An International Conference organized by the
Network of Excellence Semantic Interoperability
and Data Mining in Biomedicine
under the auspices of Working Group 6 of the
International Medical Informatics Association
Rome 29 April – 2 May 2005



The Meaning of Part

Stefan Schulz

Department of Medical Informatics
University Hospital Freiburg (Germany)

Relations in Biomedical Terminologies / Ontologies

Purpose-Specific Relations in Clinical Terminologies

Foundational Relations in Formal Ontologies

Part-Of

Part-Of

Individuals

- Algebraic Properties:
  Part-of: Transitive, Reflexive, Antisymmetric
  Proper-Part-Of: Transitive, Irreflexive, Asymmetric
- Mereological Principles:
  Sum, Product, Supplementation, Extensionality, Proper Part Principle… P.Simons, Casati & Varzi
- Subrelations:
  direct-part-of, *functional-part-of*, *component-of*, *subdivision-of*, *boundary-of*, … GALEN, FMA

Part-Of	Continuants	Occurrents
Individuals	• Algebraic Properties: *Part-of*: Transitive, Reflexive, Antisymmetric *Proper-Part-Of*: Transitive, Irreflexive, Asymmetric • Mereological Principles: Sum, Product, Supplementation, Extensionality, Proper Part Principle… P.Simons, Casati & Varzi • Subrelations: *direct-part-of, functional-part-of, component-of, subdivision-of, boundary-of*, … GALEN, FMA	

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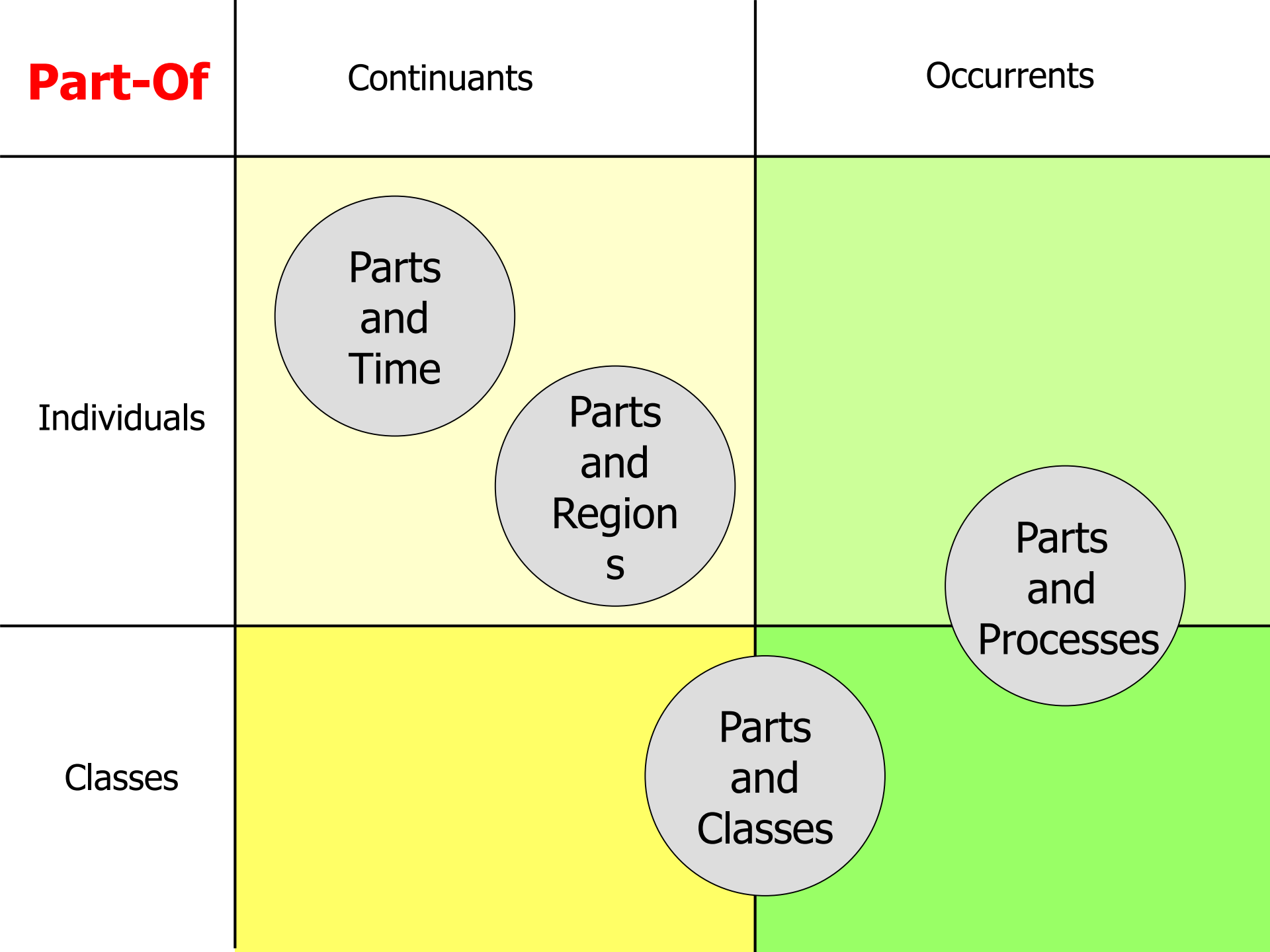
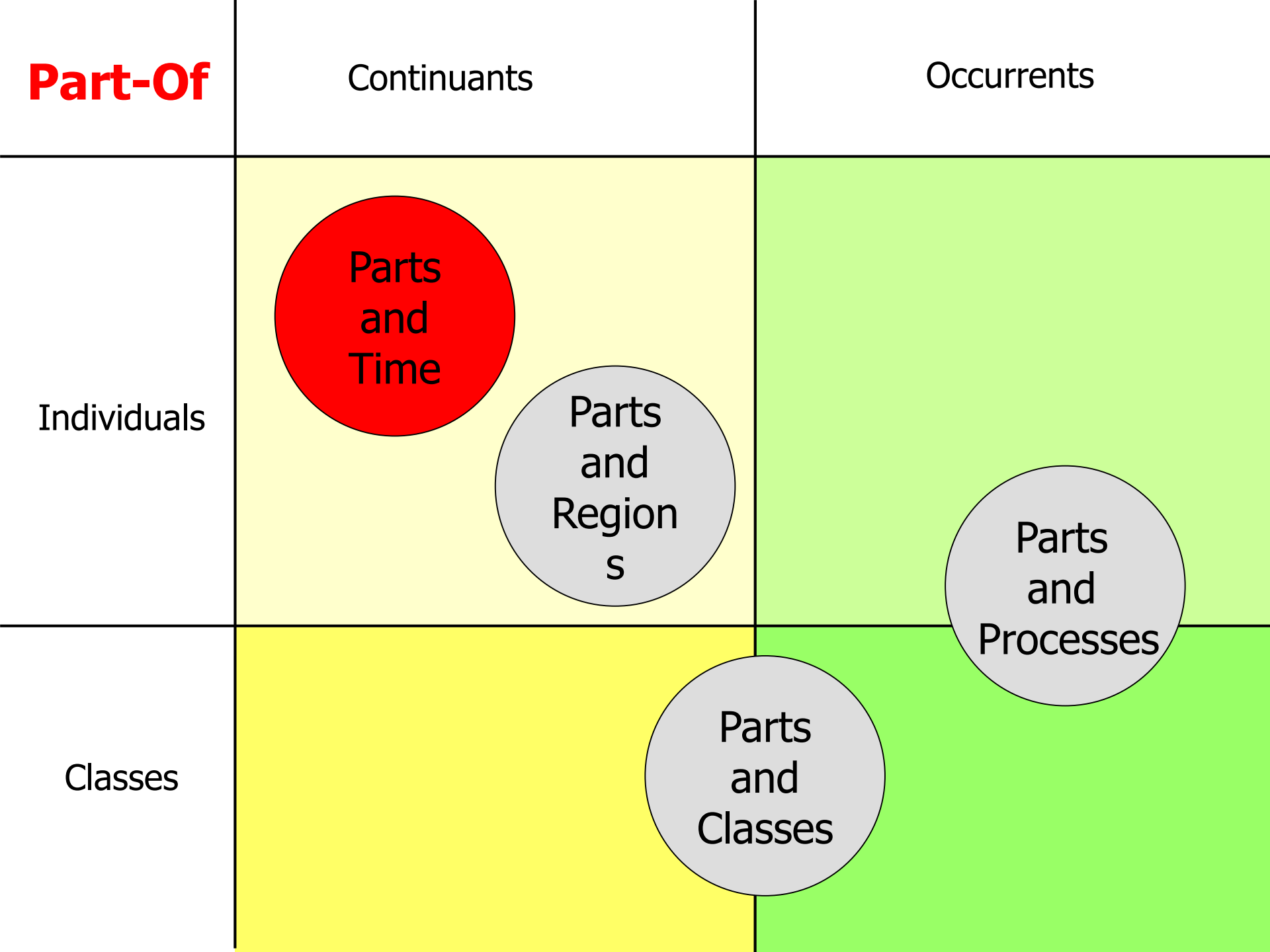
Classes,		


Part-Of
Continuants
Occurrents
Individuals
Classes
Parts and Time
Parts and Regions
Parts and Processes
Parts and Classes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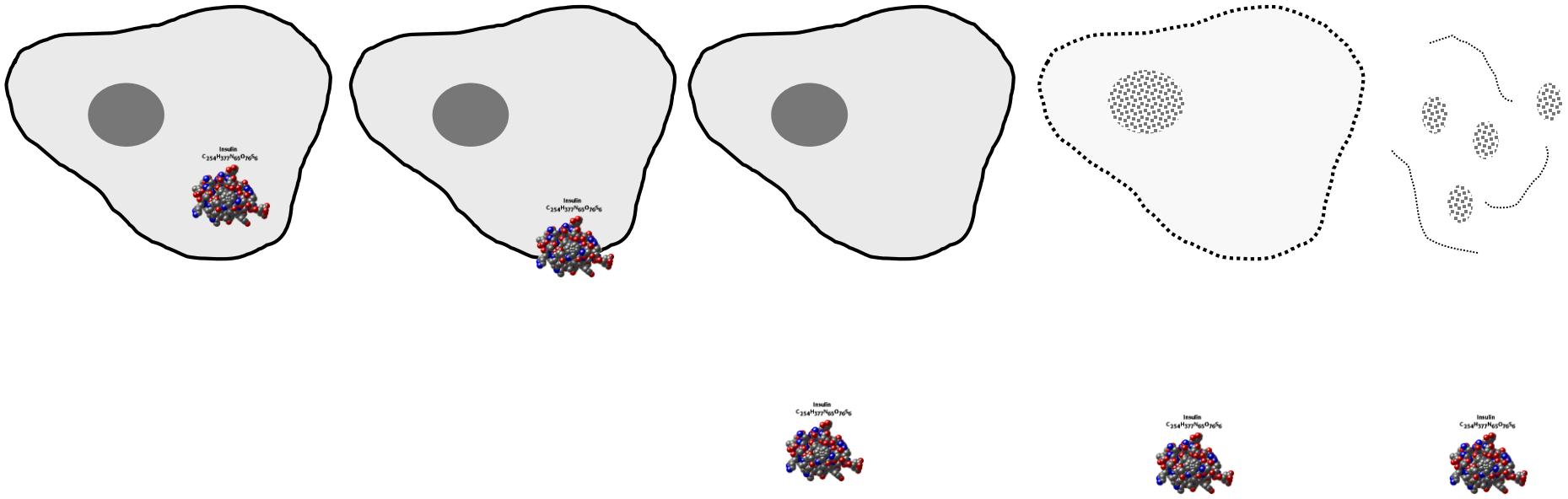
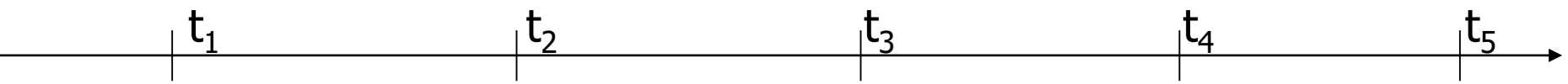
Parts and Time

Example I





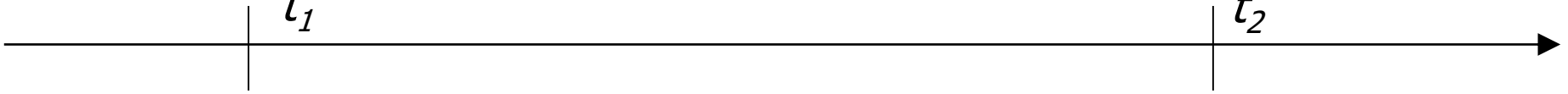
Parts and Time

Example II

d

d'

t



Parts and Time

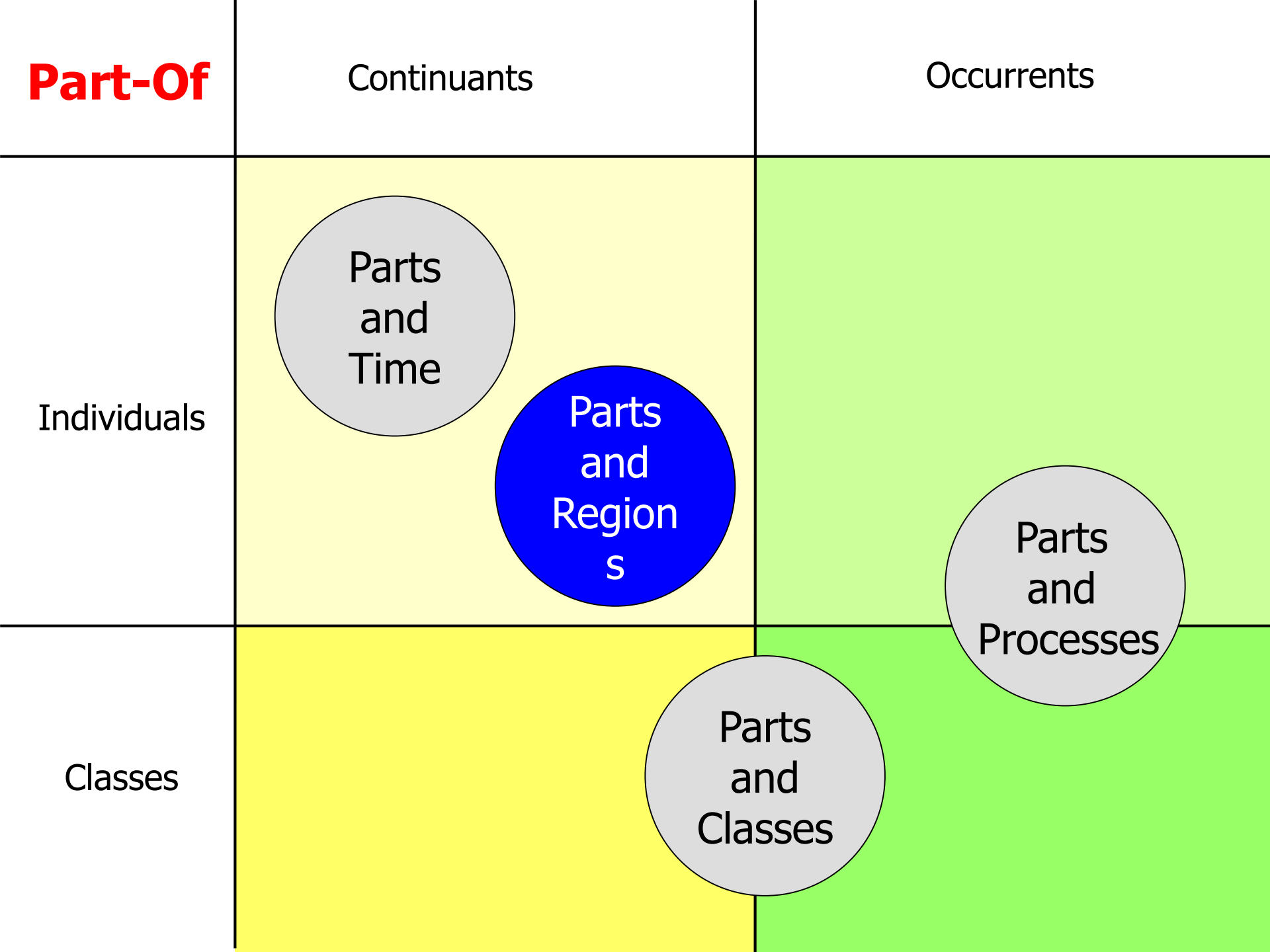
Two views

1. The tooth is no longer considered part of the dental arcade after extraction: $d = d'$
   Problem: it has still some kind of relation with the dental arcade. Which one ?
2. The tooth continues being considered a (now disconnected) part of the dental arcade even after extraction: $d = d' + t \rightarrow d \neq d'$
   Problem: what is then the spatial extension of the dentition? Is the dental arcade no longer the same ?

Parts and Time

Historic Parthood

- Don't take historic parthood for parthood
  "bone (in an archeologic site) forming part of a skeleton…"
  "transplanting part of a liver…"
  "sample of gastric mucosa of patient X was examined"
- Time-indexed parthood:
  $part\text{-}of\ (a, b, t)$
- Historic parthood:
  $hist\text{-}part\text{-}of\ (a, b) =_{def} \exists t,u:\ part\text{-}of\ (a, b, t) \wedge \neg part\text{-}of\ (a, b, u) \wedge earlier(t, u)$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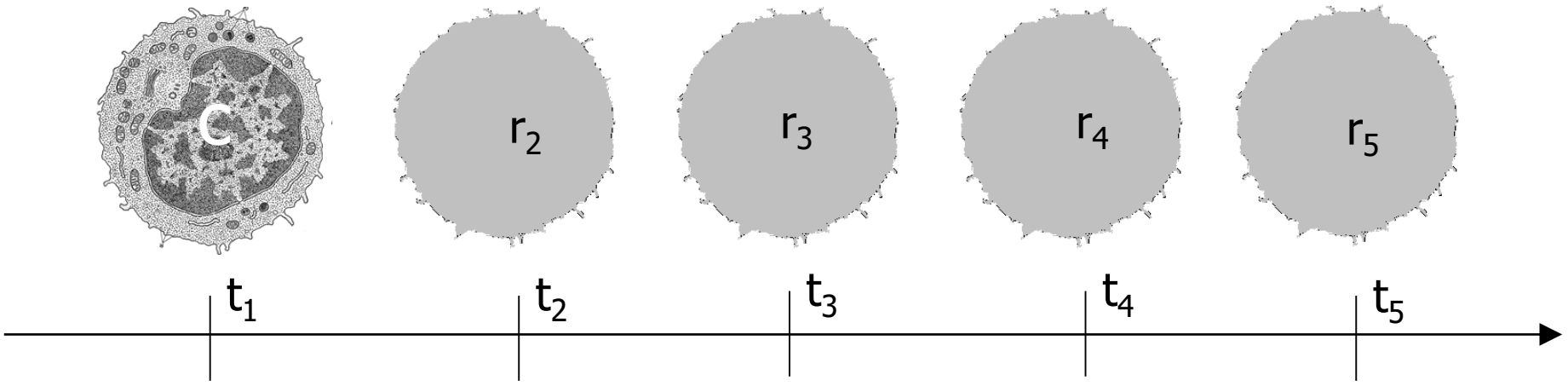
Parts and Regions

Regions

- At every moment in time a spatial object is located in a single region of space
- At different moments spatial objects may be located in different regions



Parts and Regions

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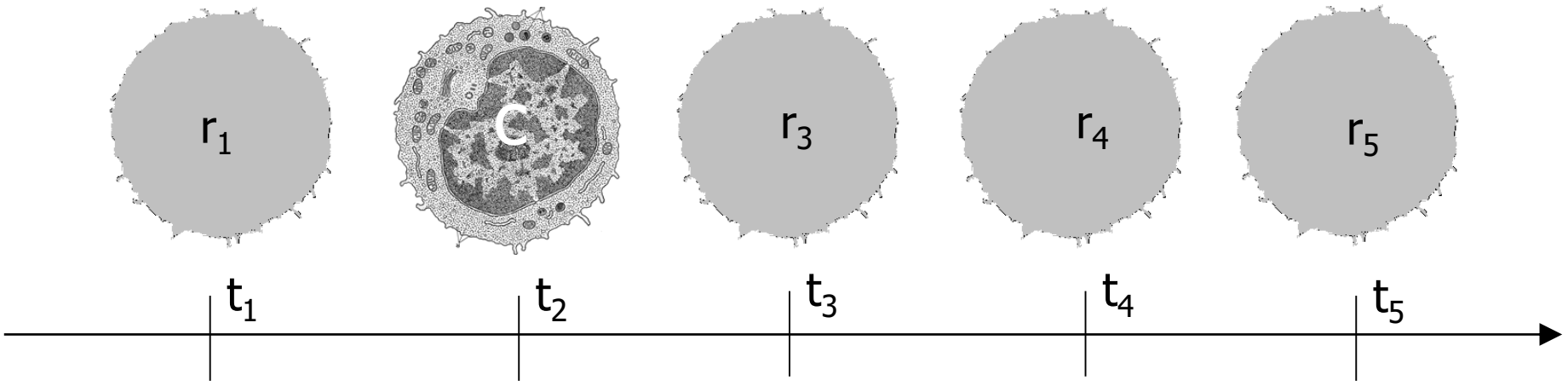

Parts and Regions

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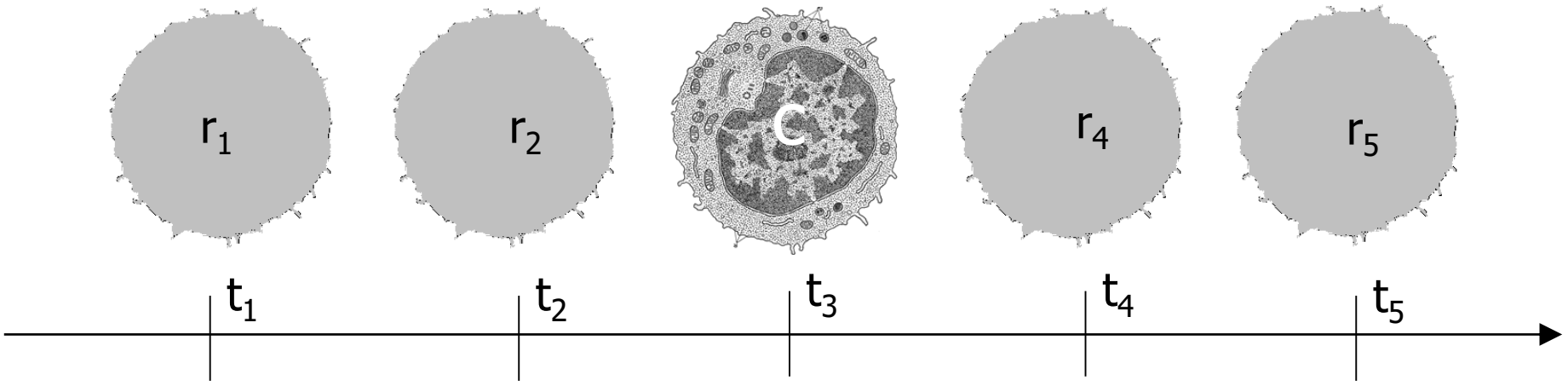

Parts and Regions

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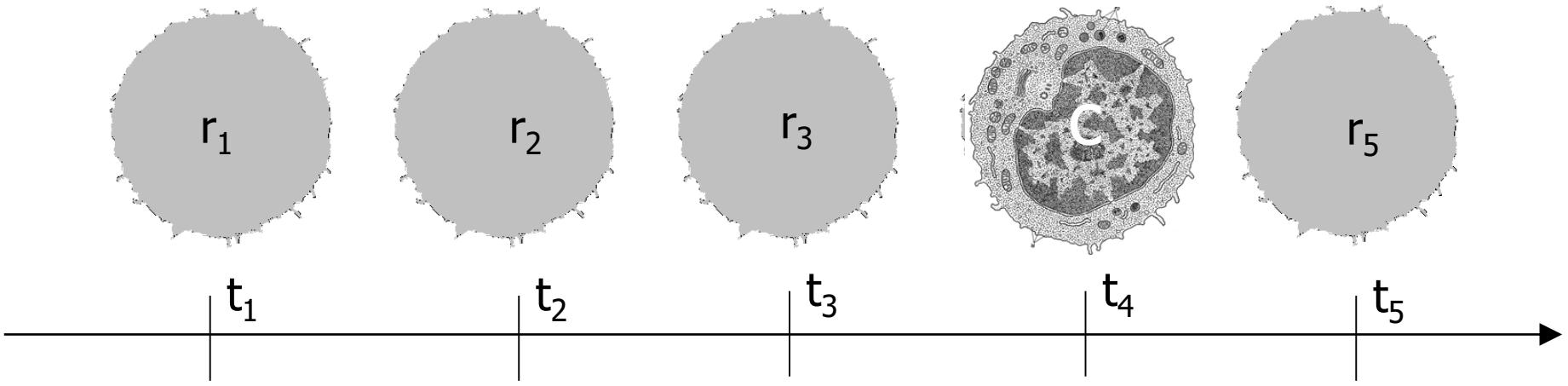

Parts and Regions

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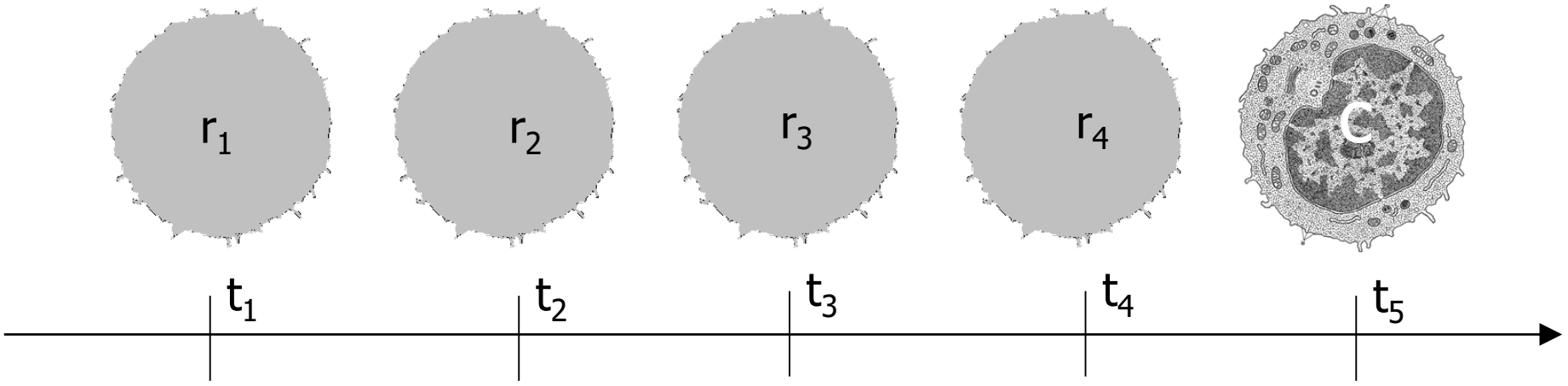


Parts and Regions

Parthood and Spatial Inclusion

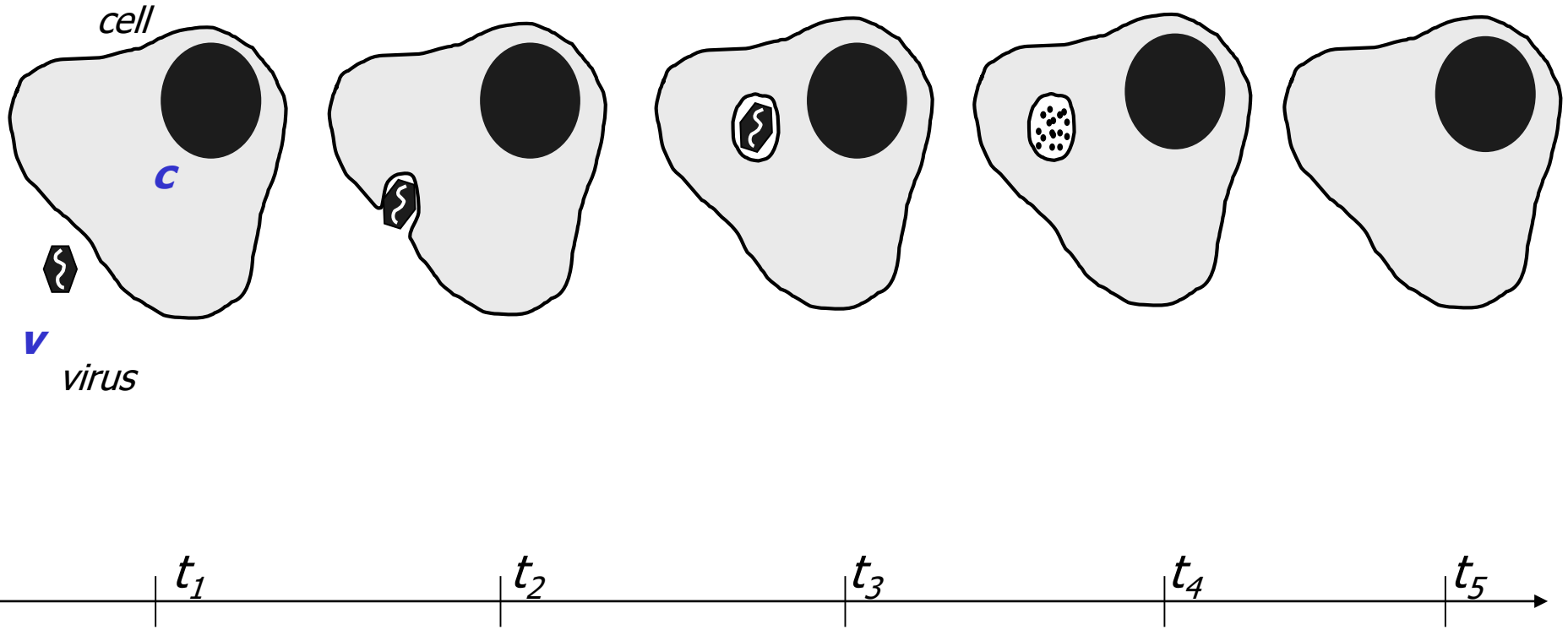
- $R(z)$ z is a region in space
  $z = r(x, t)$ z is the region where x is located at t
- $part\text{-}of(x, y, t) \rightarrow part\text{-}of(r(x, t), r(y, t))$

  (Donnelly, IJCAI 03)
- Spatial inclusion (coverage, (partly) location,…)
- $spatially\text{-}included(x, y, t) =_{def} part\text{-}of(r(x, t), r(y, t))$
  x is spatially included by y at t

Parts and Regions

Phagocytosis / Digestion

Objects: Cell, Virus

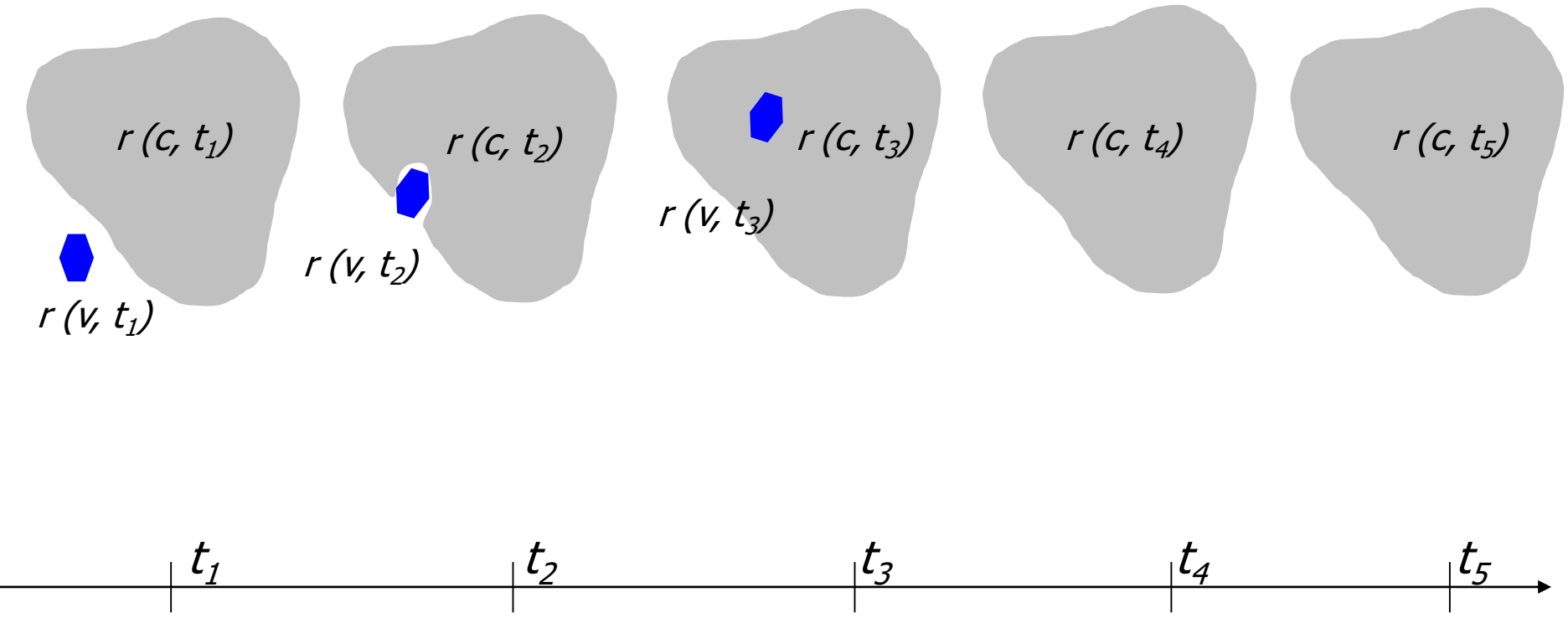


Parts and Regions

Phagocytosis / Digestion

Regions: Space occupied by Cell, space occupied by Virus

part-of (r (v, t_3), r (c, t3))



Parts and Regions

General Problem

- Parthood always implies spatial inclusion, but spatial inclusion does not always imply parthood:
  $part\text{-}of\ (x, y, t) \rightarrow spatially\text{-}included\ (x, y, t)$
- Under which circumstances ϕ can we infer parthood from spatial inclusion ? When does inclusion without parthood obtain ?
  $spatially\text{-}included\ (x, y, t) \wedge \phi \rightarrow part\text{-}of\ (x, y, t)$
  $spatially\text{-}included\ (x, y, t) \wedge \phi' \rightarrow \neg\, part\text{-}of\ (x, y, t)$

Parts and Regions

Inferring part from spatial inclusion: 1. Sortality

Rules out objects of certain sort as parts:

- x is material, y is immaterial:

$$Solid(x) \wedge Hole \rightarrow (y) \wedge spatially\text{-}included(x, y) \rightarrow \neg\, part\text{-}of(x, y)$$

$$spatially\text{-}included(myBrain, myCranialCavity) \rightarrow \neg\, part\text{-}of(myBrain, myCranialCavity)$$

- x is an non-biological artifact:

$$spatially\text{-}included(myPacemaker, myBody) \rightarrow \neg\, part\text{-}of(myPacemaker, myBody)$$

$$spatially\text{-}included(myInlay, myTooth) \rightarrow \neg\, part\text{-}of(myInlay, myTooth)$$

Parts and Regions

Inferring part from spatial inclusion: 2. Genetic Identity

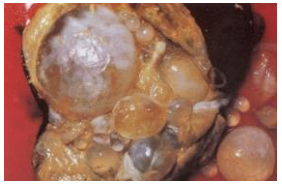
Rules out objects of different genetic origin:

- Symbionts:

  spatially-included (anEcoliBacterium , myIntestine) $\rightarrow$
  $\neg$ *part-of (anEcoliBacterium , myIntestine)*

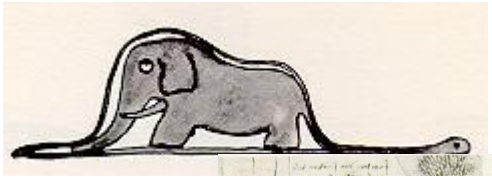
- Parasites:

  spatially-included (anEchinococcus, myLiver) $\rightarrow$
  $\neg$ *part-of (anEchinococcus, myLiver)*



- Preys:

  spatially-included (anElephant, aSnake) $\rightarrow$
  $\neg$ *part-of (anElephant, aSnake)*



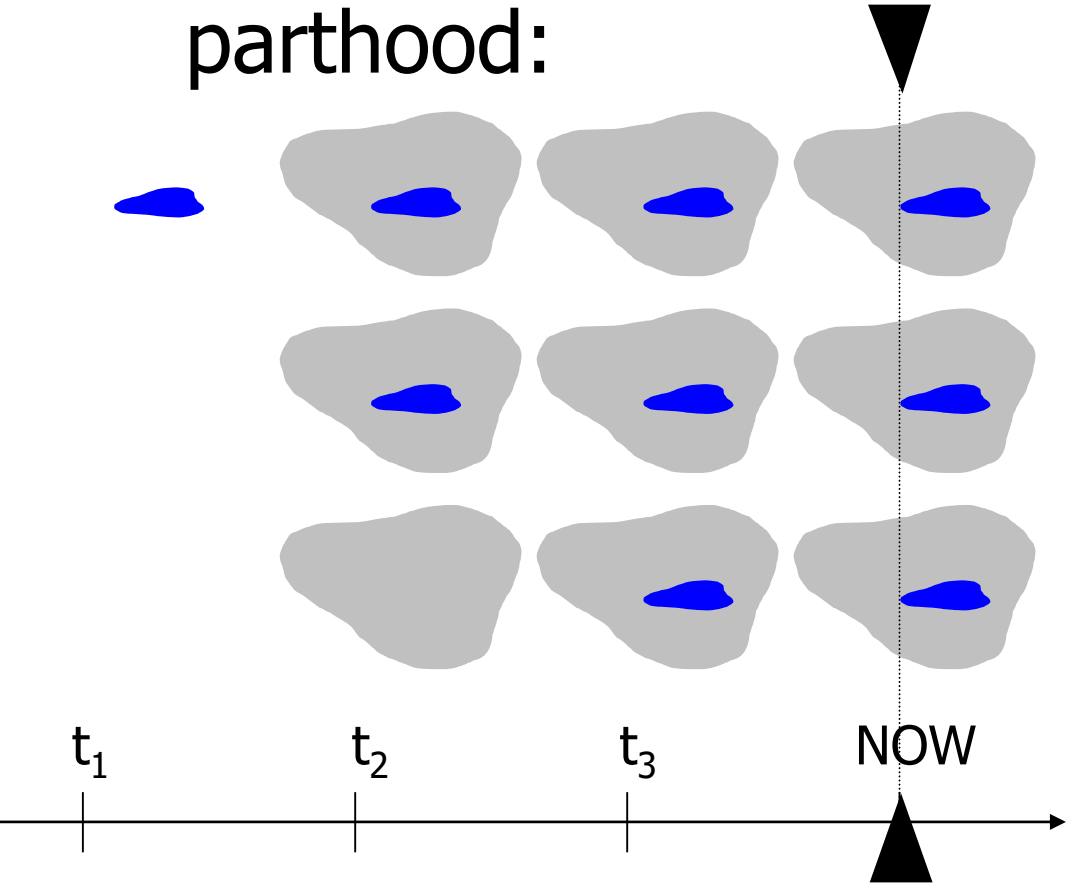
- Embryos, Fetuses:

  spatially-included (Leonardo, Caterina) $\rightarrow$
  $\neg$ *p (Leonardo, Caterina)*

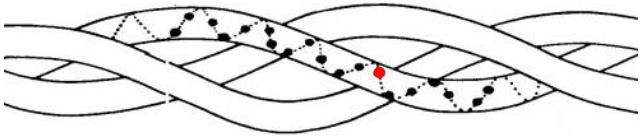
Parts and Regions

Inferring part from spatial inclusion: 3. Life Cycle

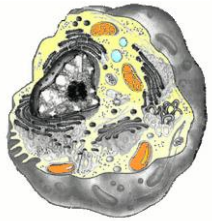
3. Life Cycle patterns which allow to assert parthood:



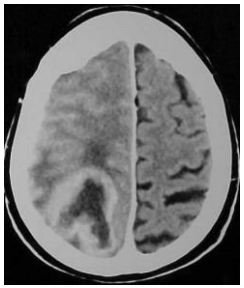
aGlycinMolecule, aCollagenFiber



aCytoplasm, aCell



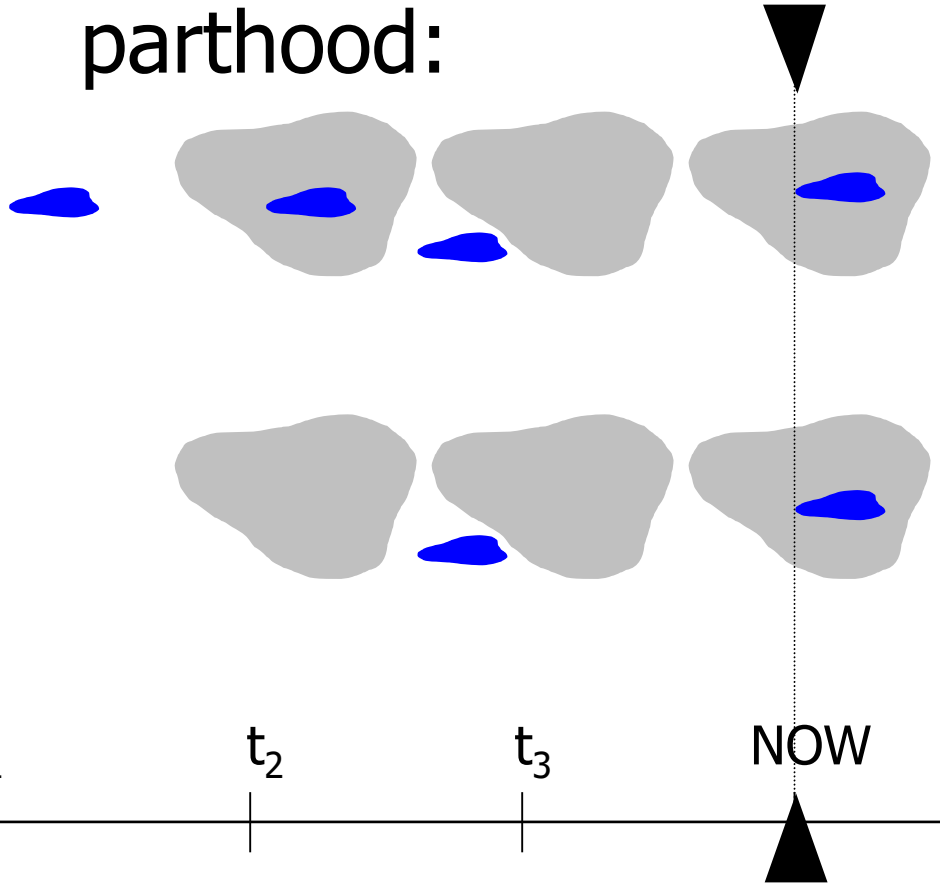
aGlioblastoma, aBrain



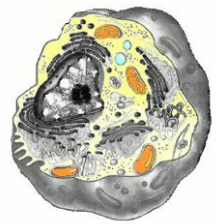
Parts and Regions

Inferring part from spatial inclusion: 3. Life Cycle

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

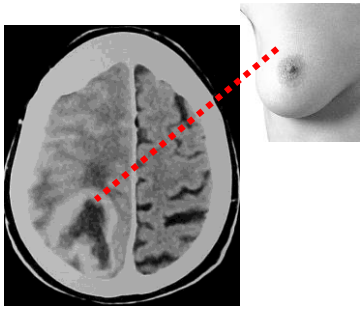


aWaterMolecule, aCell



aBrainMetastasis, aBrain

but : *part-of what ?*



Parts and Regions

Inferring part from spatial inclusion: 4. Function

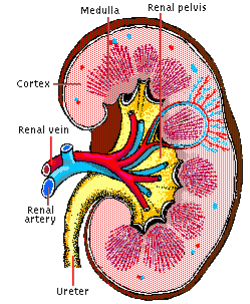
4. Essential for function

- Transplants

functionally_related (aTransplant, anOrganism)

$\wedge$ *spatially-included (aTransplant, anOrganism)* $\rightarrow$

part-of (aTransplant, anOrganism)

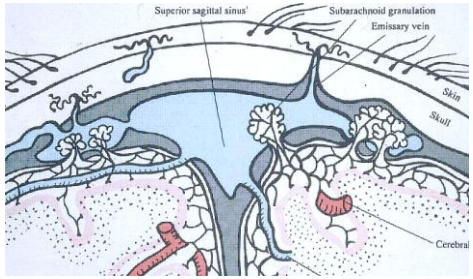


- Body Substances:

functionally_related (myCSF, myCNS)

$\wedge$ *spatially-included (myCSF, myCNS)* $\rightarrow$

part-of (myCSF, myCNS)

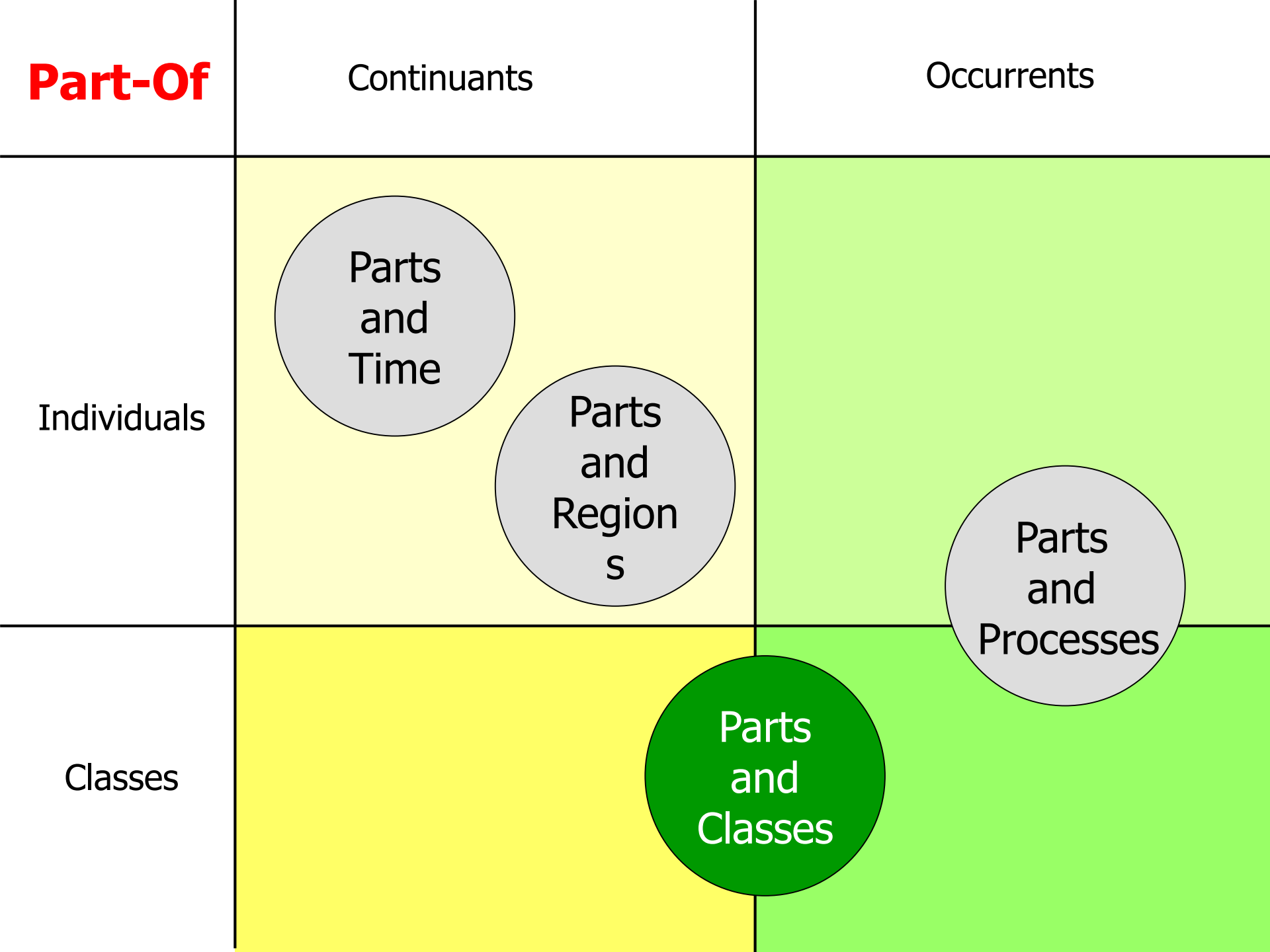


… but not: *part-of (thisVolumeOfUrine, myBladder),* because not essential for function

Parts and Regions

Inferring part from spatial inclusion: Decision algorithm

If **located_in** (*c*, *d*, *t*)
  If **Artifact**(*c*) then
    contained_in(*c*, *d*, *t*)
  Else
    If **functionally_related** (*c*, *d* , *t*) then
      part_of (*c*, *d*, *t*)
    Else
      If not **same_genetic_origin** (*c*, *d*) or
      (**material** (*c*) and **immaterial** (*d*)) then
        contained_in (*c*, *d*, *t*)
      Else
        If **originates_in** (*c*, *d*) or
        originates_in (*c*, *m*) and **part_of** (*m*, *d*, *t*) then
          part_of (*c*, *d*, *t*)
        Else
          contained_in (*c*, *d*, *t*)
        End If
      End If
    End If
  End If
End If


Part-Of
Continuants
Occurrents
Individuals
Classes
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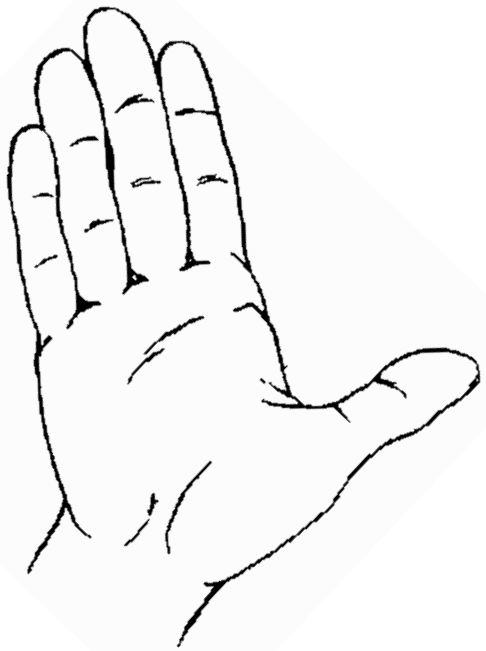
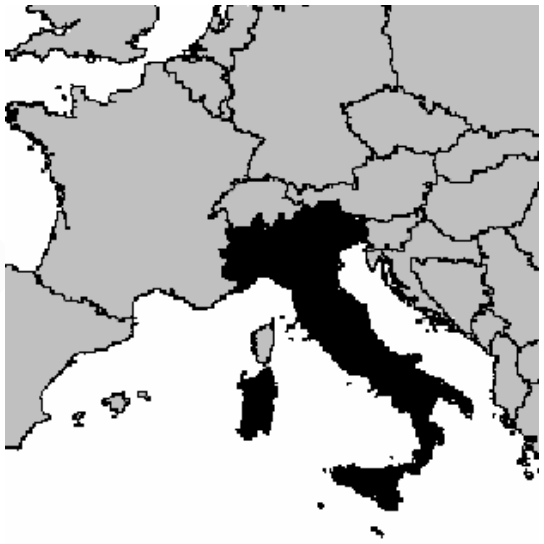
Parts and Classes

Parts and Classes

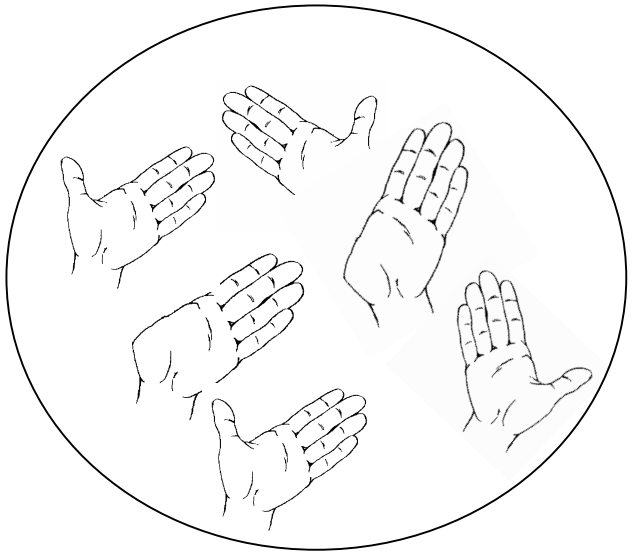
Part-of between individuals and universals (classes)





myThumb part-of myHand *Italy part-of Europe*

Individuals



Thumb part-of Hand

Classes

Parts and Classes

Do Classes or Concepts Have Parts ?

UMLS Metathesurus: MRREL table

CUI1 CUI2 RELA

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C0043520|A2655138|AUI|RN|C1181669|A2661552|AUI|part_of|R04504406||UWDA|UWDA|||N||
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C0043520|A2655138|AUI|RN|C1181967|A2658311|AUI|part_of|R04504405||UWDA|UWDA|||N||
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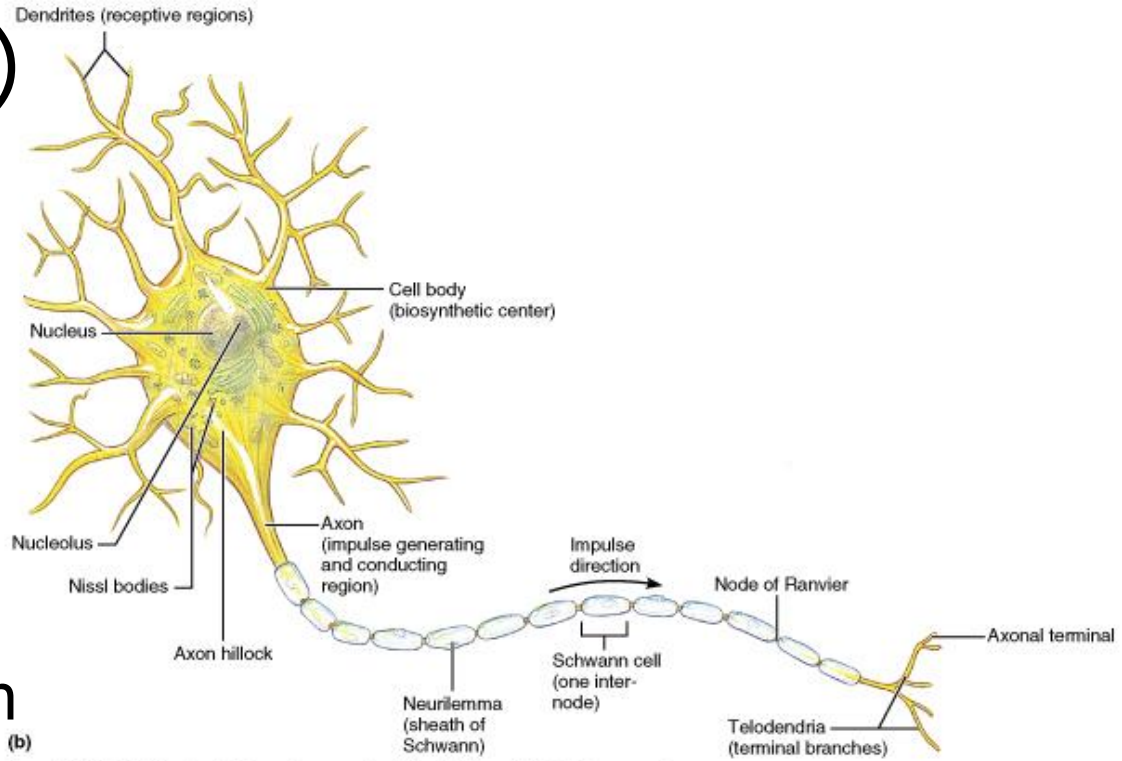
Parts and Classes

Do Classes Have Parts ?

- "*Axon part-of Cell*" (Gene Ontology)
  - Do cells without axons exist ?
  - Do axons without cells exist ?
- "*Axon part-of Neuron*" (FMA)
  - Does every neuron has an axon?



Parts and Classes

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  - Do cells without axons exist ?
  - Do axons without cells exist ?
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  - Does every neuron has an axon?

"Keep in mind that part_of means can be a part of, not is always a part of "
GO Editorial Style Guide, Oct 2003

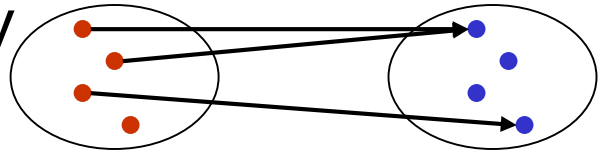
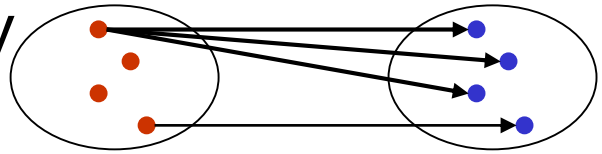
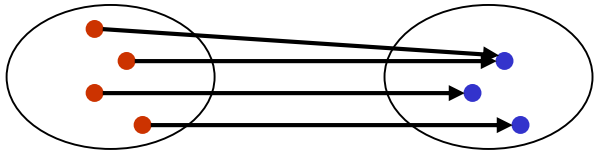
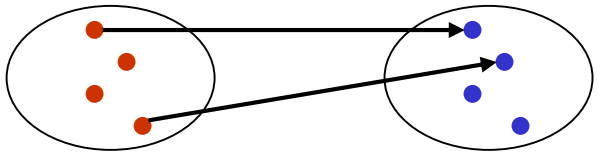
***"The part_of relationship (…) is usually "necessarily* is_part""**
GO Editorial Style Guide, May 2005

"A part_of B if and only if: for any instance x of A there is some instance y of B which is such that x stands to y in the instance-level part relation, and vice versa".

Rosse & Smith MEDINFO 2004

Parts and Classes

Class-level Part-Of : Different Interpretations

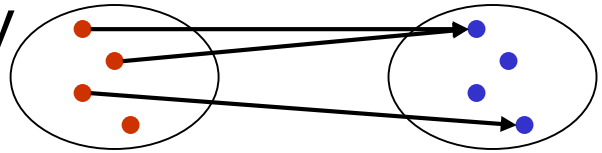
	Class A (part) / Class B (whole)	Examples
■ One-sided Dependency Part on Whole		Cell Nucleus – Cell Uterus – Human Body Prostate Tumor – Prostate
■ One-sided Dependency Whole on Part		Sulfur – Methionin Cell – Human Body Connective Tissue – Liver
■ Mutual Mereological Dependency		Cell Membrane – Cell Vertebra – Vertebrate Brain - Head
■ Mereological Independency		Uterus – Mammal Sulfur – Amino Acid Tooth – Human

Parts and Classes

Class-level Part-Of : Different Interpretations

GALEN, Gene Ontology 05 / 2005

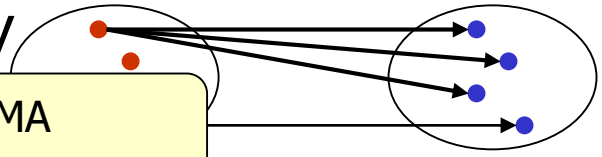
- One-sided Dependency Part on Whole



Examples

Cell Nucleus – Cell
Uterus – Human Body
Prostate Tumor – Prostate

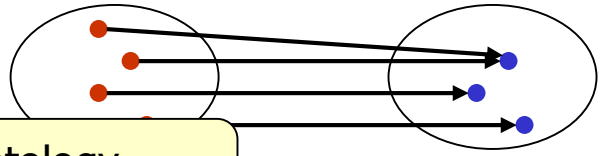
- One-sided Dependency Whole on Part



FMA

Sulfur – Methionin
Cell – Human Body
Connective Tissue – Liver

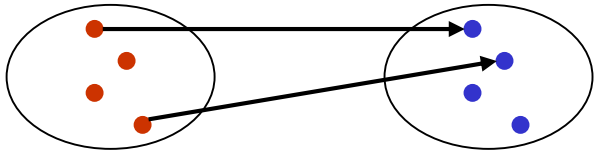
- Mutual Mereological Dependency



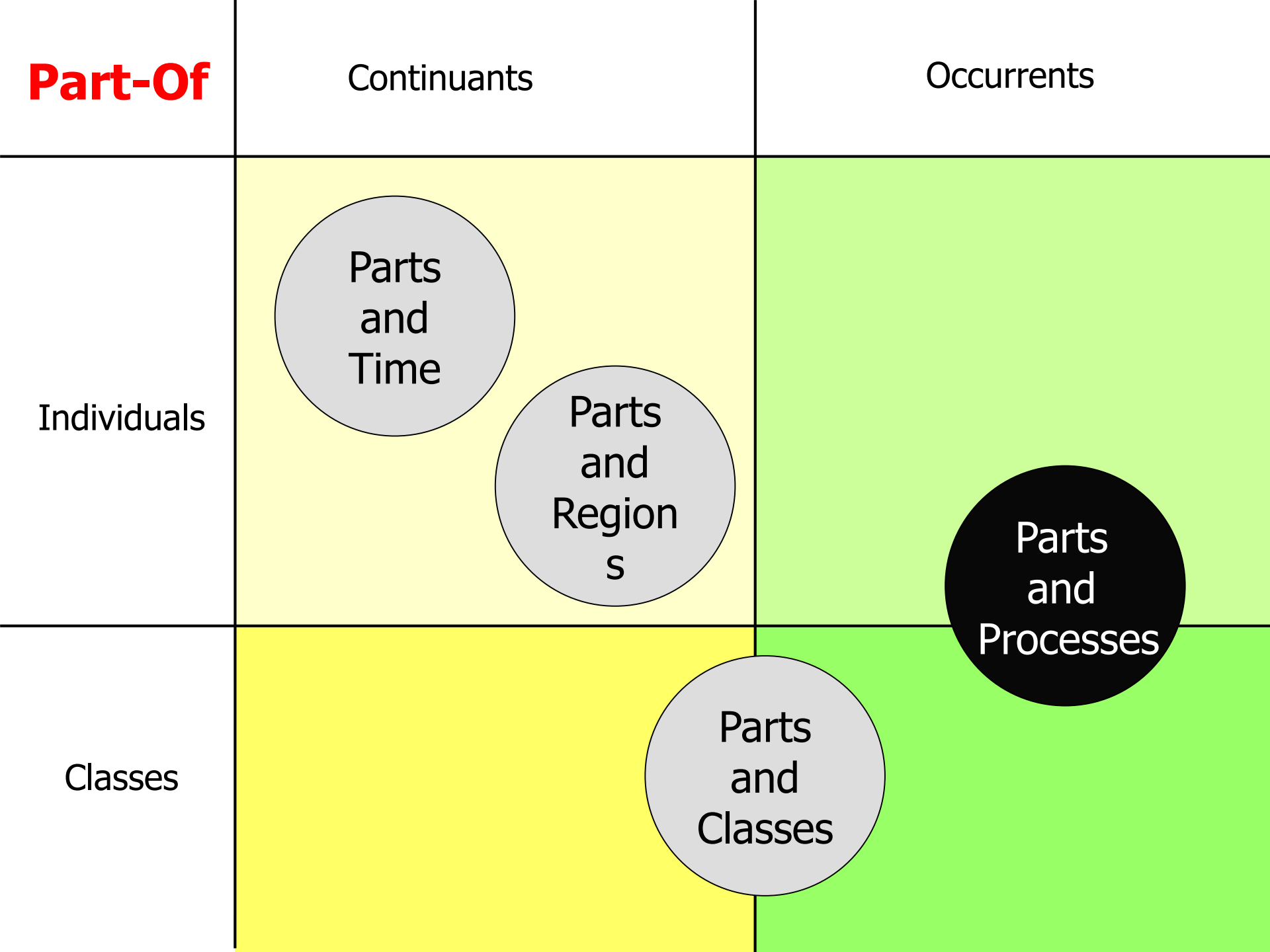
Gene Ontology 11 / 2003

Cell Membrane – Cell
Vertebra – Vertebrate
Brain - Head

- Mereological Independency

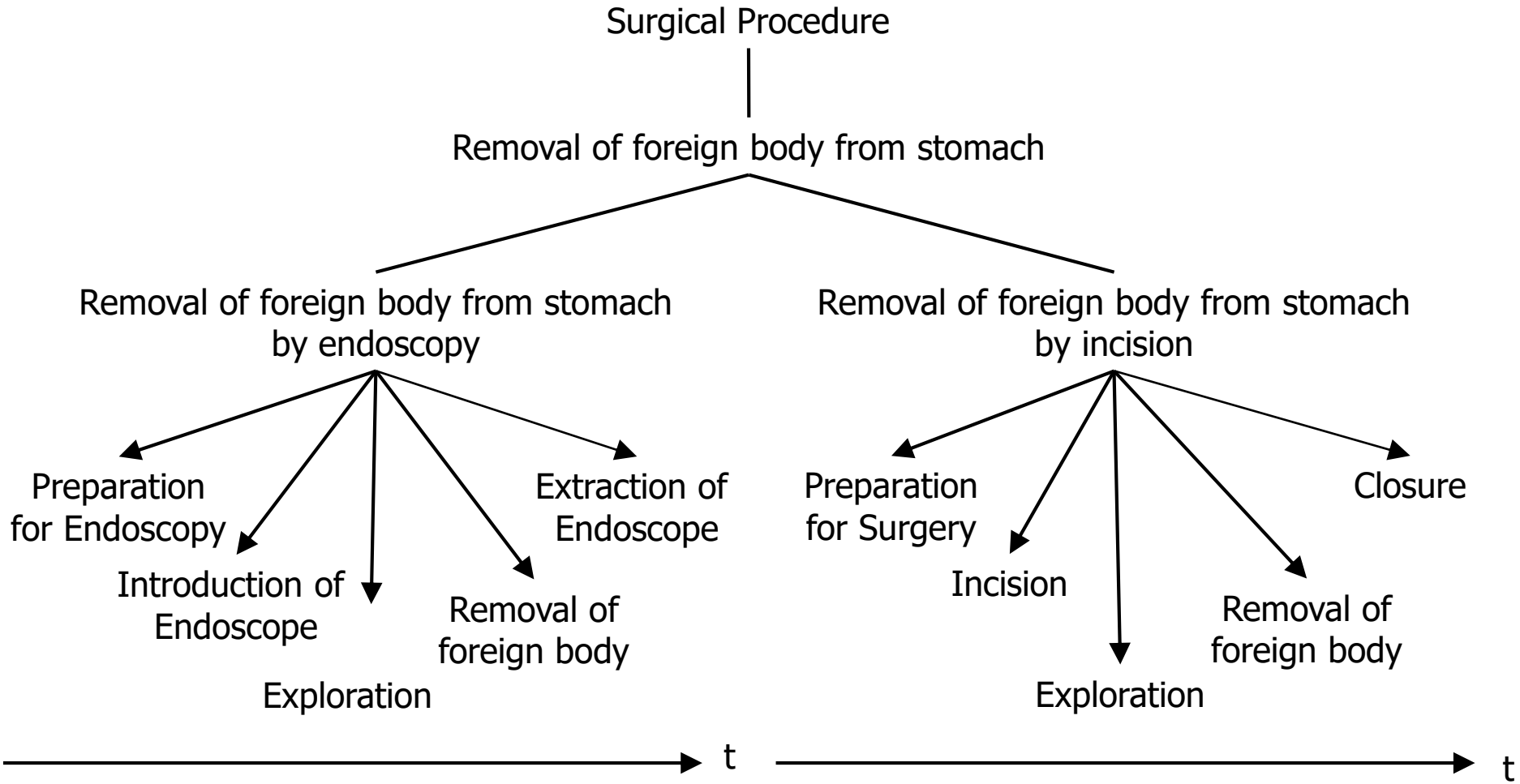


Uterus – Mammal
Sulfur – Amino Acid
Tooth – Human


Part-Of
Continuants
Occurrents
Individuals
Classes
Parts and Time
Parts and Regions
Parts and Processes
Parts and Classes

Parts and Processes

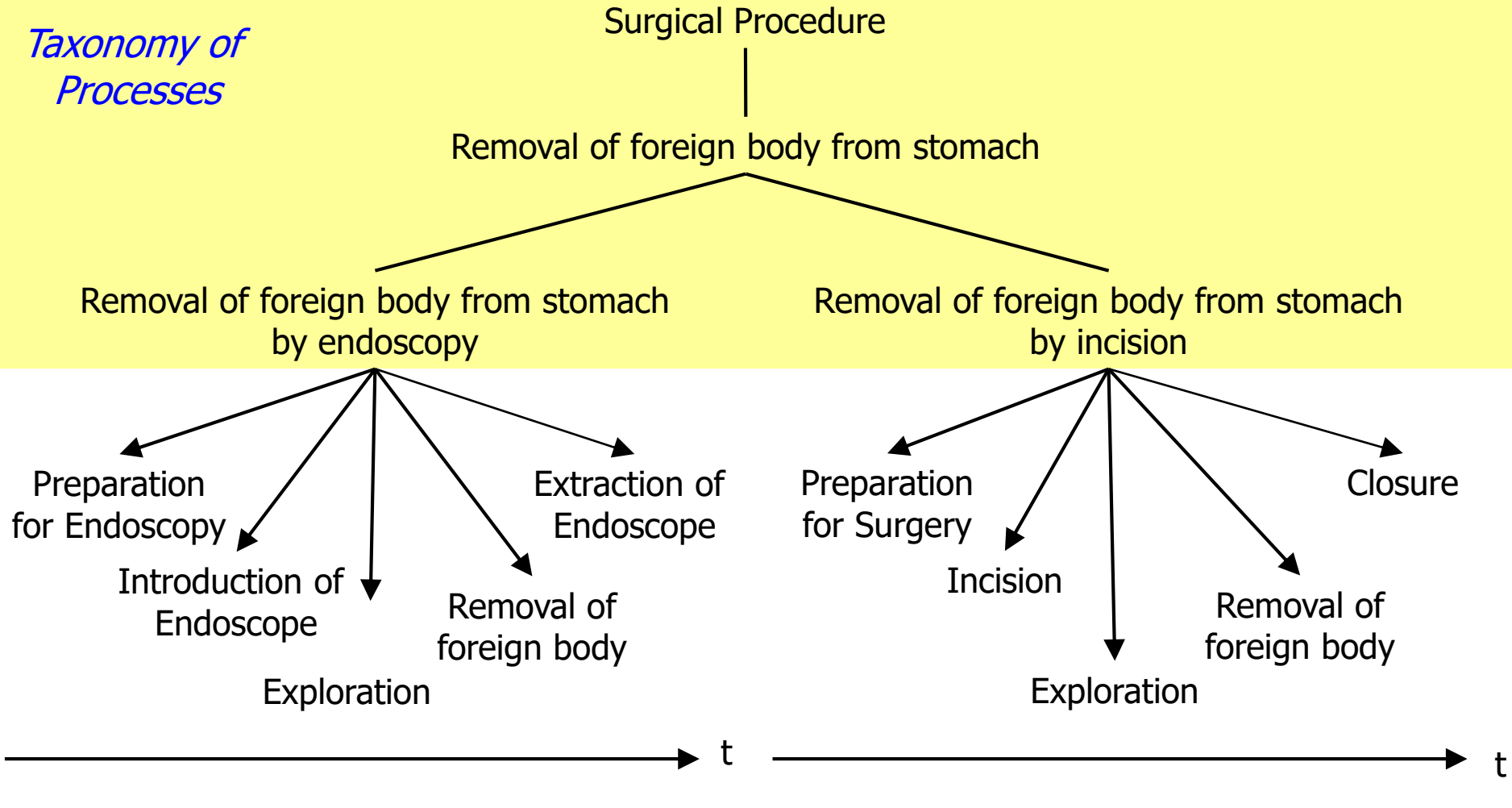
Example



Parts and Processes

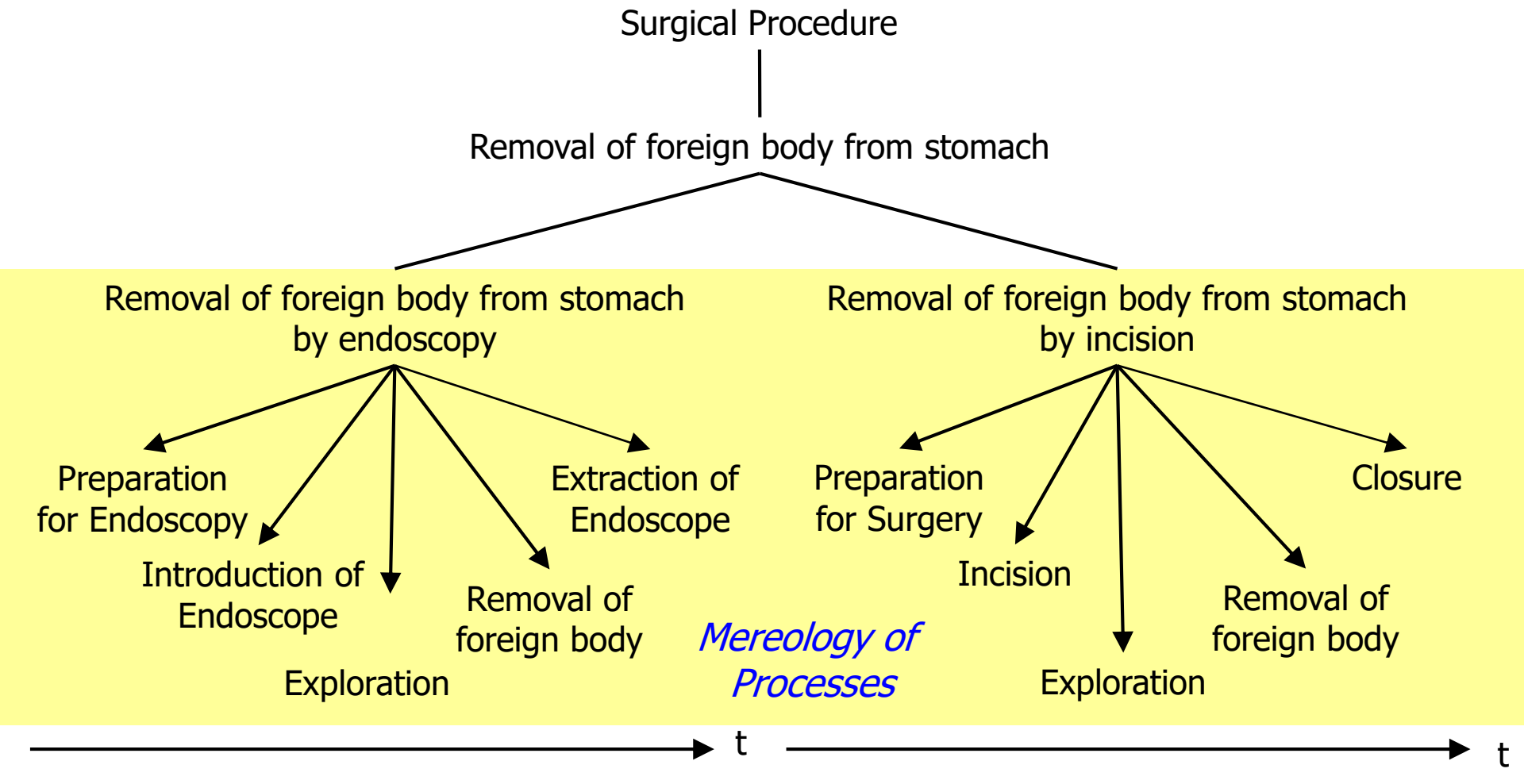
Example

Taxonomy of Processes



Parts and Processes

Example



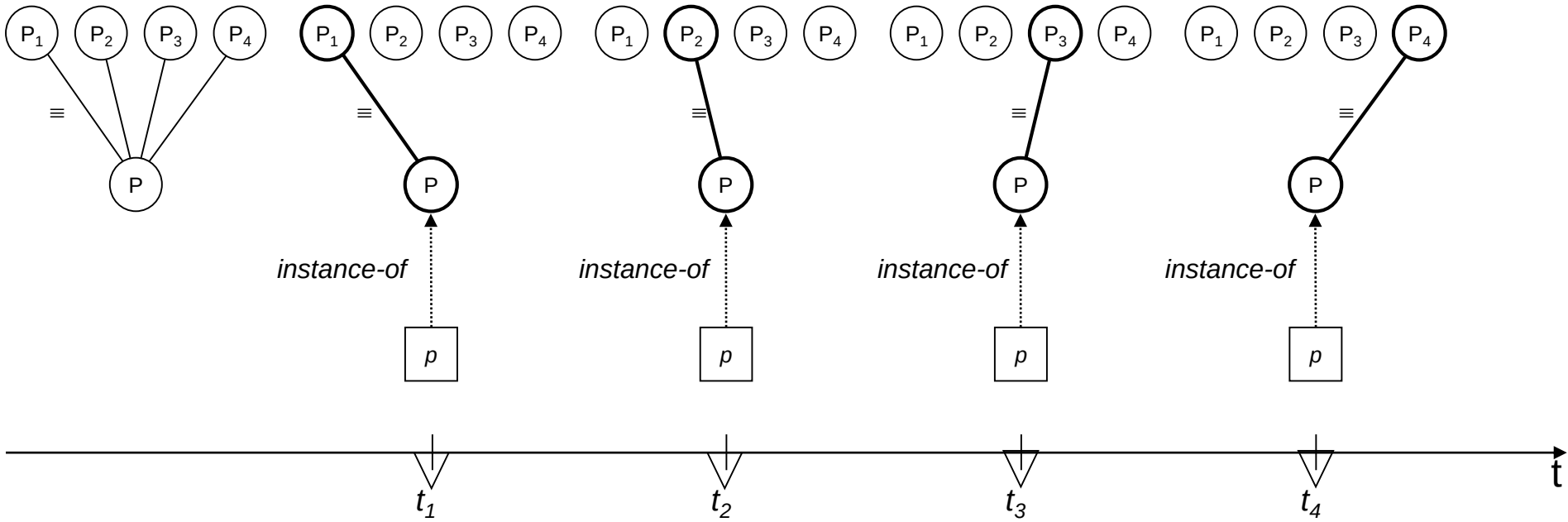
Parts and Processes

What are the instances of processes? Concurrent views

1. A process is (sequentially) instantiated by its subprocesses:
   - Subprocesses do not exist simultaneously
   - You are doing something even if you have not done it (completely)
2. A process is instantiated by its temporal parts:
   - Before having performed the complete process it is open whether the process will really be completed
   - An aborted (token) process does not fulfill the necessary conditions which define the (type) process

Parts and Processes

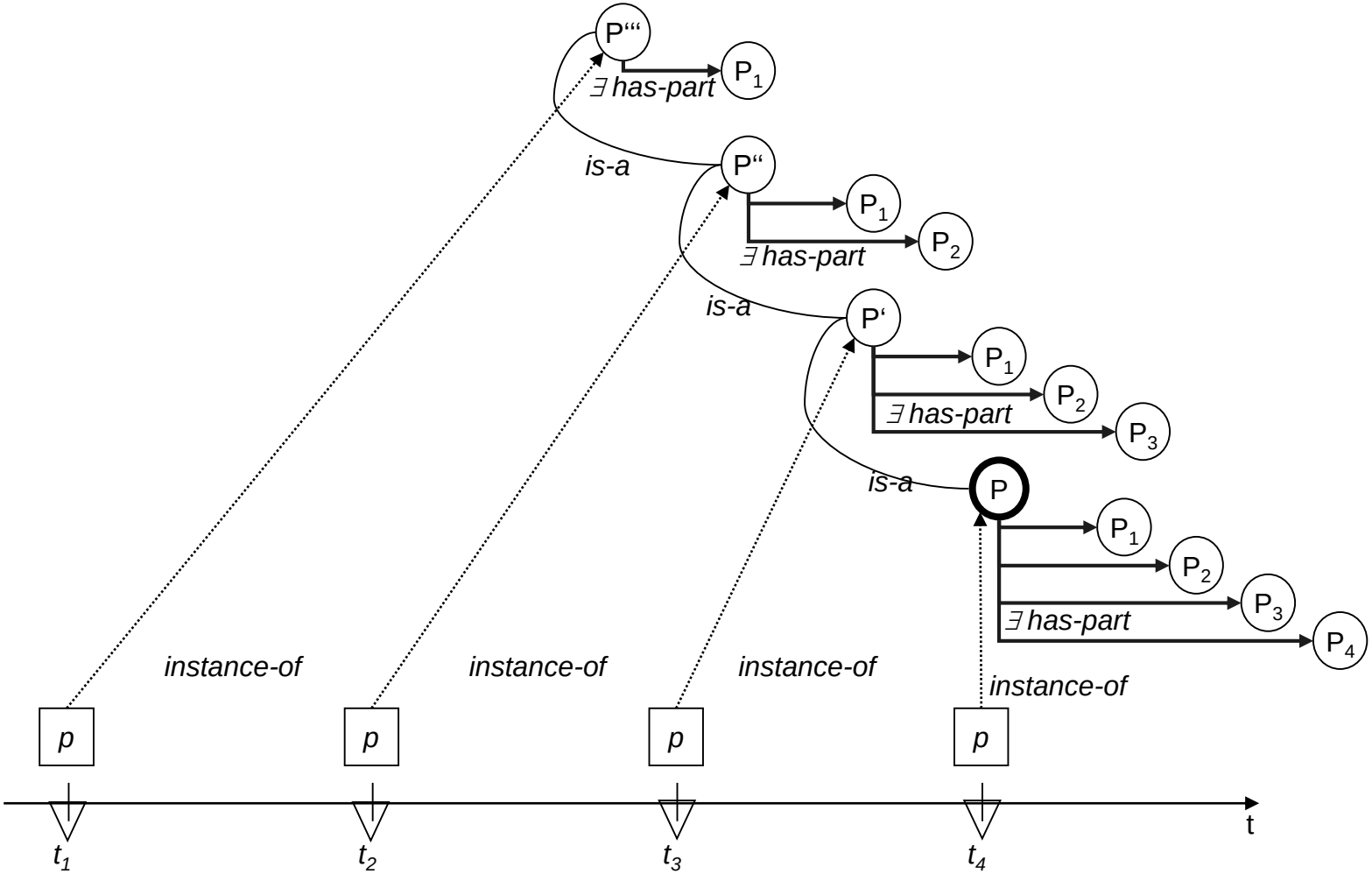
Theory 1: Process is instantiated by its subprocesses



Boris Hennig, unpublished

Parts and Processes

Theory 2: Subprocesses are parts of their parent processes

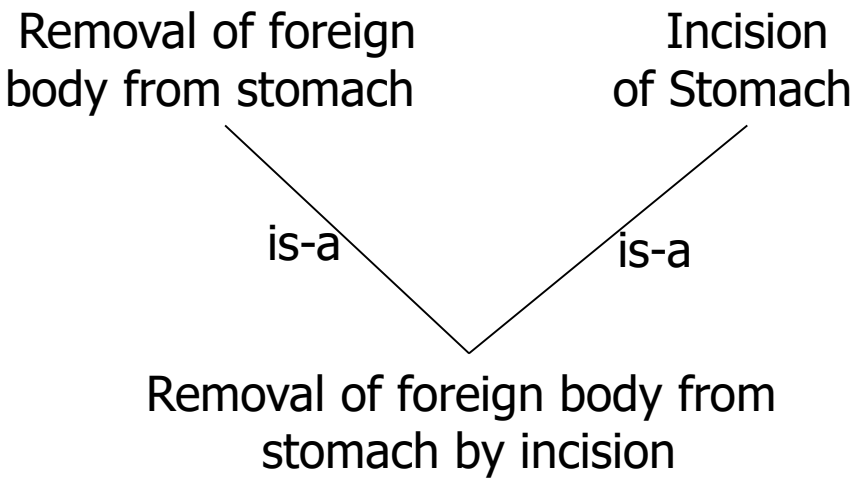


Parts and Processes

Conflicting views in Medical Terminologies

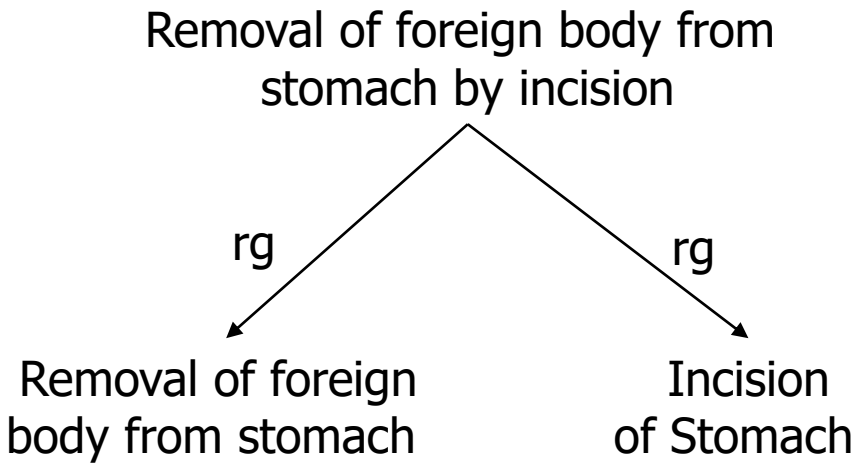
Most procedure classifications (roughly Theory 1)

Process is subsumed by its subprocesses



SNOMED CT (Theory 2)

Subprocesses are parts of their parent processes

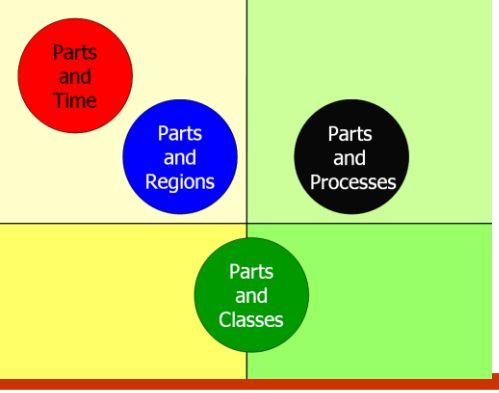


Parts and Processes

SNOMED CT

- Rg (relation group) can be re-interpreted as has-part

$$
\begin{aligned}
RemovalOfForeignBodyFromTheStomachByIncision \equiv\ & \\
& \exists\, rg.(\ \exists\, hasProcedureSite.StomachStructure \sqcap \\
& \qquad \exists\, hasMethod.IncisionAction) \sqcap \\
& \exists\, rg.(\ \exists\, hasProcedureSite.DigestiveStructure \sqcap \\
& \qquad \exists\, hasDirectMorphology.ForeignBody \sqcap \\
& \qquad \exists\, hasMethod.RemovalAction)
\end{aligned}
$$



Conclusions

- Parthood has multiple meanings
- Interoperability between ontologies and ontology based systems requires normative measures to avoid conflict between different meanings
- Spatial inclusion may be a “better” foundational relation for describing biological continuants
- Parthood between occurrents still requires thorough ontological enquiry

Thanks

Meaning of Part in Biomedical Ontologies

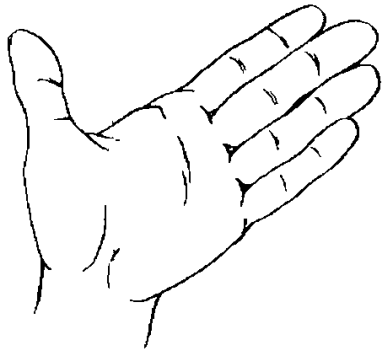
Mereological relations are fundamental for any formal ontological description of entities of the biomedical domain.

A formal account of what part is and isn't is an indispensable requirement for interoperability between human and software agents

Basics

- Mereology(-ies): Formal theory(-ies) of parts and wholes (P. Simons 1987, Casati & Varzi 1999)
- part-of: transitive, reflexive, antisymmetric relation between individuals:
  - part-of (myThumb, myHand) & part-of (myHand, myBody)
    -> part-of (myThumb, myHand)
  - part-of (myThumb, myHand)
    -> NOT part-of (myHand, myThumb)
  - part-of (myThumb, myThumb)

Part-Of: derived relations



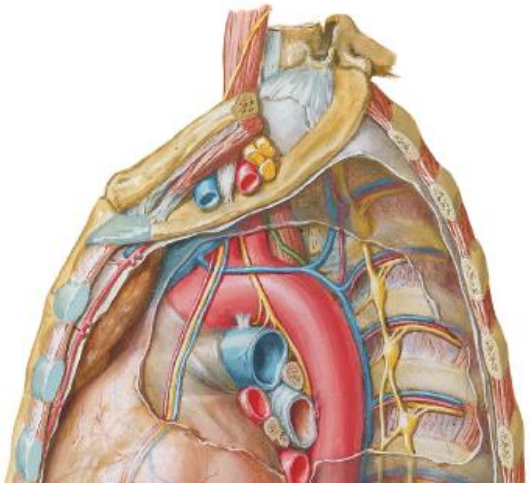
- proper-part-of:
  - proper-part-of (myThumb, myHand)
  - NOT proper-part-of (myThumb, myThumb)

  more suitable for the biomedical domain, e.g.:

  "partial resection of stomach" ≠ "total resection of stomach"
- proper overlap
  - sharing of proper parts
    overlap (myThorax, myVagusNerve)
    ("exclusive part-of", cf. R. Schubert 1999)

  unorthodox understanding of parthood-

  not to be taken for parthood



Part-Of Subrelations (1)

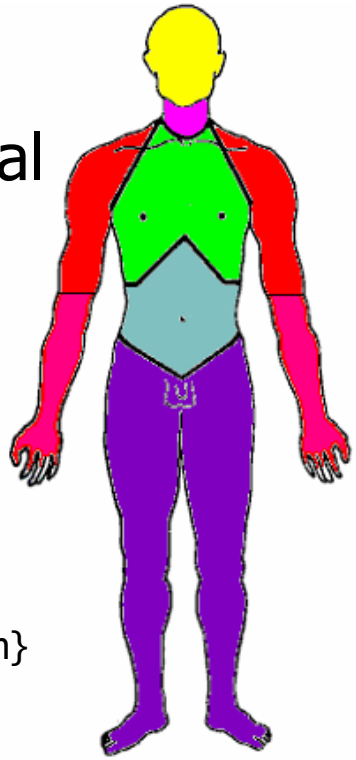
- Partitions / Subdivisions:
  disjoint parts which jointly sum up to a whole (Bittner 2004)
  decomposition of the entire body or any anatomical structure in a given context (Mejino 2004)

p1 = {my Body}

p2 = {my head, my neck, my torso, my limbs}

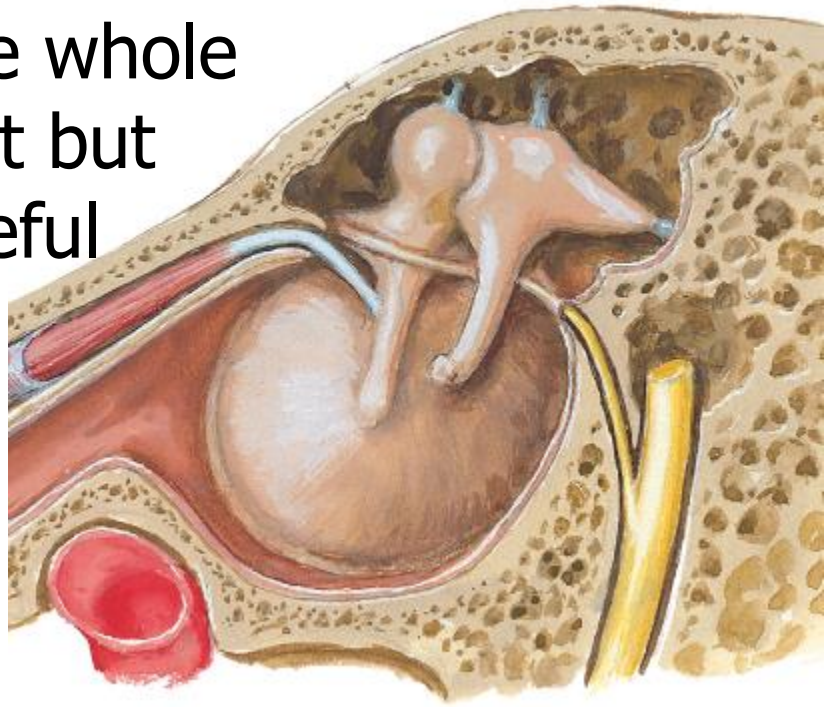
p3 = {my head, my neck, my torso, my left leg, my right leg, my left arm, my right arm}

p4 = {my head, my neck, my thorax, my abdomen, my left leg, my right leg, my left upper arm, my left lower arm, my right upper arm, my right lower arm}



Part-Of Subrelations (2)

- (Functional) Components of integral compounds:
  - The part contributes to the whole not just as a structural unit but as essential to the purposeful activity of the whole
    (Pat Lambrix)
  - How to define function ?



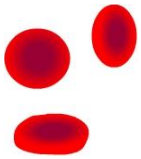
Part-Of Variations (3)

- Collections, Partonomic Inclusion

  Uniform elements, e.g. blood, water, urine

  (Gerstl 1995, Bittner 2004)

  - homomerous = parts are of the same sort



Part-of: Dimensionality

- part-of (a, b) requires dim(a) ≤ dim(a):
  - -> e.g. 2D boundaries can be part of 3D objects
- in Medicine: different conceptualizations, e.g. in the FMA boundaries cannot be part of 3D objects