

# **Standardization of Anatomy Parts and Wholes – From Function to Location**

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# Standardization of Biological Structure (Anatomy/Anatomies): Creating consensus about...

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- Top-level Properties

dimensionality, solid / hollow, boundary, count, mass, collection

- Foundational Relations

is-a, instance-of, part-of, has-location, has-branch, has-developmental-form, descends-from, connects, bounds

- Theories

species, development, granularity, canonicity

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# Part-Of in Anatomies: Consensus required about

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- Domain and range of part-of relations
- Algebraic properties of part-of relations
- Intended meaning of part-of relations in the domain of biology and medicine

# Part-Of in Anatomies: Consensus required about

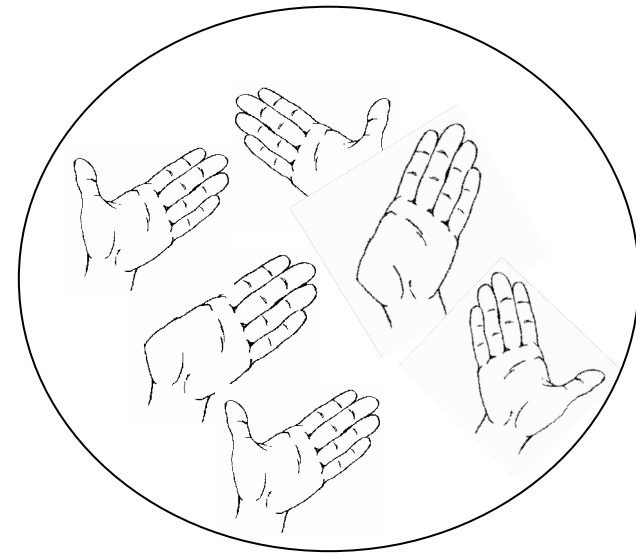
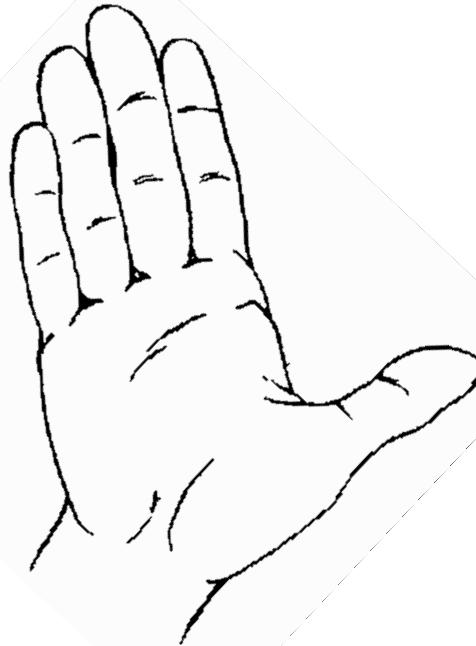
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- Domain and range of part-of relations
- Algebraic properties of part-of relations
- Intended meaning of part-of relations in the domain of biology and medicine

# Part-of between individuals and universals



Hungary *part-of* Europe    myThumb *part-of* myHand



Thumb *part-of* Hand

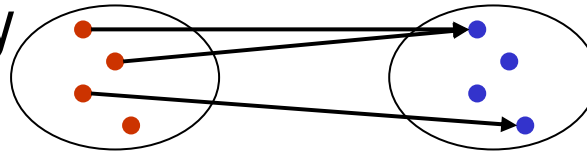
# Class-level Part-Of : Different Interpretations

	Class A (part)	Class B (whole)	Examples
<ul style="list-style-type: none"> <li>One-sided Dependency Part on Whole</li> </ul>			Cell Nucleus – Cell Chlorophyll – Organism Prostate Tumor – Prostate
<ul style="list-style-type: none"> <li>One-sided Dependency Whole on Part</li> </ul>			Sulfur – Methionin Wing – Chicken Heart – Drosophila
<ul style="list-style-type: none"> <li>Mutual Mereological Dependency</li> </ul>			Cell Membrane – Cell Vertebra – Vertebrate Body Surface – Body
<ul style="list-style-type: none"> <li>Mereological Independency</li> </ul>			Uterus – Mammal Sulfur – Amino Acid Tooth – Human

# Class-level Part-Of : Different Interpretations

GALEN,  
Gene Ontology 07 / 2004 (whole)

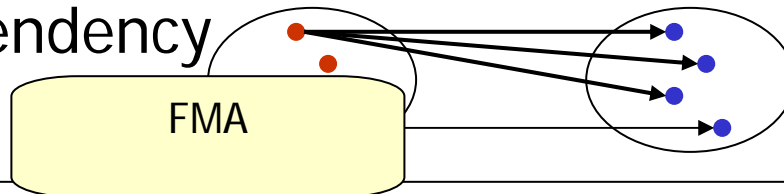
- One-sided Dependency  
Part on Whole



## Examples

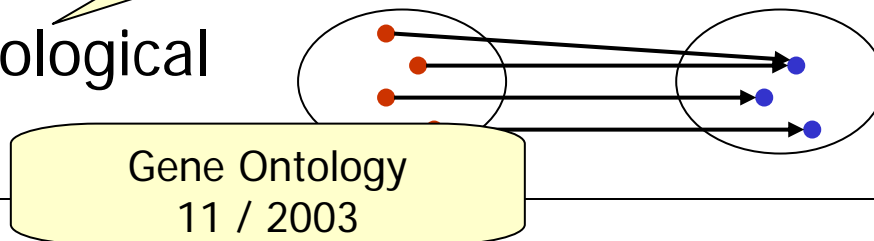
Cell Nucleus – Cell  
Chlorophyll – Organism  
Prostate Tumor – Prostate

- One-sided Dependency  
Whole on Part



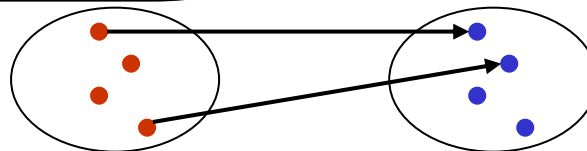
Sulfur – Methionin  
Wing – Chicken  
Heart – Drosophila

- Mutual Mereological  
Dependency



Cell Membrane – Cell  
Vertebra – Vertebrate  
Body Surface – Body

- Mereological  
Independency



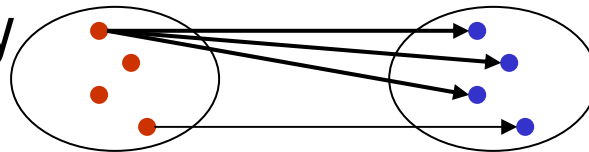
Uterus – Mammal  
Sulfur – Amino Acid  
Tooth – Human

# Class-level Part-Of : Different Interpretations, Different Names

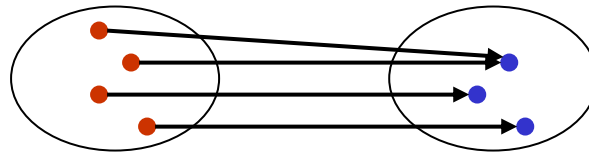
■ *Part-For* (A, B) = *def*\*

$\forall x: inst\text{-of}(x, A) \rightarrow \exists y: inst\text{-of}(y, B) \wedge part\text{-of}(x, y)$

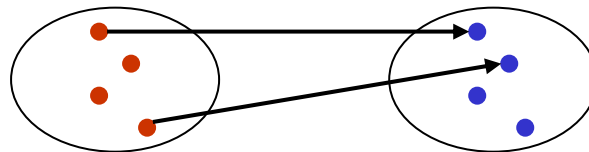
■ One-sided Dependency  
Whole on Part



■ Mutual Mereological  
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■ Mereological  
Independency



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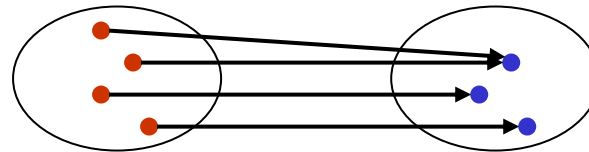
■ *Part-For* (A, B) =  $_{def^*}$

$$\forall x: inst-of(x, A) \rightarrow \exists y: inst-of(y, B) \wedge part-of(x, y)$$

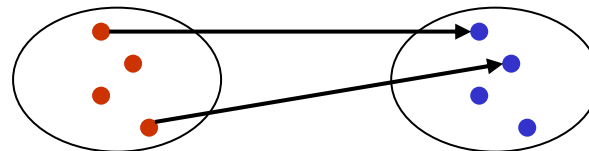
■ *Has-Part* (B, A) =  $_{def^*}$

$$\forall y: inst-of(y, B) \rightarrow \exists x: inst-of(x, A) \wedge part-of(x, y)$$

■ Mutual Mereological Dependency



■ Mereological Independency



# Class-level Part-Of : Different Interpretations, Different Names

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- $Part\text{-}For(A, B) =_{def^*} \forall x: inst\text{-}of(x, A) \rightarrow \exists y: inst\text{-}of(y, B) \wedge part\text{-}of(x, y)$

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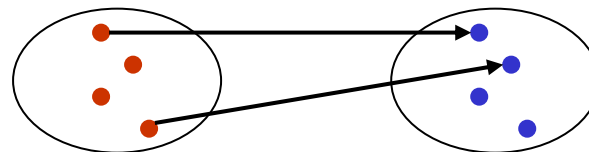
- $Has\text{-}Part(B, A) =_{def^*} \forall y: inst\text{-}of(y, B) \rightarrow \exists x: inst\text{-}of(x, A) \wedge part\text{-}of(x, y)$

---

- $Part\text{-}Of(A, B) =_{def^*} \widetilde{Part\text{-}For}(A, B) \wedge \widetilde{Has\text{-}Part}(B, A)$

---

- Mereological  
Independency



# Class-level Part-Of : Different Interpretations, Different Names

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■  $Part\text{-}For(A, B) =_{def^*}$   
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■  $Has\text{-}Part(B, A) =_{def^*}$   
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■  $Part\text{-}Of(A, B) =_{def^*} \overline{Part\text{-}For(A, B)} \wedge \overline{Has\text{-}Part(B, A)}$

---

■  $Possible\text{-}Part(A, B) =_{def}$   
 $\exists x, y: inst\text{-}of(x, A) \wedge inst\text{-}of(y, B) \wedge part\text{-}of(x, y)$

\*cf. Smith & Rosse, MEDINFO 2004

# Part-Of in Anatomies: Consensus required about

---

- Domain and range of part-of relations
- Algebraic properties of part-of relations
- Intended meaning of part-of relations in the domain of biology and medicine

# Algebraic Properties: *Part-Of / Has-Part vs. part-of / has-part*

## ■ Instance level :

$part-of(a, b), part-of(b, c) \rightarrow part-of(a, c)$  **Transitivity ?**

$part-of(a, b) \rightarrow \neg part-of(b, a)$  **Asymmetry**

$part-of(a, b) \rightarrow a \neq b$  **Irreflexivity ?**

$part-of(a, b) \rightarrow has-part(b, a)$  **Inverse Relation**

## ■ Class level\* :

$Part-For(A, B), Part-For(B, C) \rightarrow Part-For(A, C)$

$Part-For(A, B) \rightarrow \neg Part-For(B, A)$

$Part-For(A, B) \rightarrow \neg Is-A(A, B)$  **?**

$Part-For(B, A)$  does not necessarily imply  $Has-Part(A, B)$

$Possible-Part(B, A)$  implies  $Has-Possible-Part(A, B)$

(...)

# Part-Of in Anatomies: Consensus required about

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# Different notions of part-of

---

- Time-independent:
  - Compositional
  - Functional
  - Topological
- Time-dependent:
  - *a part-of b* at any point of time →  
*a part-of b* at every point of time
  - *a part-of b* at one point of time,  
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# Parts as Components

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Parts “build”  
the whole

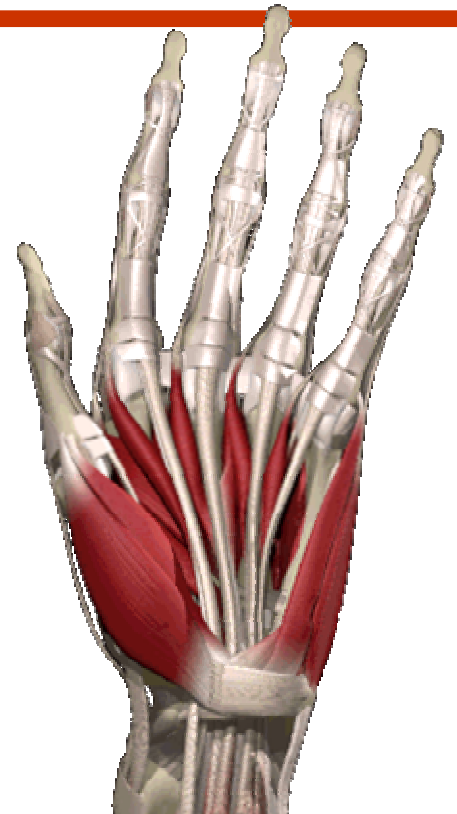
*part-of (Finger, Hand)*

*part-of (Bone Marrow, Bone)*

*part-of (Sodium Ion, Cytoplasm) ?*

*part-of (Sarcomer, Muscle)*

*part-of (Heart, Human Body)*



“Intuitive” notion of part. Controversial

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# Parts as Functional Components

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Part contributes to the function of the whole

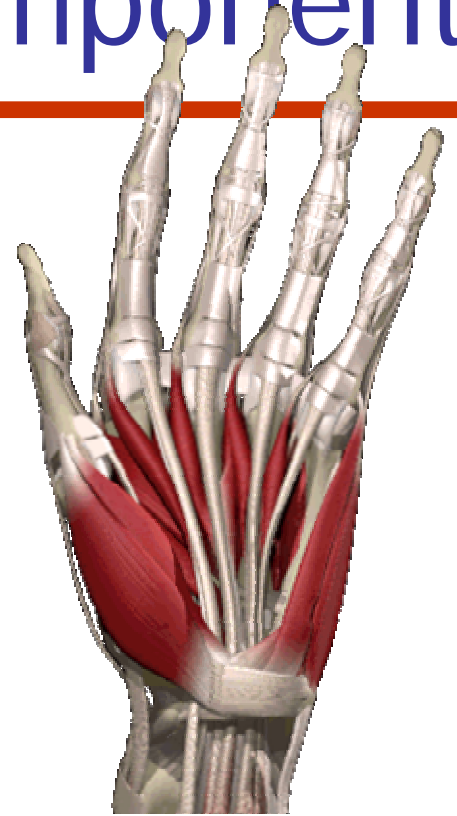
*part-of (Finger, Hand)*

*part-of (Lymph Node, Lymphatic System)*

*part-of (Cell Nucleus, Cell)*

*part-of (Tendon, Muscle )*

*part-of (Tooth, Jaw)*



More restricted, may conflict with notions of connection

# Different notions of part-of

---

## ■ Time-independent:

- Compositional

- Functional

- Topological

**no clear distinction !**

## ■ Time-dependent:

- *a part-of b* at any point of time →  
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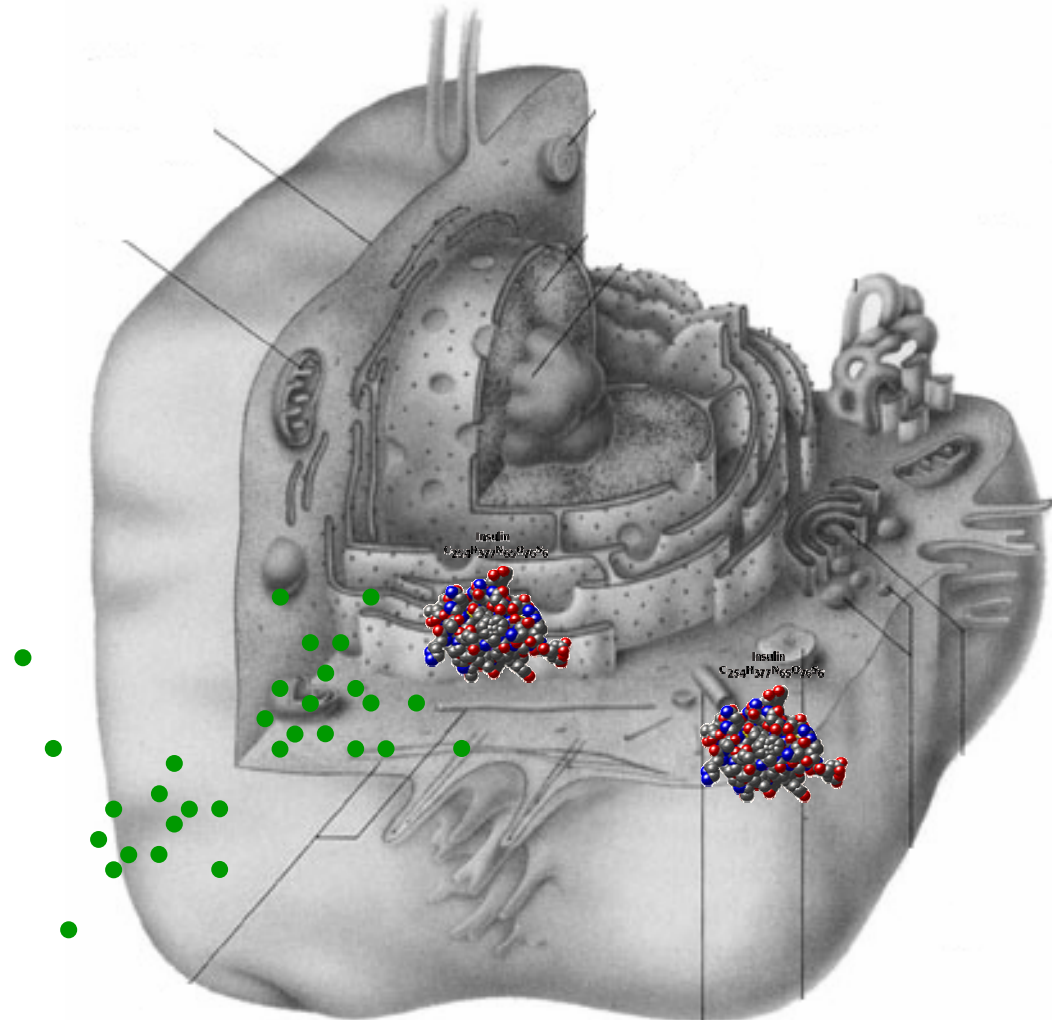
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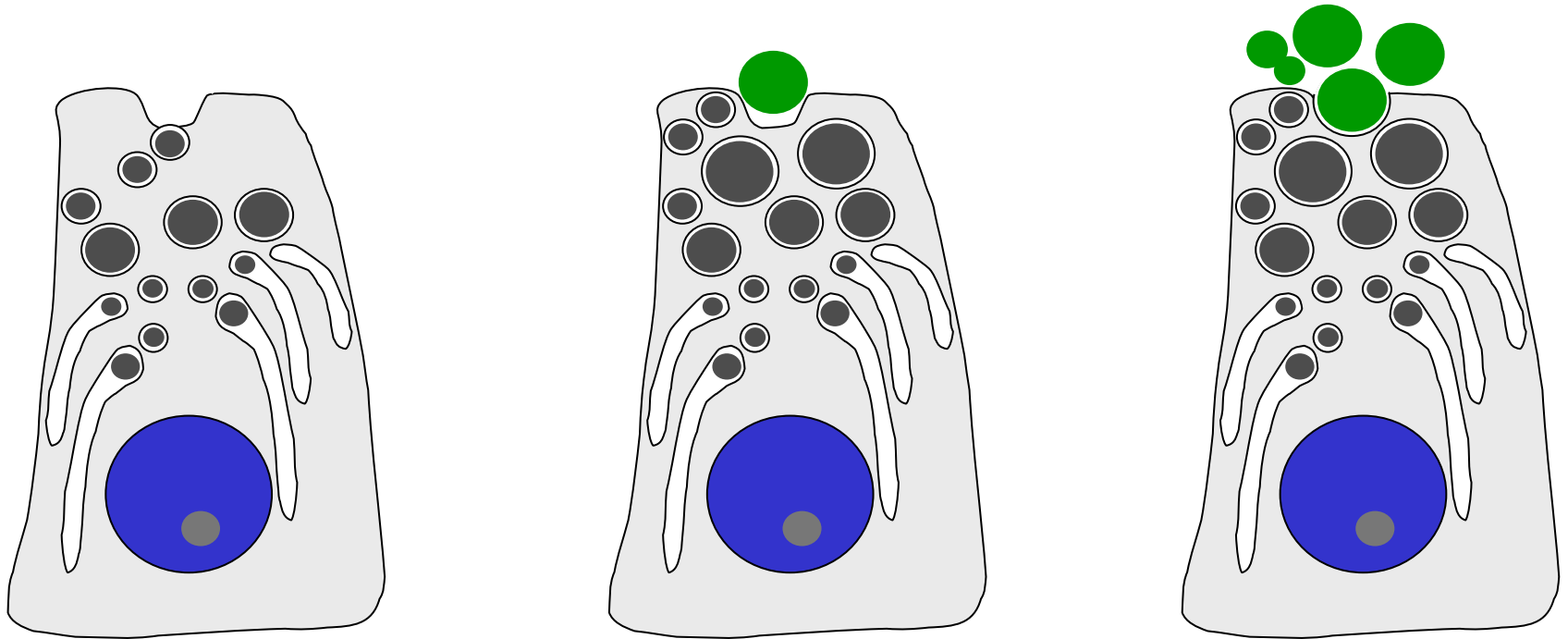
# Continuous exchange of matter

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# Excretion / Secretion

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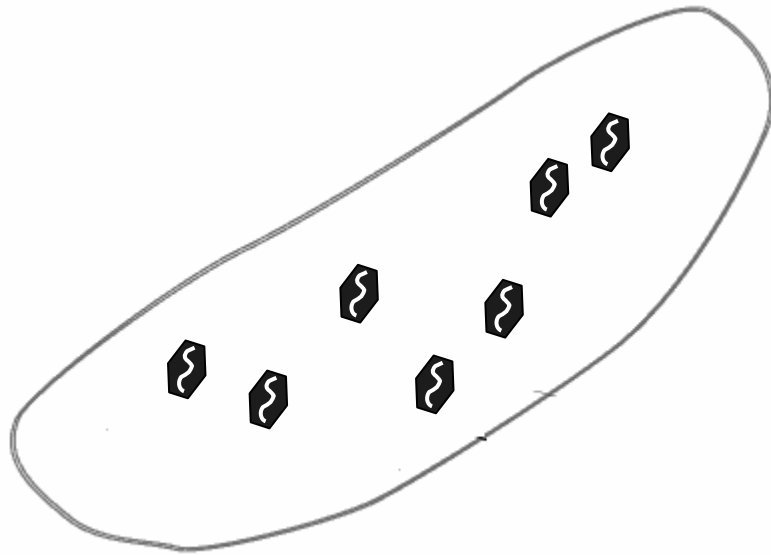


Is the secretion part of the cell ?

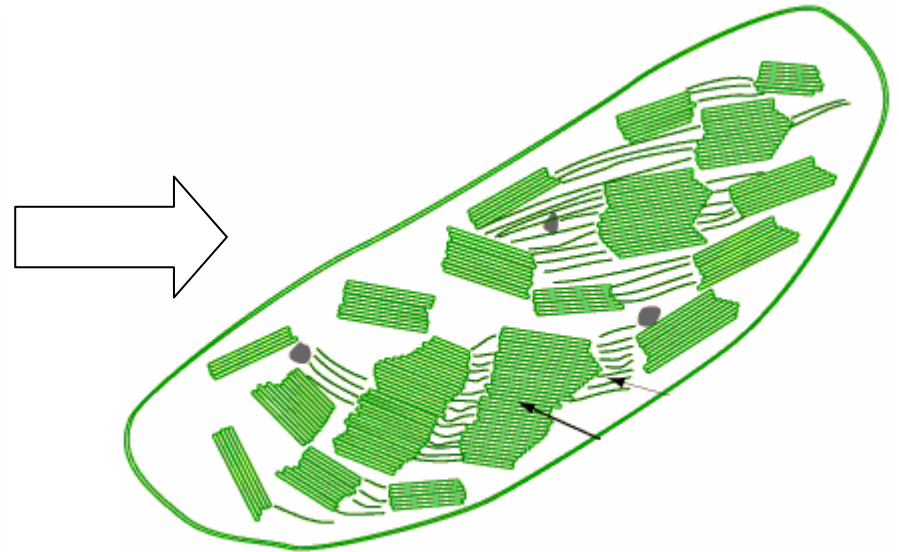
# Endosymbiont Hypothesis

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2.5 billion years ago:  
Primitive cell with  
bacterium-like symbionts

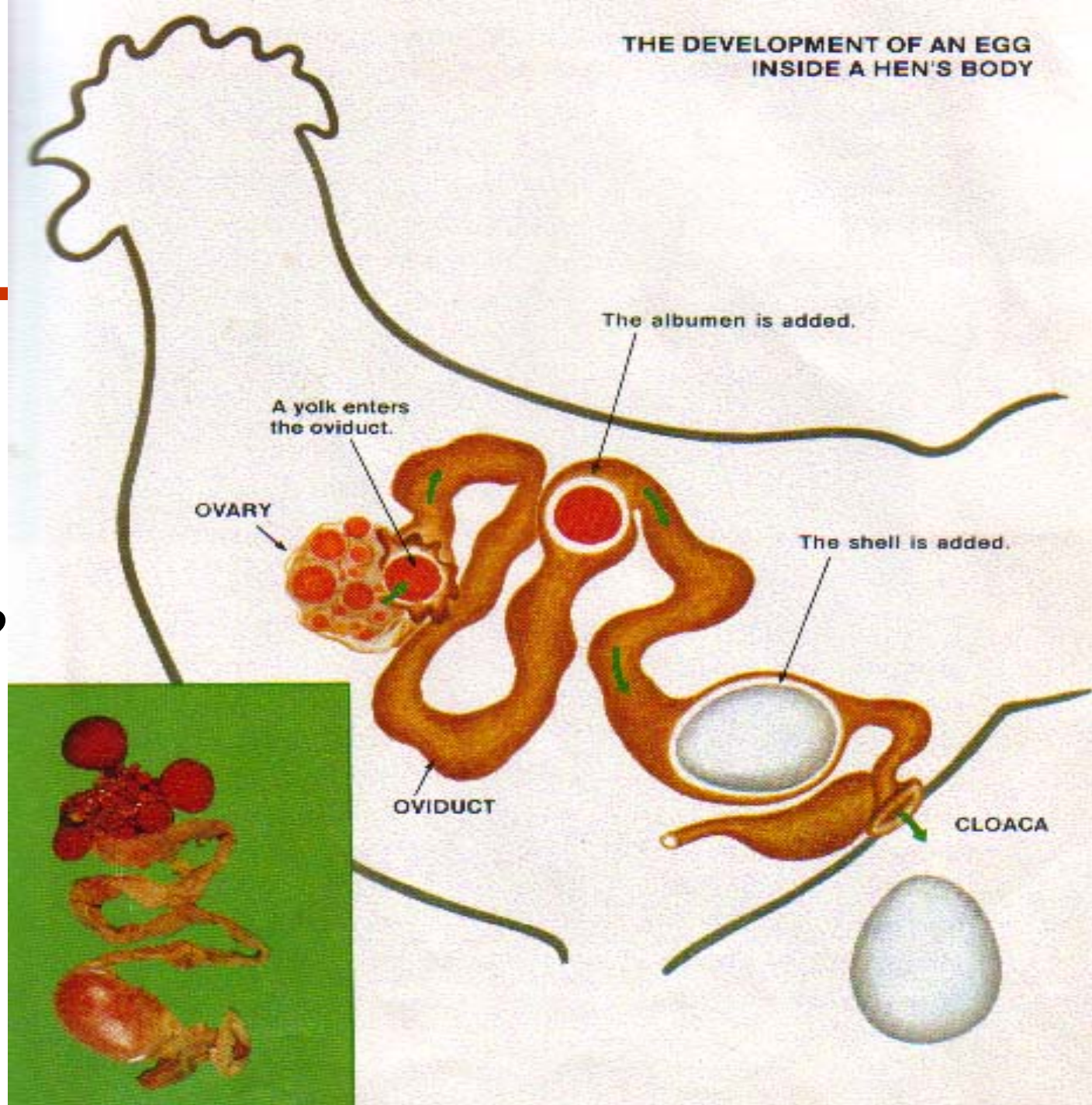


Today:  
Chloroplasts (Plants)  
Mitochondria



Are the organelles part of the cell

THE DEVELOPMENT OF AN EGG  
INSIDE A HEN'S BODY



Which eggs are part of the body ?

# Topological parts

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Located within the boundaries  
of an object

*part-of (Mitochondrion, Cell)*

*part-of (Brain, Head)*

*part-of (Brain, Cranial Cavity) ?*

*part-of (Ovum, Oviduct) ?*

*part-of (Finger, Hand)*

*part-of (Amount of Blood, Right Ventricle) ?*

*has-location* instead of *part-of* ?

# Topological parts

---

Located within the boundaries  
of an object

*has-location (Mitochondrion, Cell)*

*has-location (Brain, Head)*

*has-location (Brain, Cranial Cavity)*

*has-location (Ovum, Oviduct)*

*has-location (Finger, Hand)*

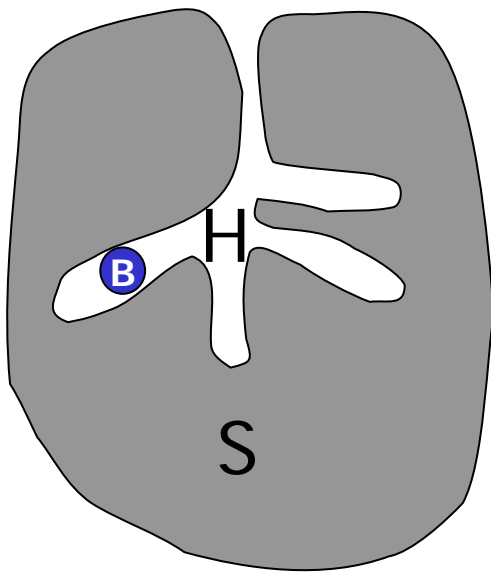
*has-location (amount of Blood, Right Ventricle)*

*has-location* as a mereotopological primitive ?

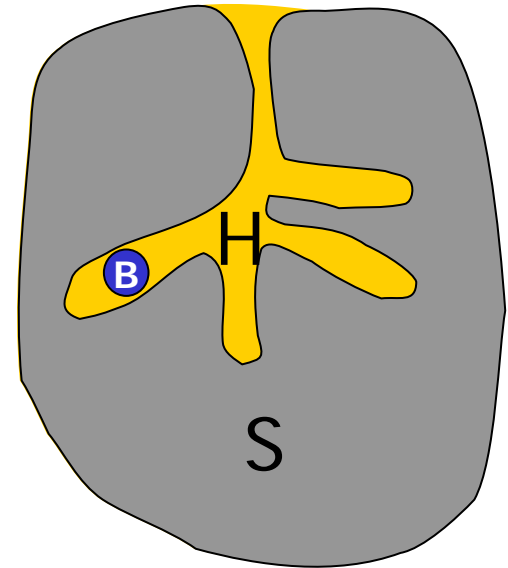
# Topological parts

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How to deal with hollow spaces ?



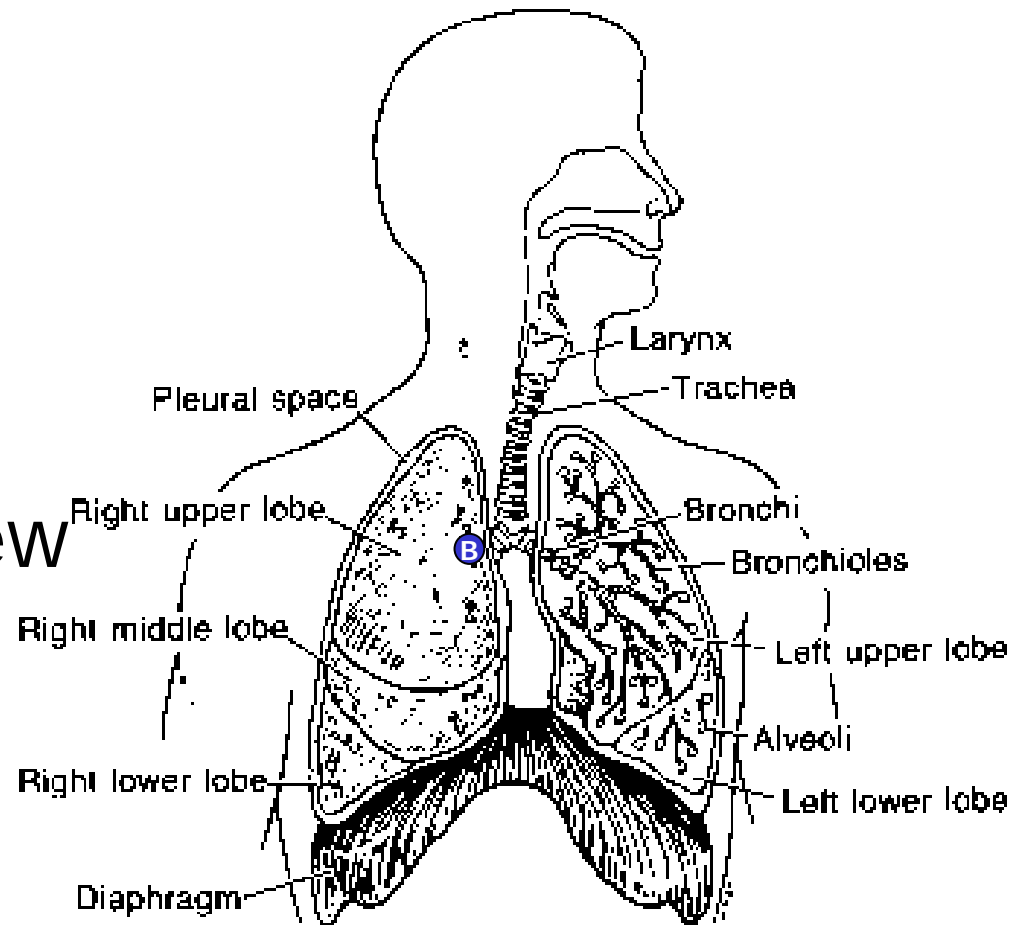
H is part of E, hence B is located **outside** of S



H is part of S, hence B is located **inside** of S

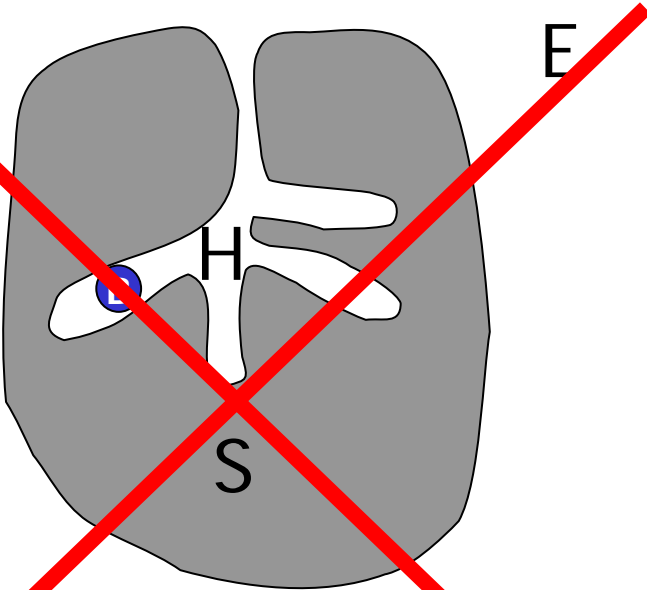
# Example

- Inside or outside ?
- Example: Bronchi  
A foreign body in a bronchus is in the lung
- Strict topological view conflicts with shared conceptualization

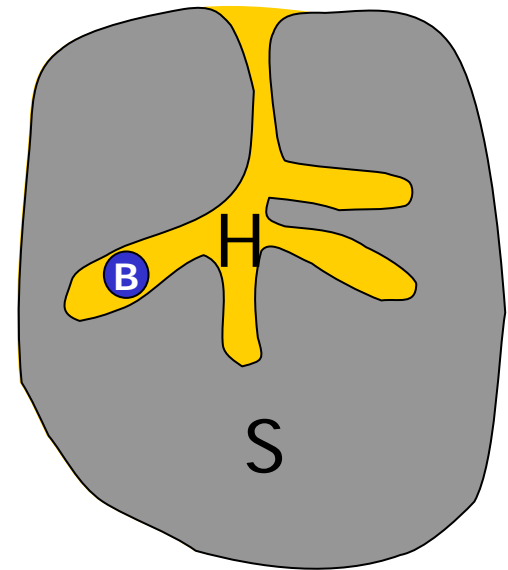


# Topological parts

How to deal with hollow spaces ?



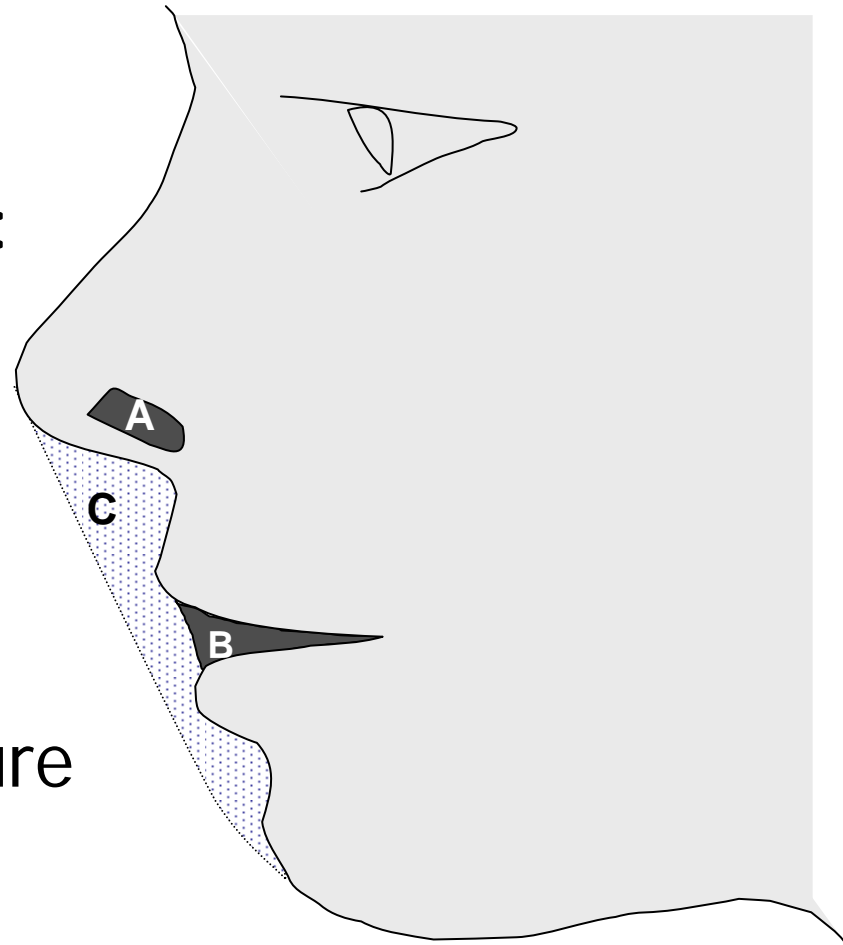
$H$  is part of  $E$ , hence  $B$  is located **outside** of  $S$



$H$  is part of  $S$ , hence  $B$  is located **inside** of  $S$

# Which hollow spaces are located / part of a solid ?

- Convex hull operator ?  
 $C$  would be "inside"
- Possible pragmatic solution:  
"Inside" a biological structure =  
located in the solid parts or in those hollow spaces which are defined ***located within*** the structure (here  $A$  and  $B$ )



# Proposal:

## generalize *part-of* to *has-location*

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- Domain: solids, hollows
- Range: solids, hollows

Examples:

*Has-Location (Brain, Cranial Cavity)*

*Has-Location (Pharyngitis, Pharynx)*

*Has-Location (Finger, Hand)*

*Has-Location (Embryo, Uterus)*

- Advantage: clear semantics, easier consensus
- Disadvantage: functional aspects hidden

# Different notions of part-of

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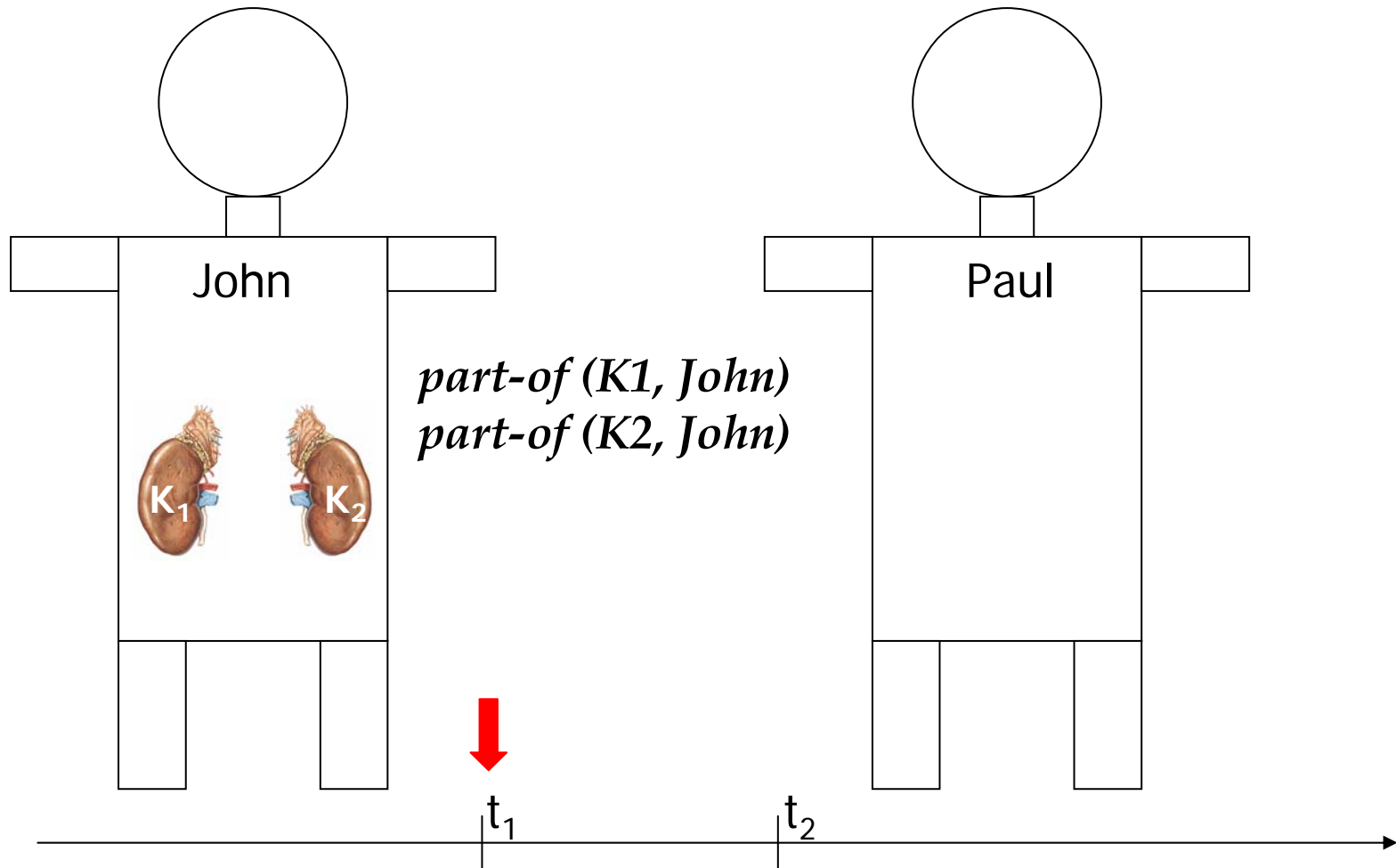
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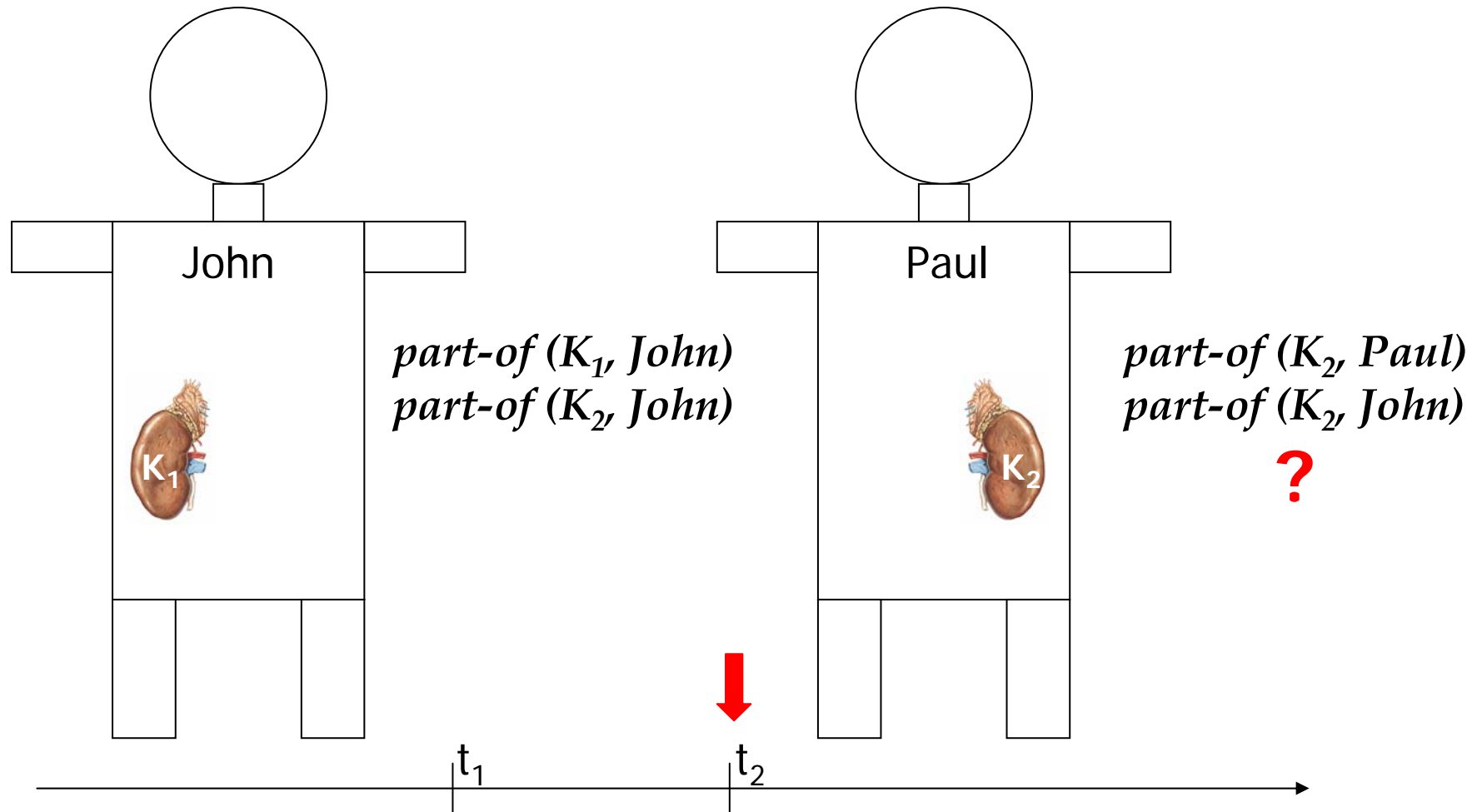
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# Example: Transplantation

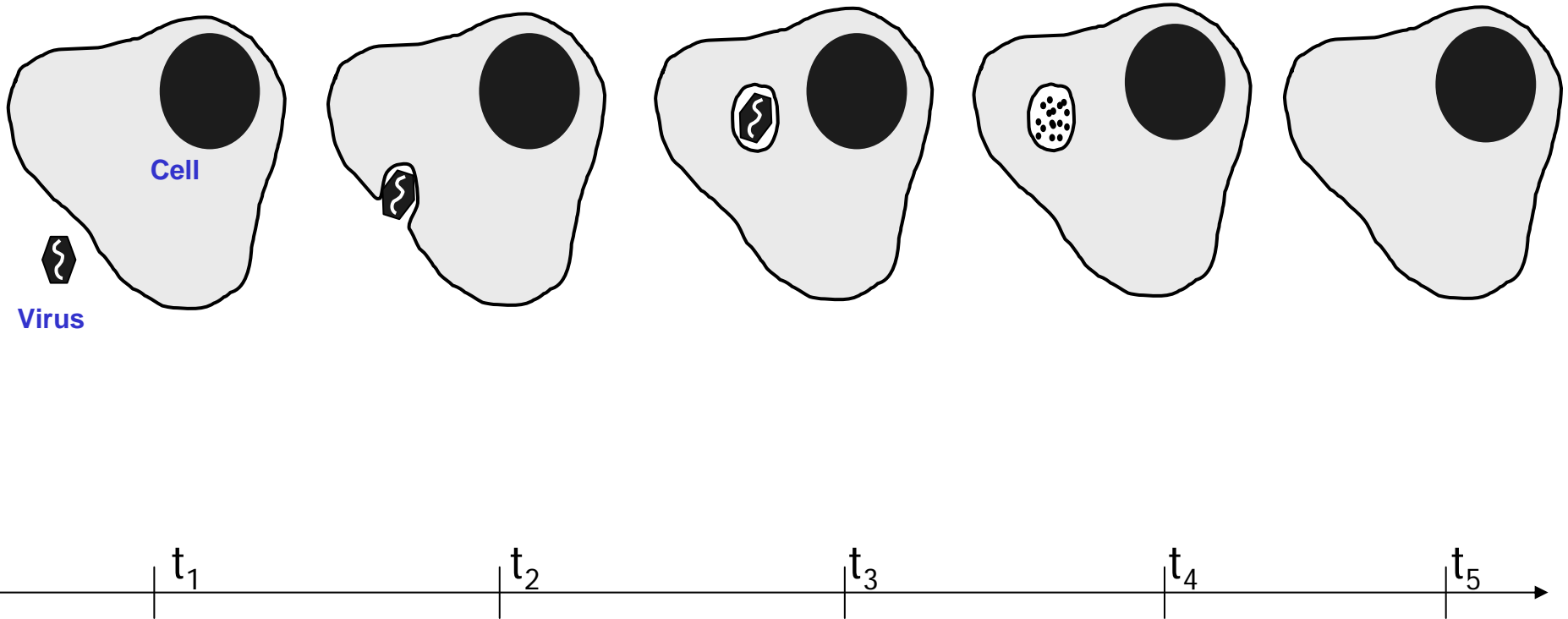


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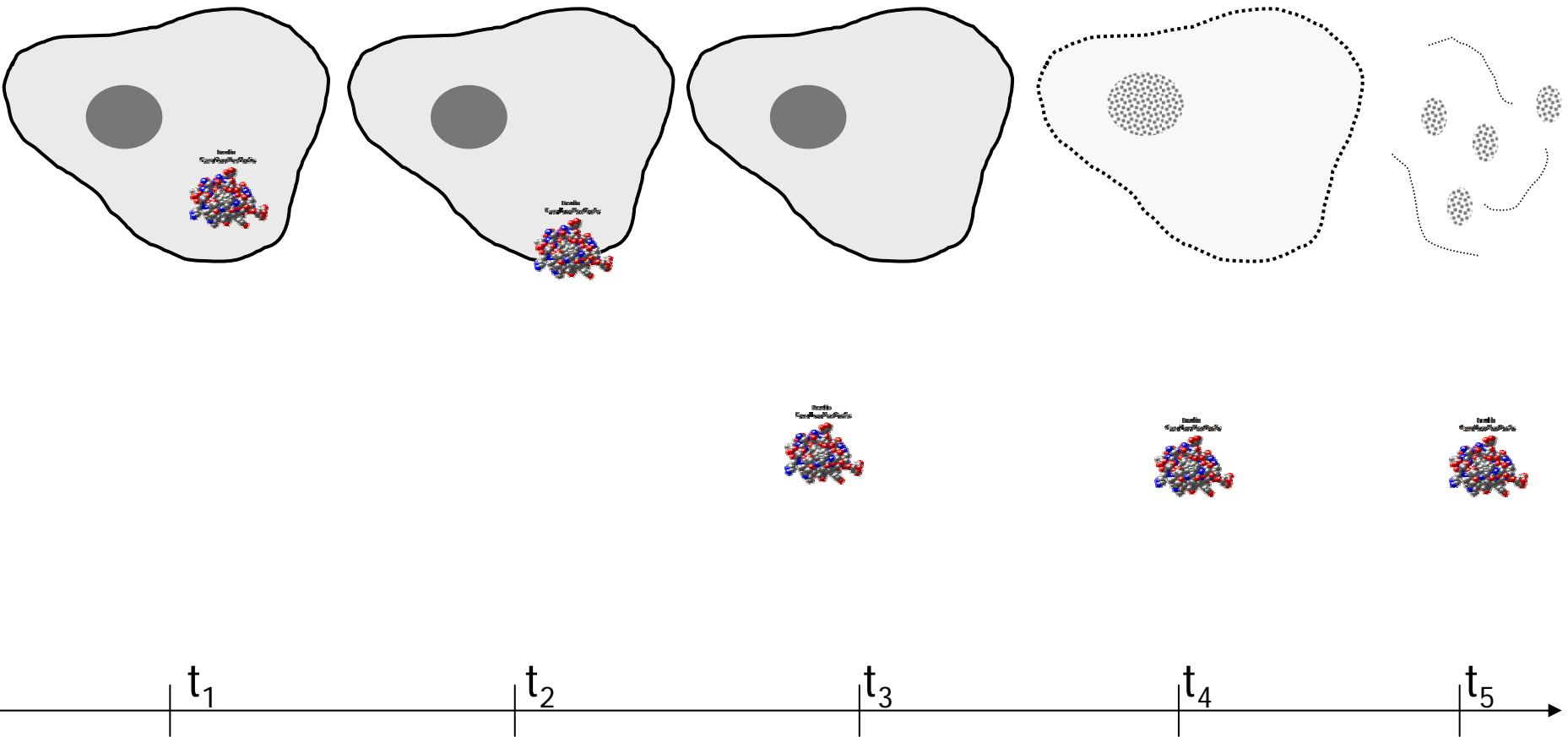


# Phagocytosis / Digestion

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# Secretion



# Conclusion

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- Part-of: example, how many different interpretations co-exist
- Standardization: need to eliminate ambiguity by precise characterization of foundational primitives (properties, relations)
- Solid theoretical basis is needed, e.g. mereotopology: Simons, Casati, Smith, Varzi,...

