Granular Partitions and Anatomical Boundaries

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Mapping the Human Body
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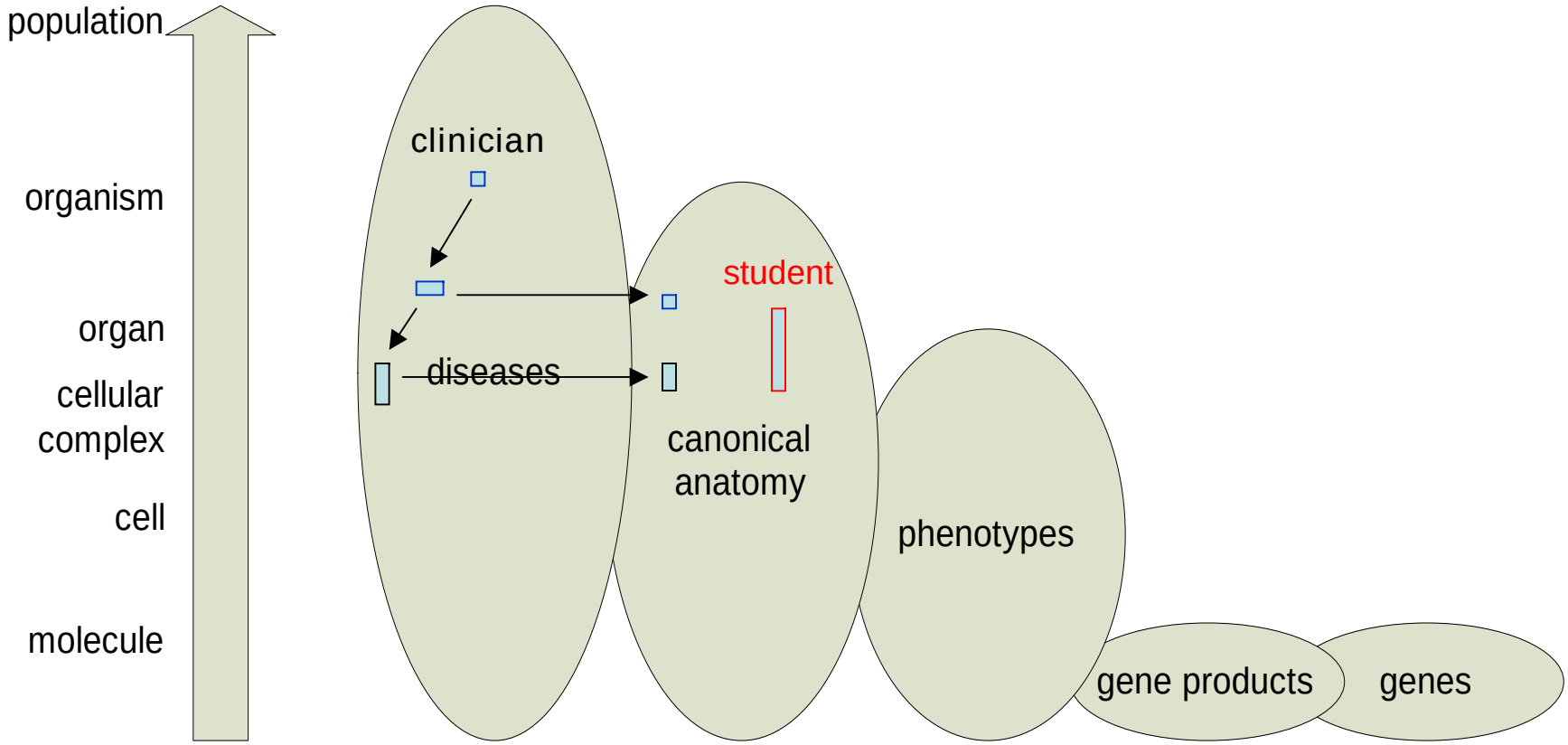
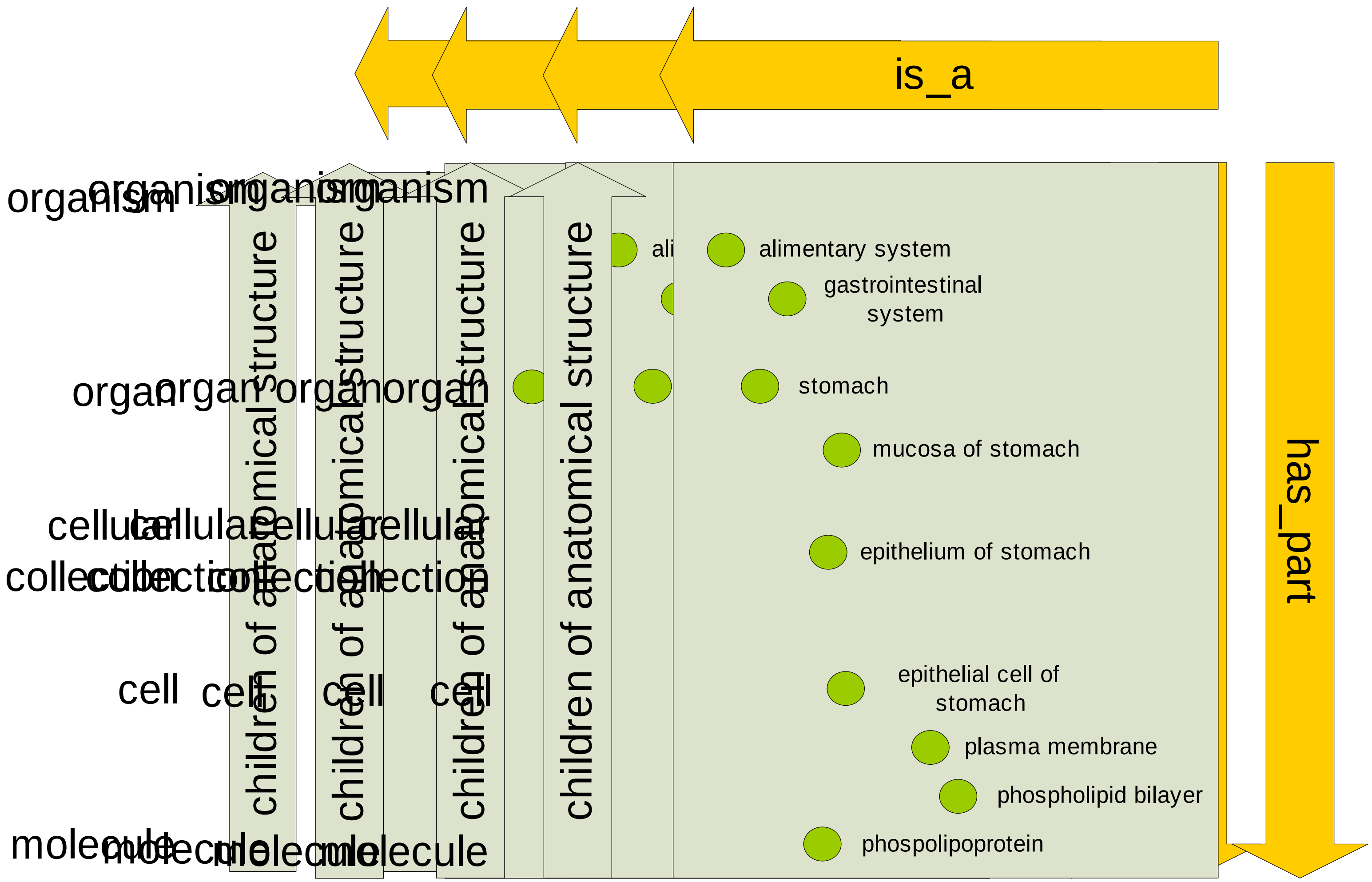
biomedical knowledge and the „focus of interest“



granularity in the FMA



anatomical granularity levels

- organism
- organ system
- cardinal body part

- organ
- organ part
- tissue
- tissue subdivision
- collection of cells
- cell
- collection of subcellular organelles
- subcellular organelle
- biological macromulecule

- body
- organ system
- principal body part
  - subdivision of principal body part
- organ
- organ part
- tissue
- tissue part
- cluster/ set of cells
- cell
- cluster/ set of cell parts

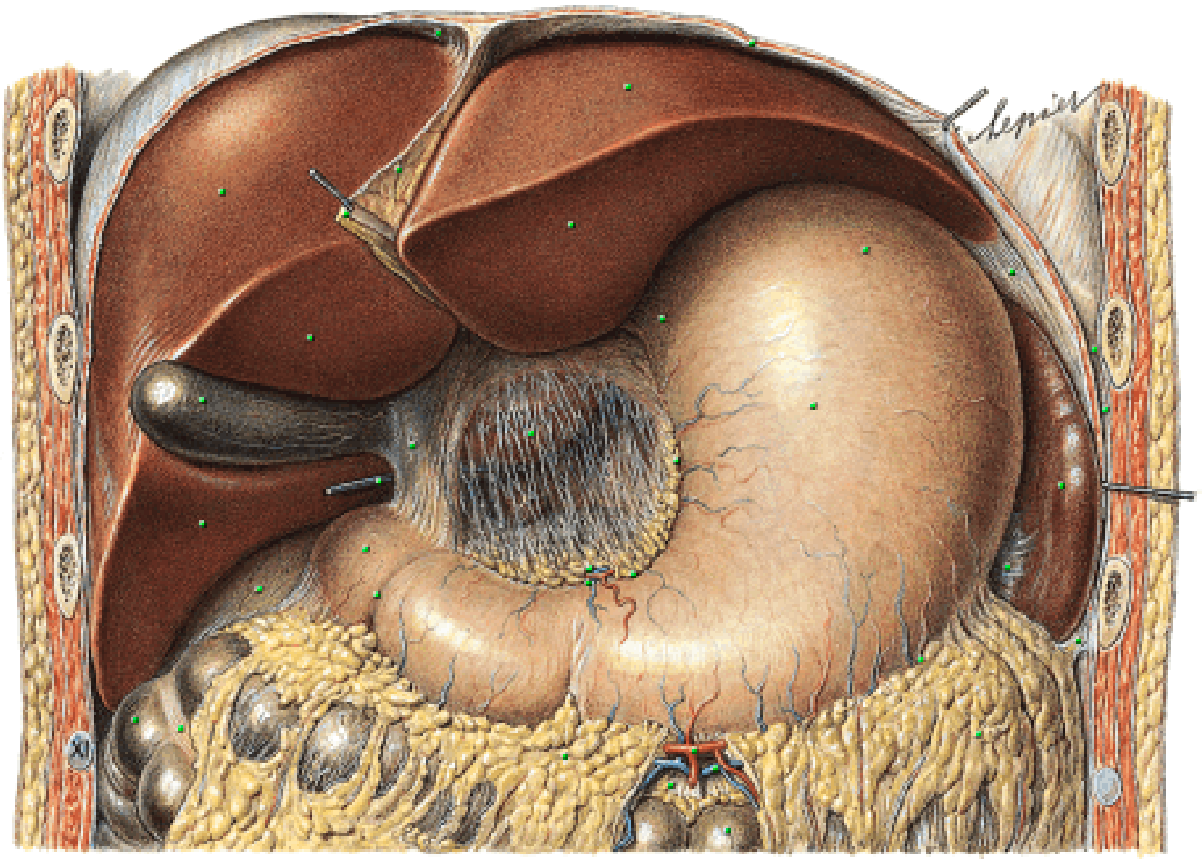
- cell part
- biological macromolecule

objectives

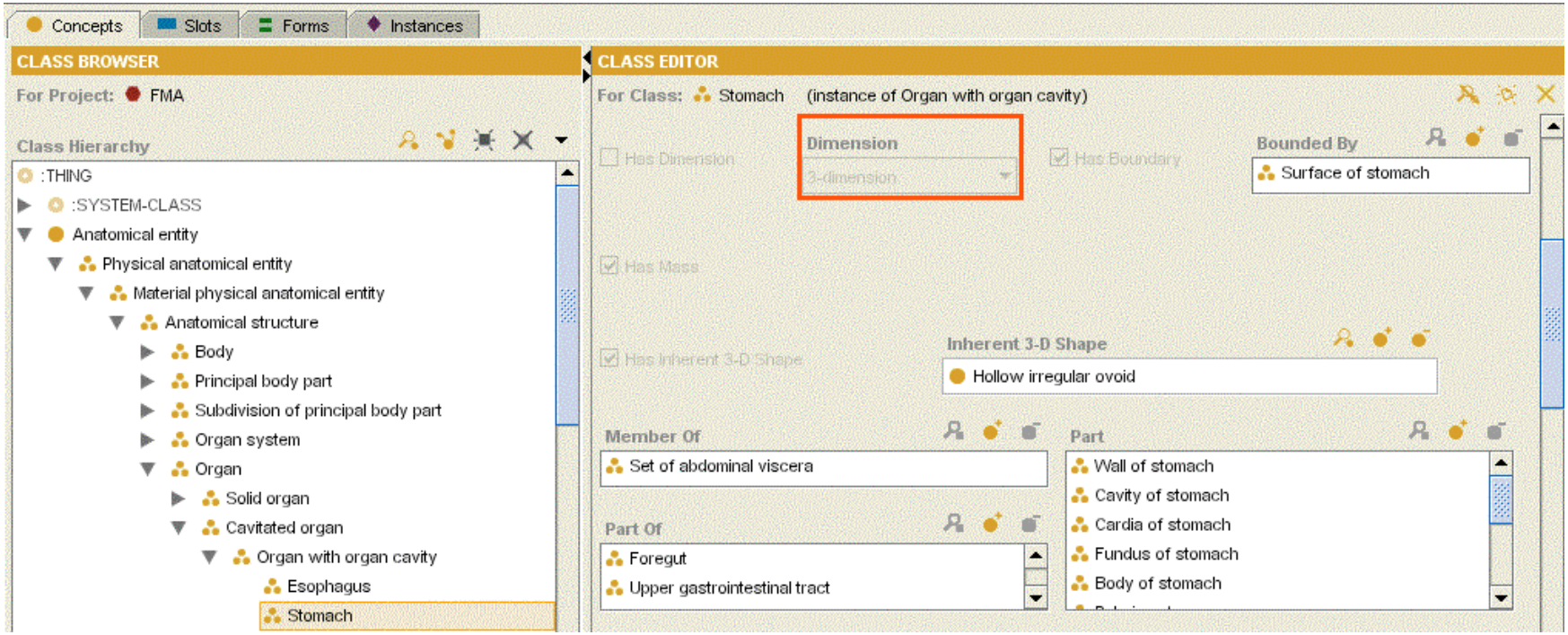
- provide user-oriented „views“ on anatomical structures
  - introduction with examples
  - basics of a theory of granular partitions
  - granular partitions in anatomy

A simple question?

- What is the boundary of the stomach?
- surface of the stomach
- physically detectable boundary *(bona fide)*



stomach in the FMA

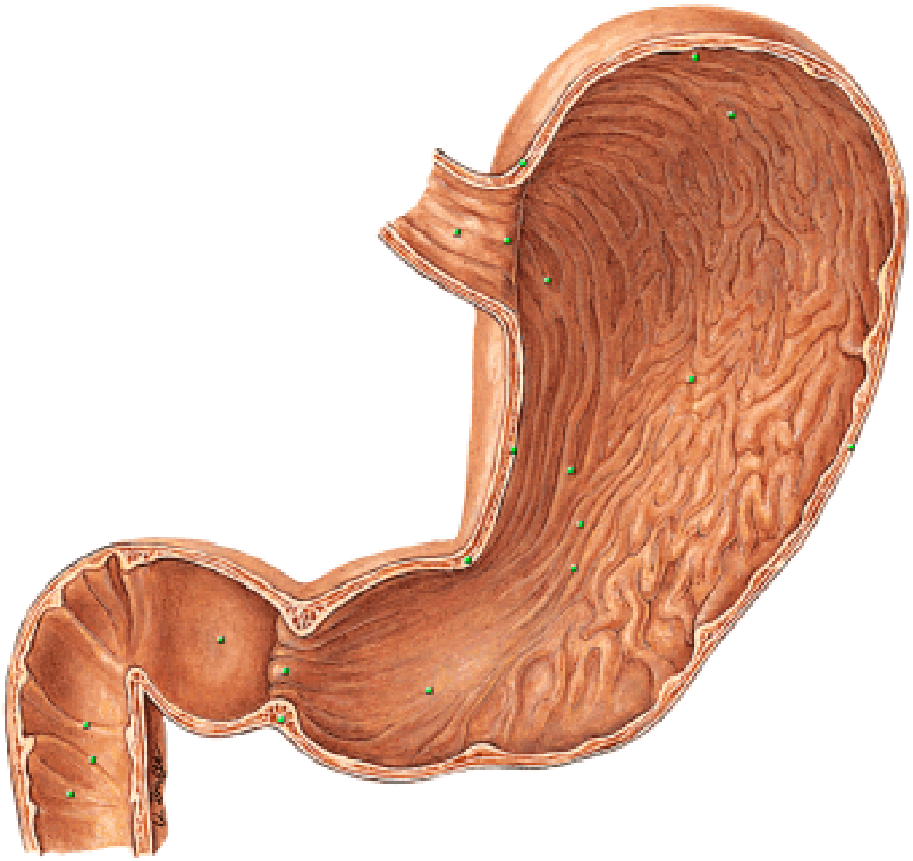


- granularity: organ
- could the question be answered in more detail?

part

- Stomach
  - Physical anatomical entity
  - Wall of stomach
  - Cavity of stomach
  - Cardia of stomach
  - Fundus of stomach
  - Body of stomach
  - Pyloric antrum
  - Pyloric canal
  - Pylorus
  - Esophagogastric junction
  - Gastroduodenal junction
  - Greater curvature of stomach
  - Lesser curvature of stomach

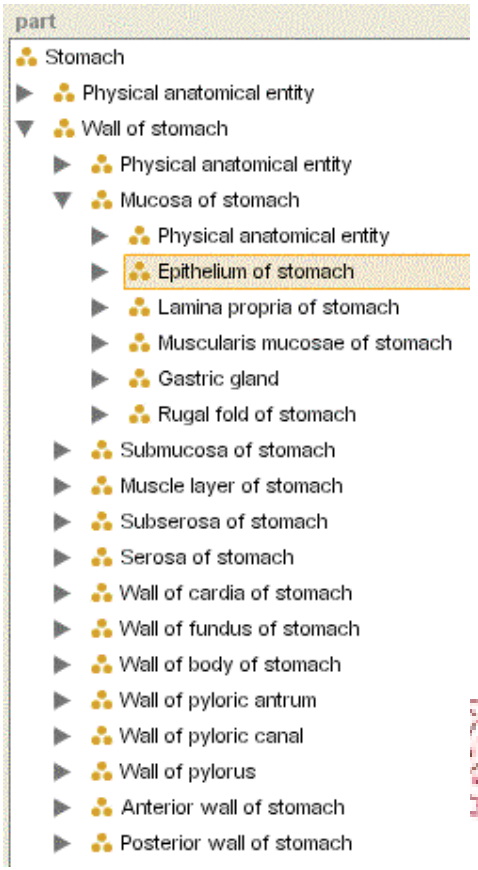
wall of stomach

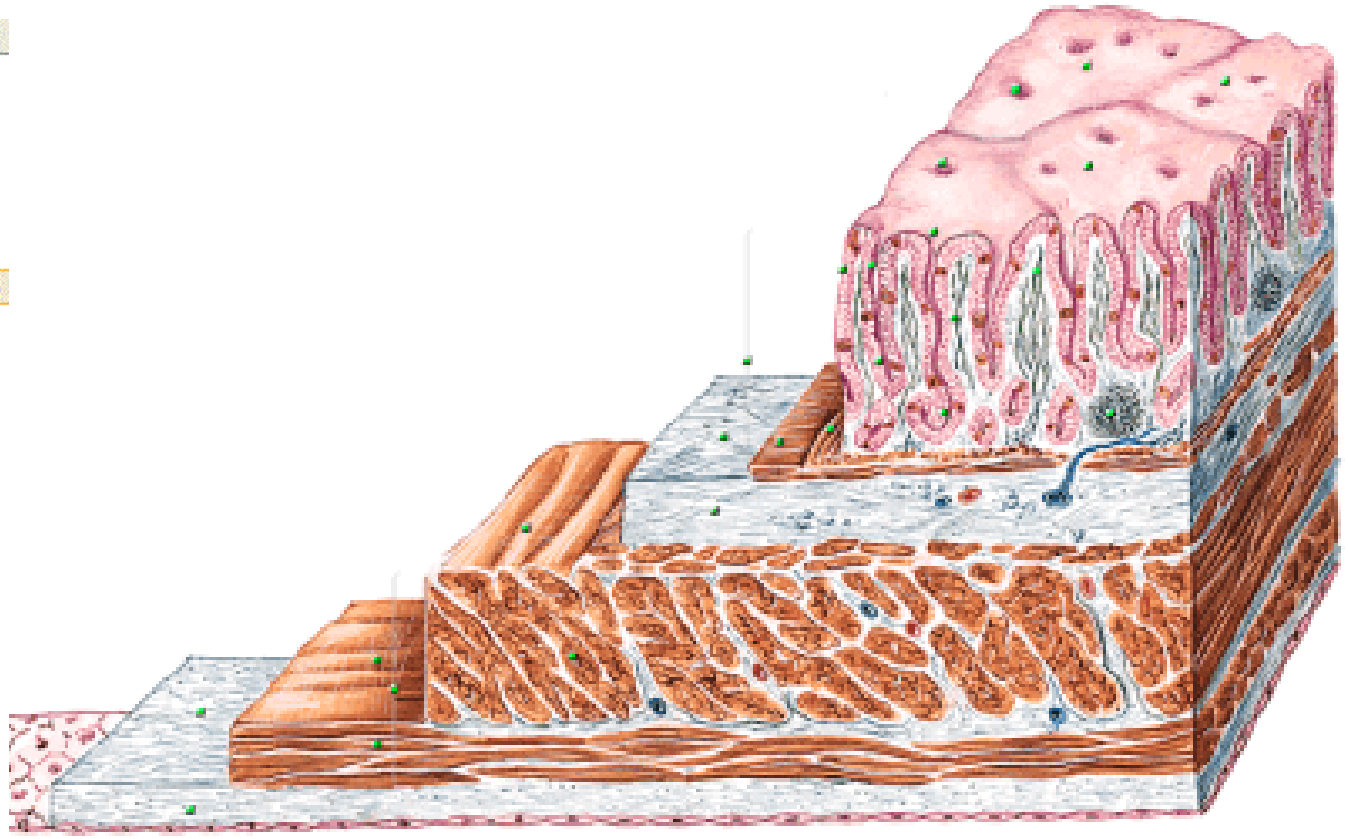


- what is the internal boundary of the wall of stomach?
- starting the cascade of transitivity of parthood-realtionship
- $p(A, B) \wedge p(B, C) \Rightarrow p(A, C)$

mucosa and epithelium of Stomach

- granularity:
  organ part – tissue

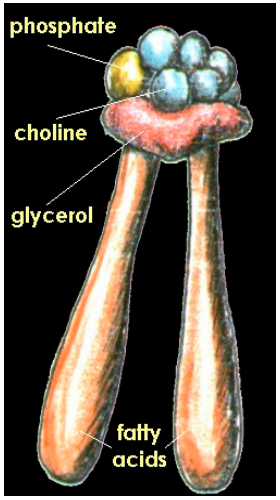


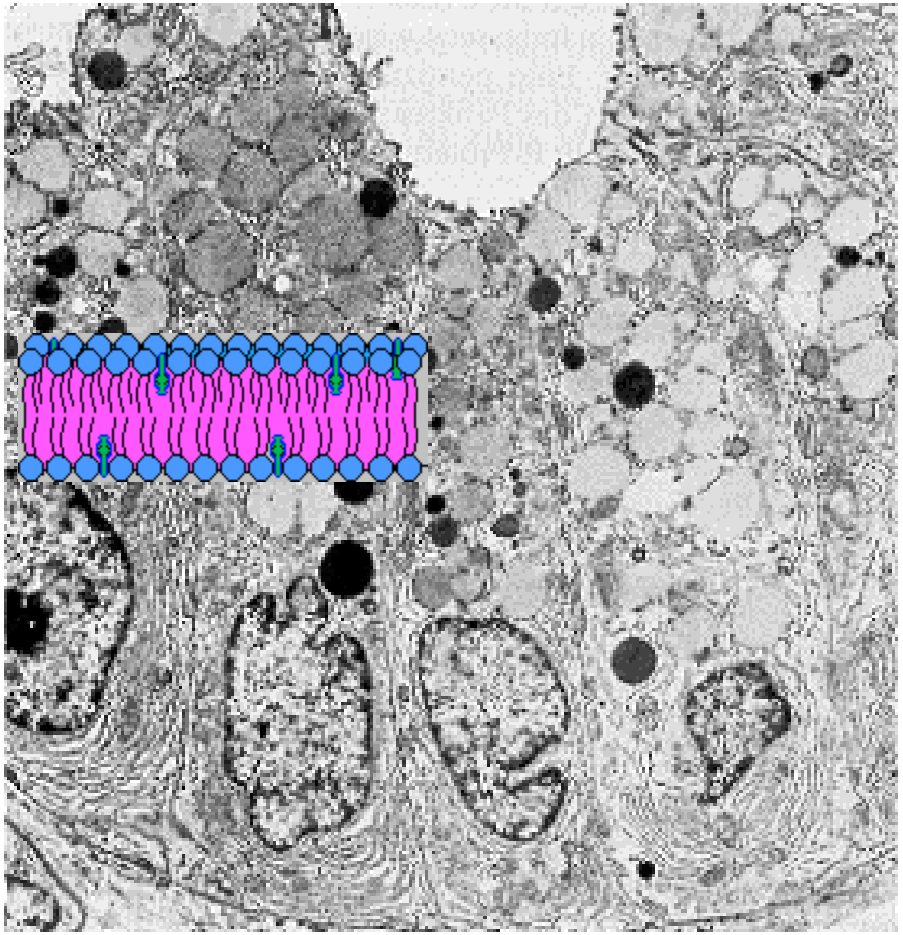


Cells, Subcellular and Macromolecular Structures of Stomach

part

- Stomach
  - Physical anatomical entity
  - Wall of stomach
    - Physical anatomical entity
    - Mucosa of stomach
      - Physical anatomical entity
      - Epithelium of stomach
        - Physical anatomical entity
        - Epithelium proper of stomach
          - Physical anatomical entity
          - Surface mucous cell of stomach
            - Anatomical entity template
            - Cell part
            - Plasma membrane
              - Physical anatomical entity
              - Cell coat
              - Plasma transmembrane protein complex
              - Plasma cell membrane protein
              - Lipid bilayer of plasma membrane
                - Physical anatomical entity
                - Outer layer of plasma membrane
                  - Physical anatomical entity
                  - Structural phospholipid molecule
                    - Physical anatomical entity
                    - Hydrophilic end of structural phospholipid molecule



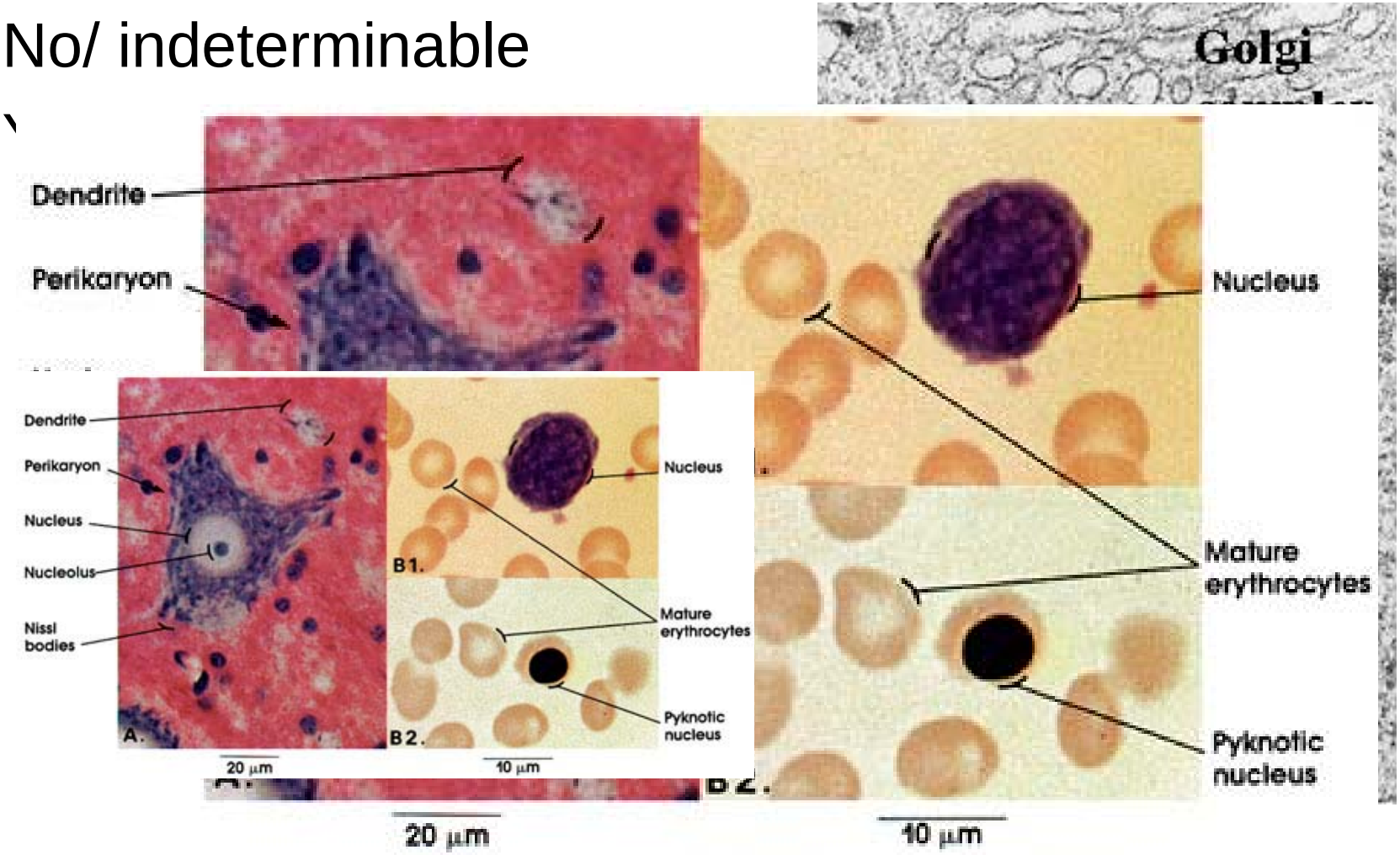


„What is the internal boundary of the stomach“?

- The internal boundary of the stomach is the mereological sum of the surfaces of the hydrophilic ends of the phospholipid molecules of the outer layer of the apical plasmamembrane of the cells of the epithelium of the mocusa of the stomach.

Is the nucleoplasm connected to the cytoplasm?

- No/ indeterminable
- `



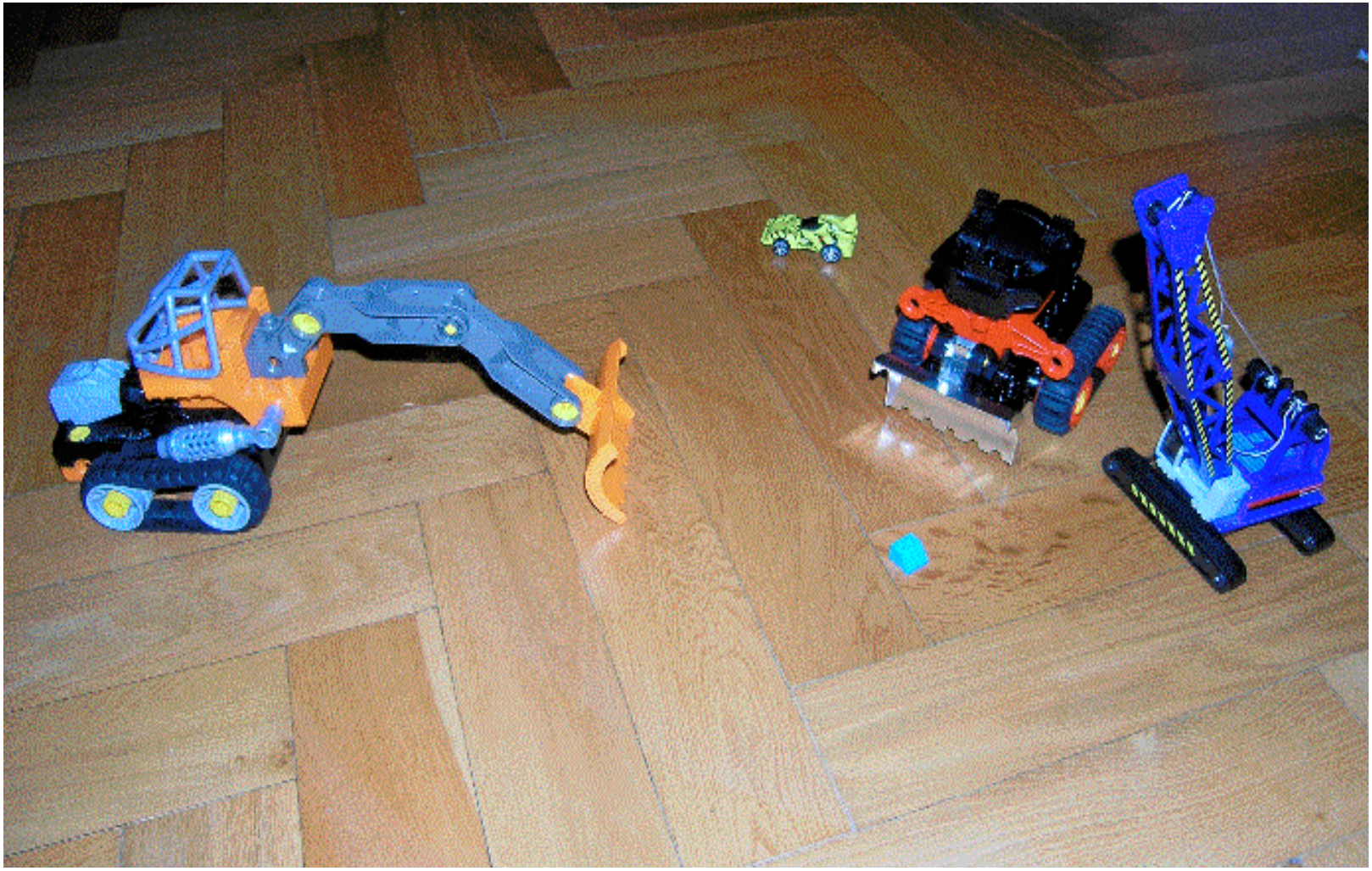
ubiquitous challenge in biomedical informatics

- define „views“ on reality restrained to a given context, scope, scale, purpose, …
  - granularity levels of interest
  - clinical speciality
    - heart: heart surgery, cardiology, anatomy
  - objective of activity
    - heart surgery: coronary bypass, valve replacement
  - method
    - heart imaging: conventional x-ray, cross section (CT, MR)

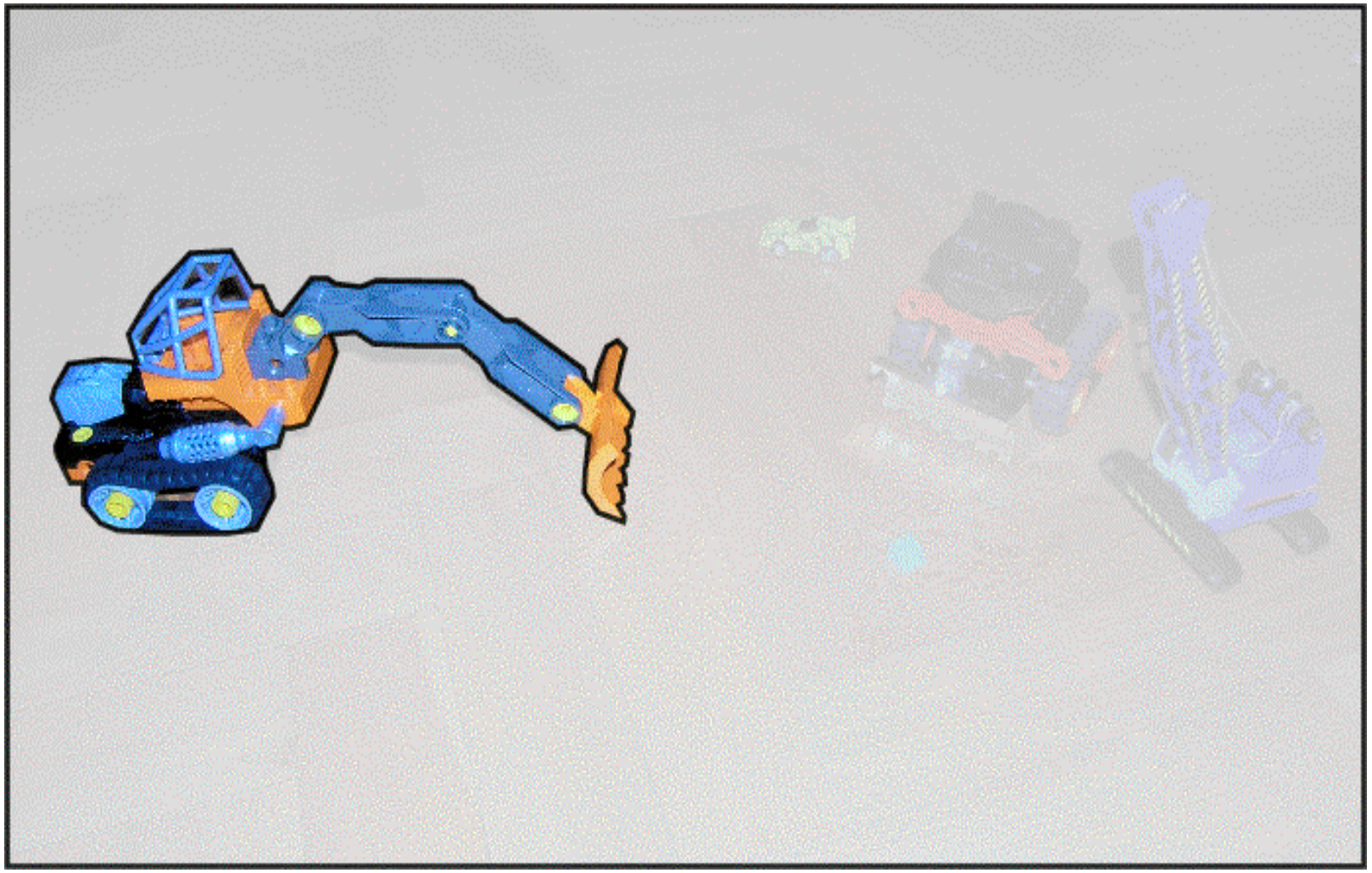
objective

- one reality with one ontological representation
- provide „views“ on reality with varying scope, scale and focus?
- granular partitions of reality
  - on different granularity levels
  - with different inner granular structure
  - with different relations between entities

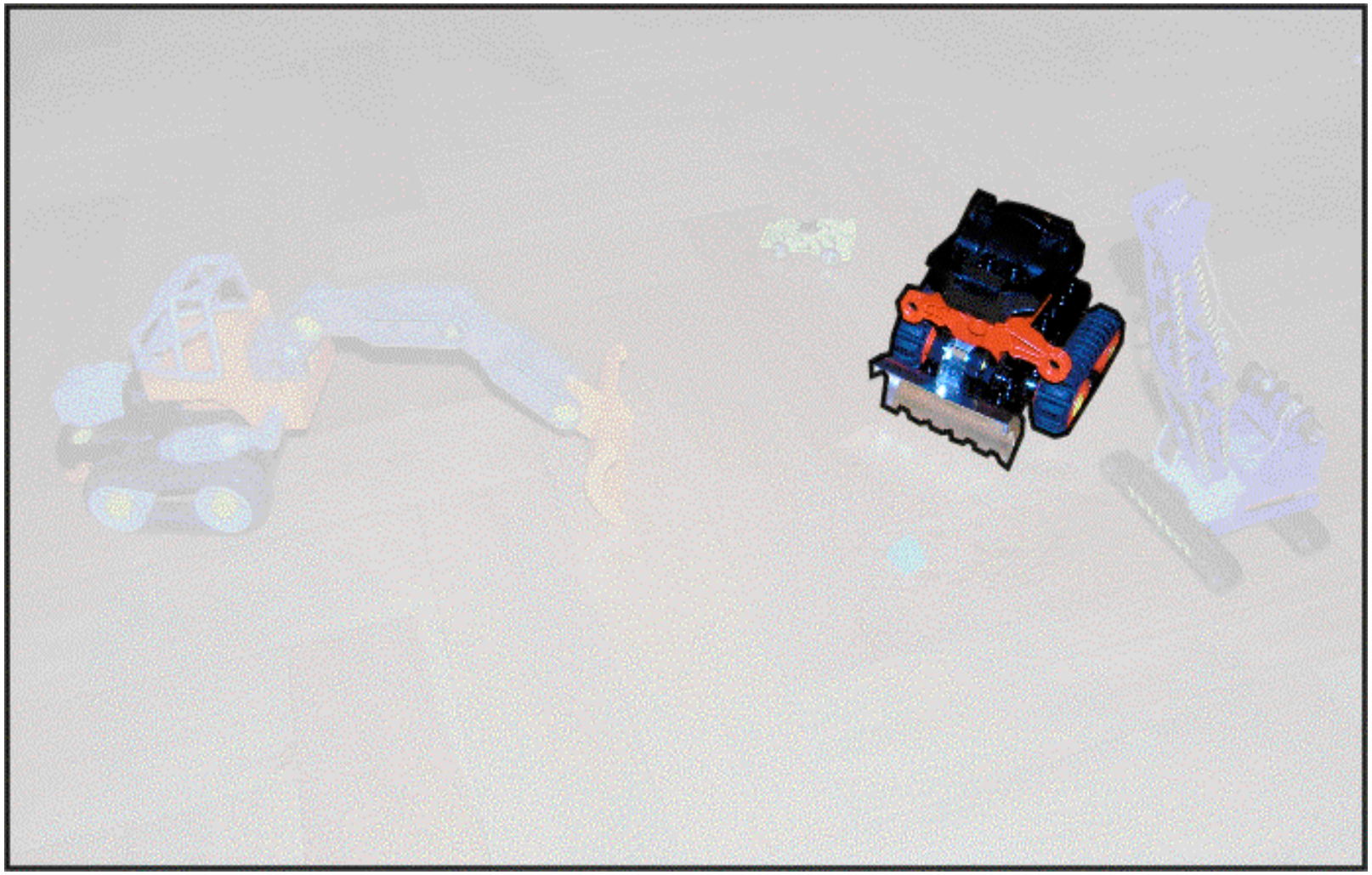
and now the world …



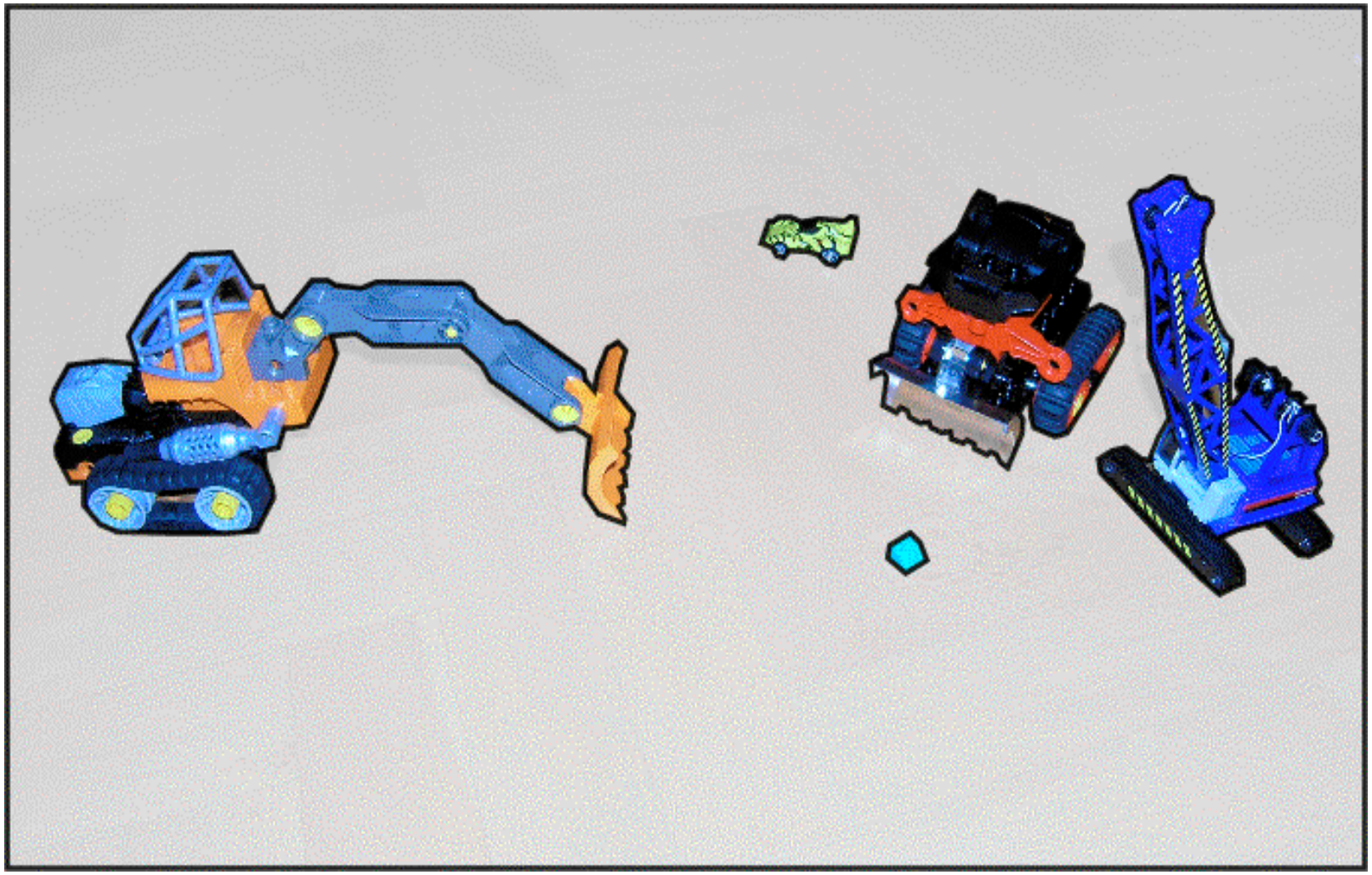
bringing objects into foreground …



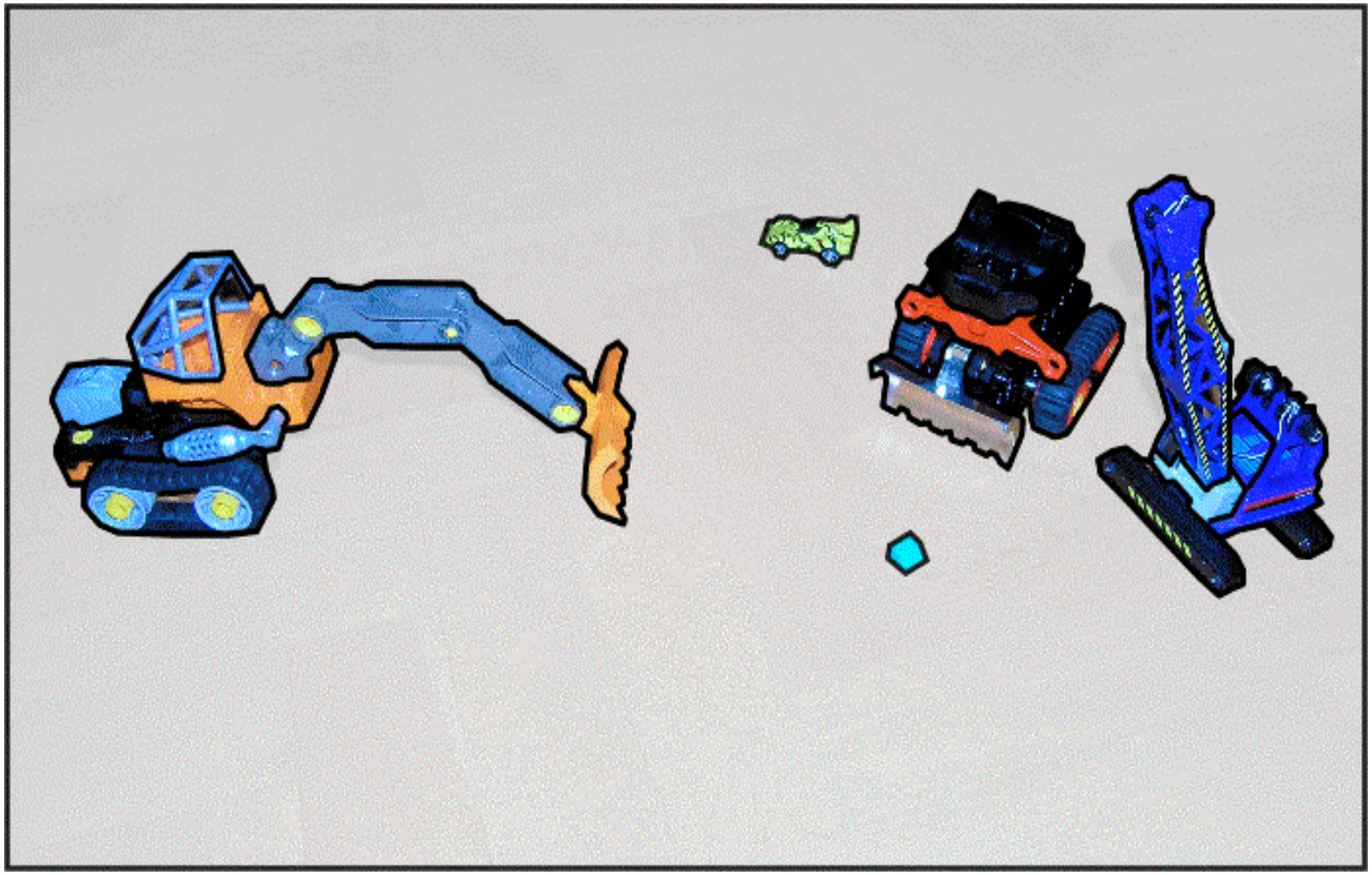
… sending others to background



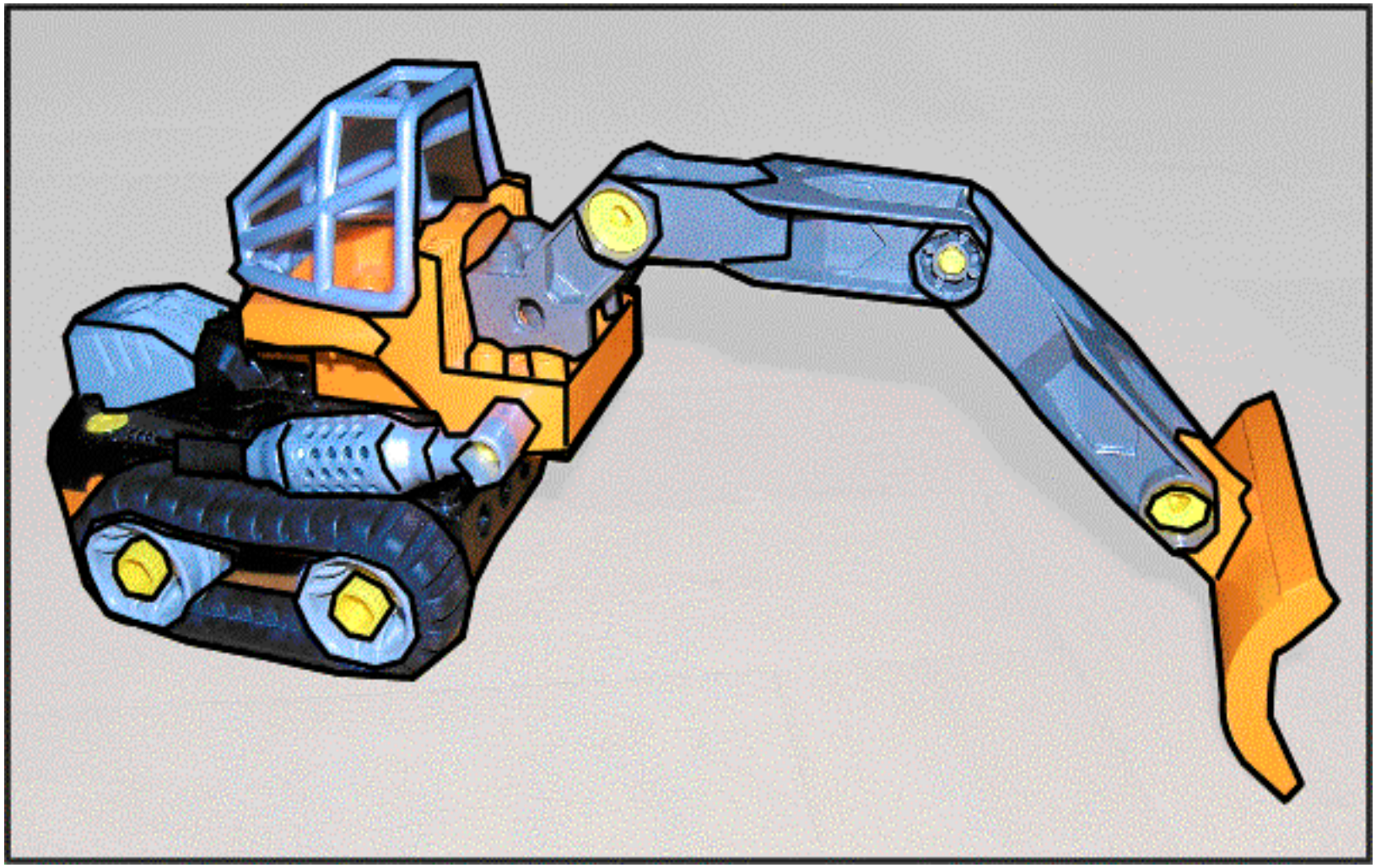
ontological regrouping



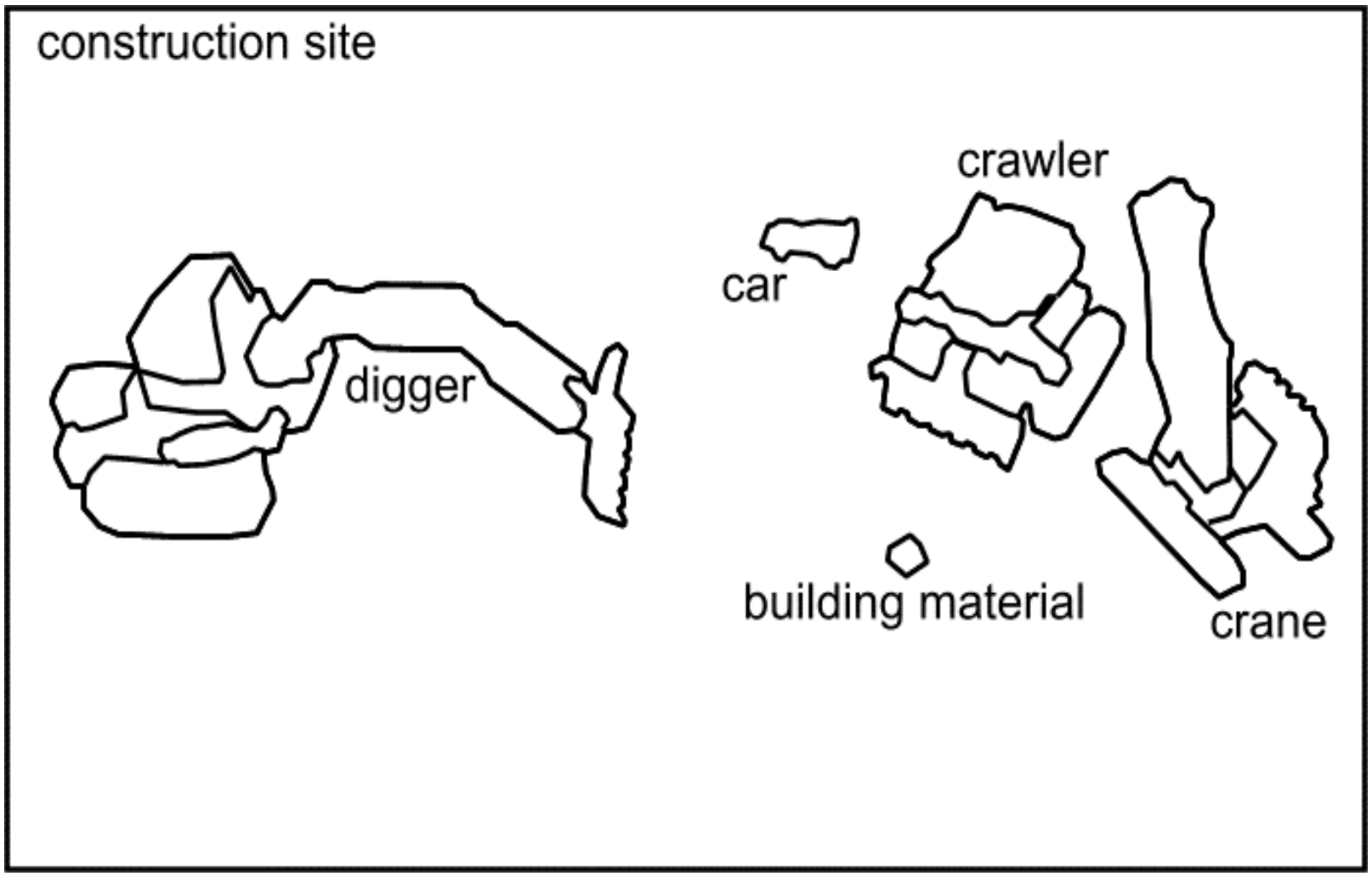
recognition of certain parts – tracing over others



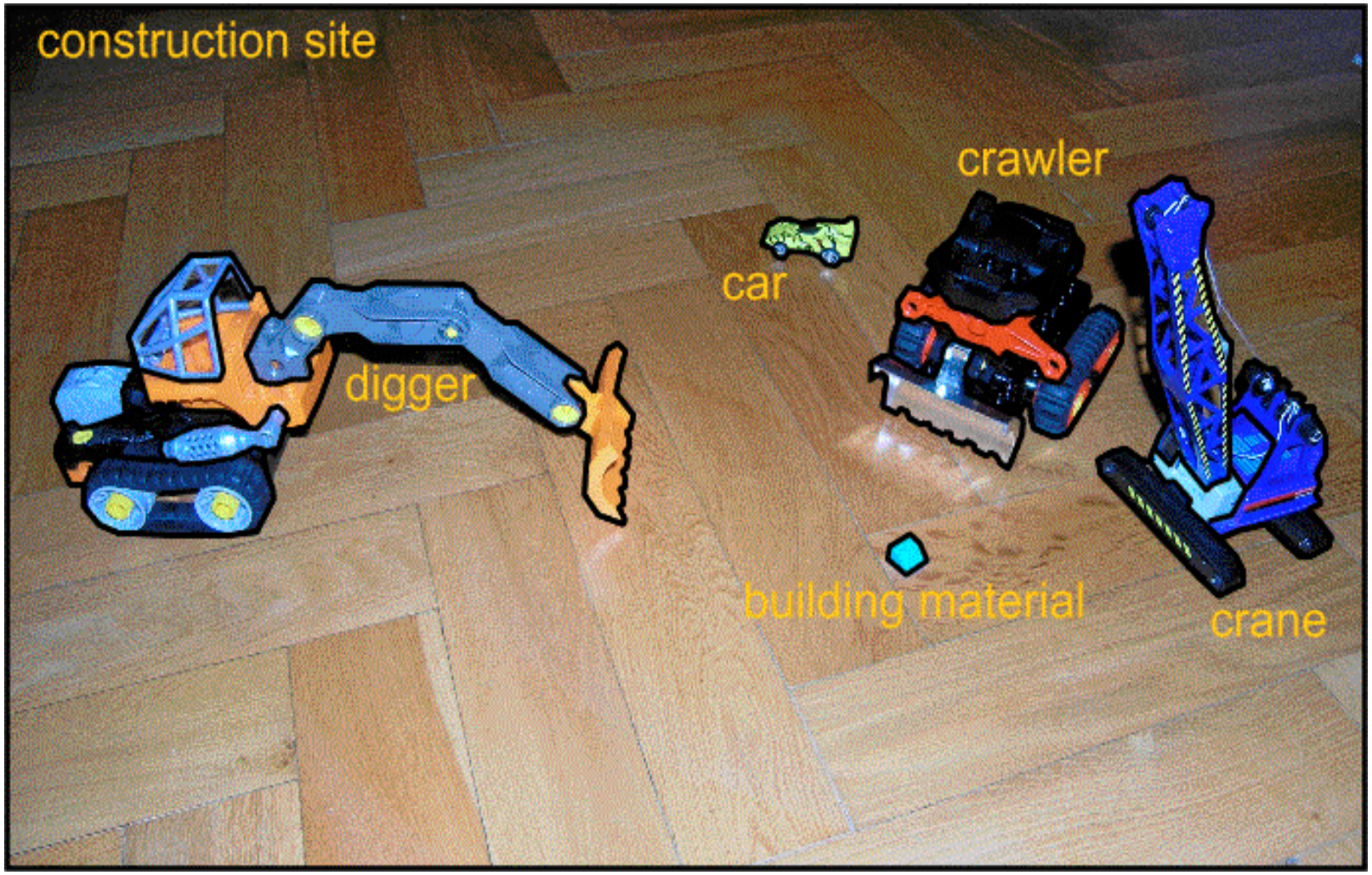
ontological zooming



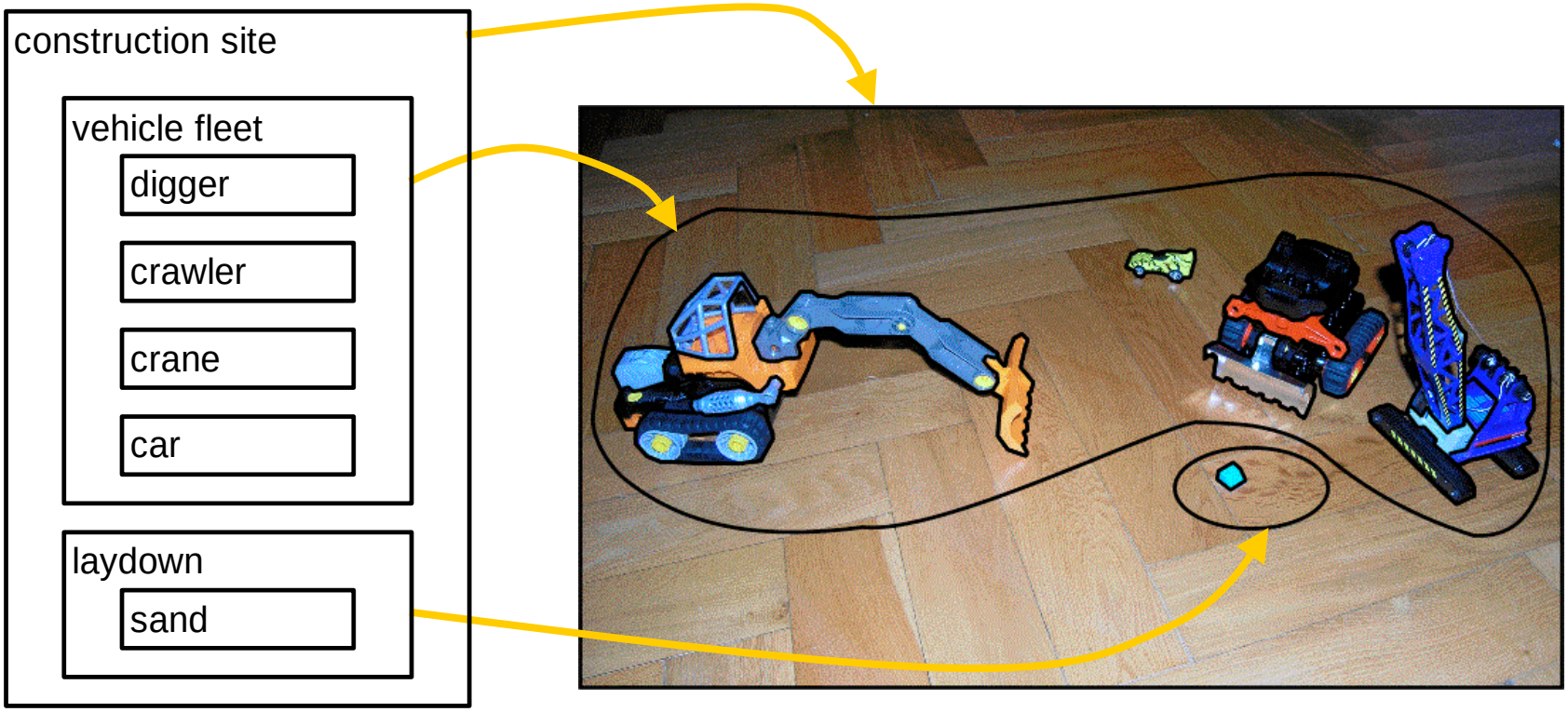
maps and cells



projection onto reality – location into cells



theory of granular partitions



- relations between cells, subcells and the partitions in which they are contained
- relations between partitions and objects in reality

system of cells I

- subcell relation: $z_1 \subseteq_A z_2$
- **MA1**: the subcell relation $\subseteq$ is reflexive, antisymmetric and transititve
- **DMax**: *maximal cell* or *root* r(A)
  $\mathrm{Max}(z_1, A) \equiv Z(z_1, A) \wedge \forall z: (z, A) \rightarrow z \subseteq z_1$
- **MA2**: every partition has a maximal cell in the sense of DMax

system of cells II

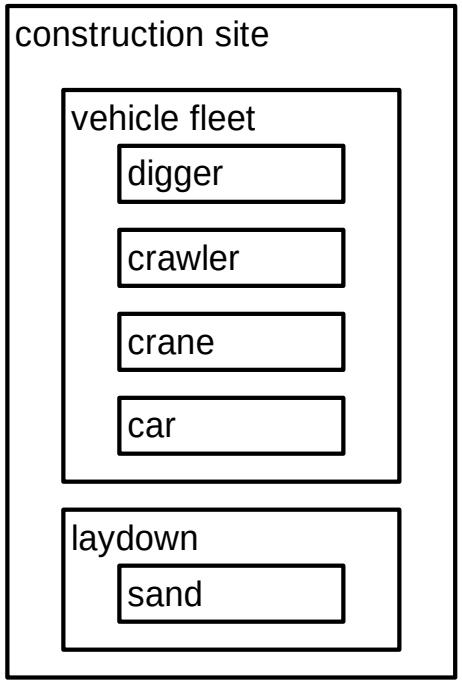
- transitivity generates chains of cells:
  $z_1 \supset z_2 \supset \ldots \supset z_n$ with z_1 as root
- **DMin**: *minimal cells* or *leaves*
  $\mathrm{Min}(z_1, A) \equiv Z(z_1, A) \wedge \forall z: (z, A) \rightarrow (z \subseteq z_1 \rightarrow z = z_1)$
- **MA3**: each cell in a partition is connected to the root via a finite chain of immediate succeeding cells
- immediate successor:
  $\mathrm{ISucc}(z_2, z_1) \equiv z_1 \subseteq z_2 \wedge \neg\exists z_3: z_1 \subset z_3 \subset z_2$

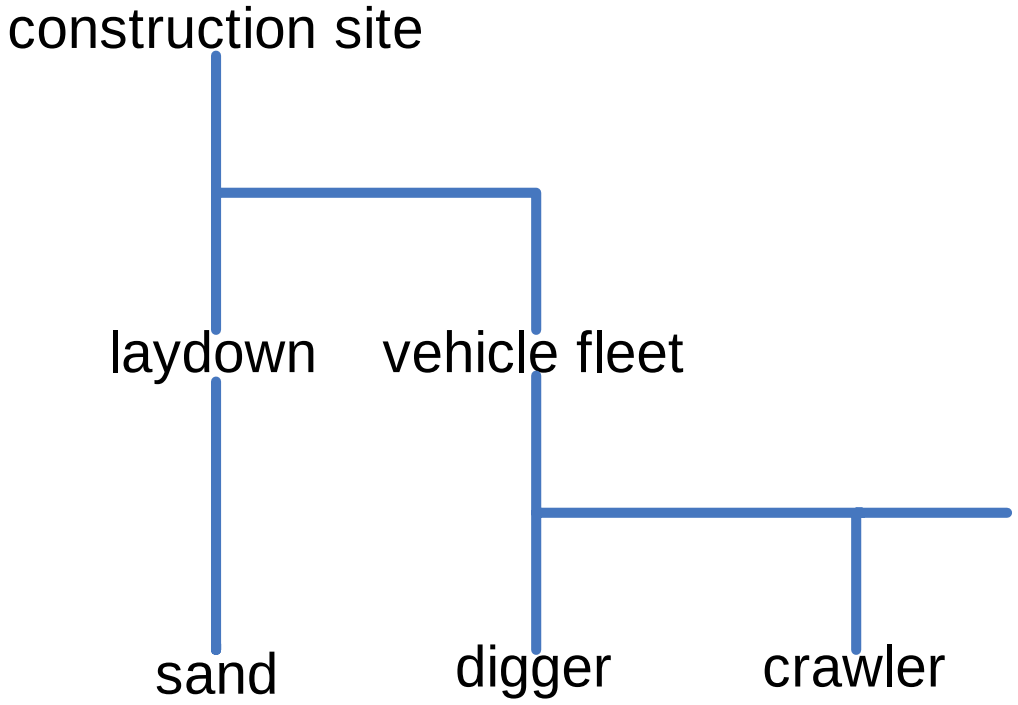
system of cells III

- something wrong with a partition having a cell redBaggers and a cell catarpillarBaggers
  - double counting
  - no natural relationship between these cells, they belong to different partitions
- **MA4**: if two cells in a partition overlap, then one cell is subcell of the other

$$\exists z : (z \subseteq z_1 \wedge z \subseteq z_2) \rightarrow z_1 \subseteq z_2 \vee z1 \supset z_2$$

system of cells IV





- tree: directed graph without cycles
  - nodes and directed edges
  - every pair of nodes is connected by only one chain of edges
- finite granular partition: rooted tree with finite depth

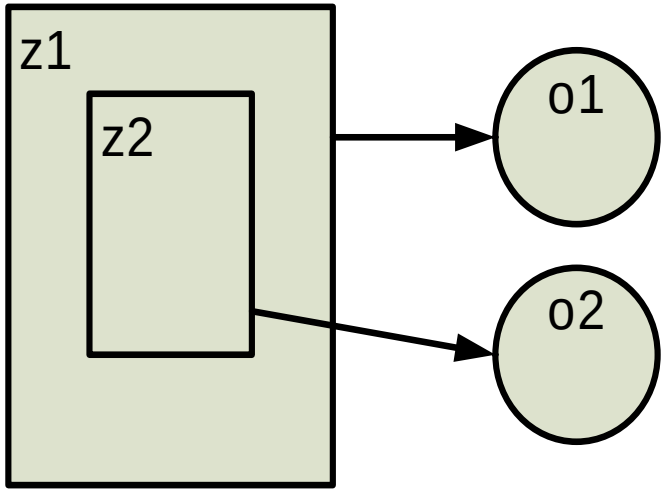
projective relation to reality I

- from mind to reality
  P(z, o): cell z is projected onto object o
- from reality to mind
  L(o, z): object o is located at cell z
- **MB1**: $L(o, z) \rightarrow P(z, o)$
  location presupposes projection
  an object is never located in a cell unless through the projection relation associated with the relevant partition
- **MB2**: $P(z, o) \rightarrow L(o, z)$
  projection presupposes location
  if a partition projects a given cell onto a given object, then that object is located in the corresponding cell
- **DTr**: $Tr(A) \equiv \forall z \forall o : P_A(z, o) \leftrightarrow L_A(o, z)$
  projection and location are converse relations:
  transparent partition

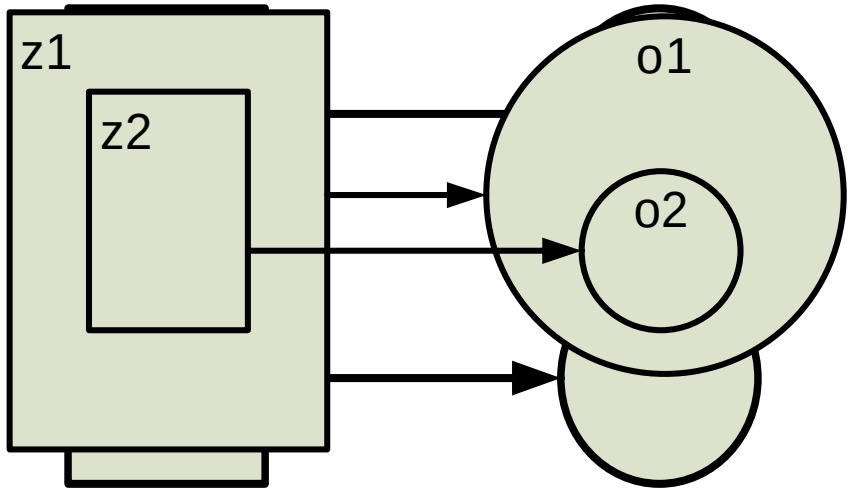
projective relation II

- **MB3**: $P(z, o_1) \wedge P(z, o_2) \rightarrow o_1 = o_2$
  projection is functional
  - one cell projecting on more than one entity
- **MB4**: $L(o, z_1) \wedge L(o, z_2) \rightarrow z_1 = z_2$
  location is functional
  - two cells called „stomach“ and „gaster“ project onto stomach

mereological structure I



mereological structure within the partition is not correctly representing the mereological structure of objects



mereological structure within the partition is correctly representing the mereological structure of objects

mereological structure II

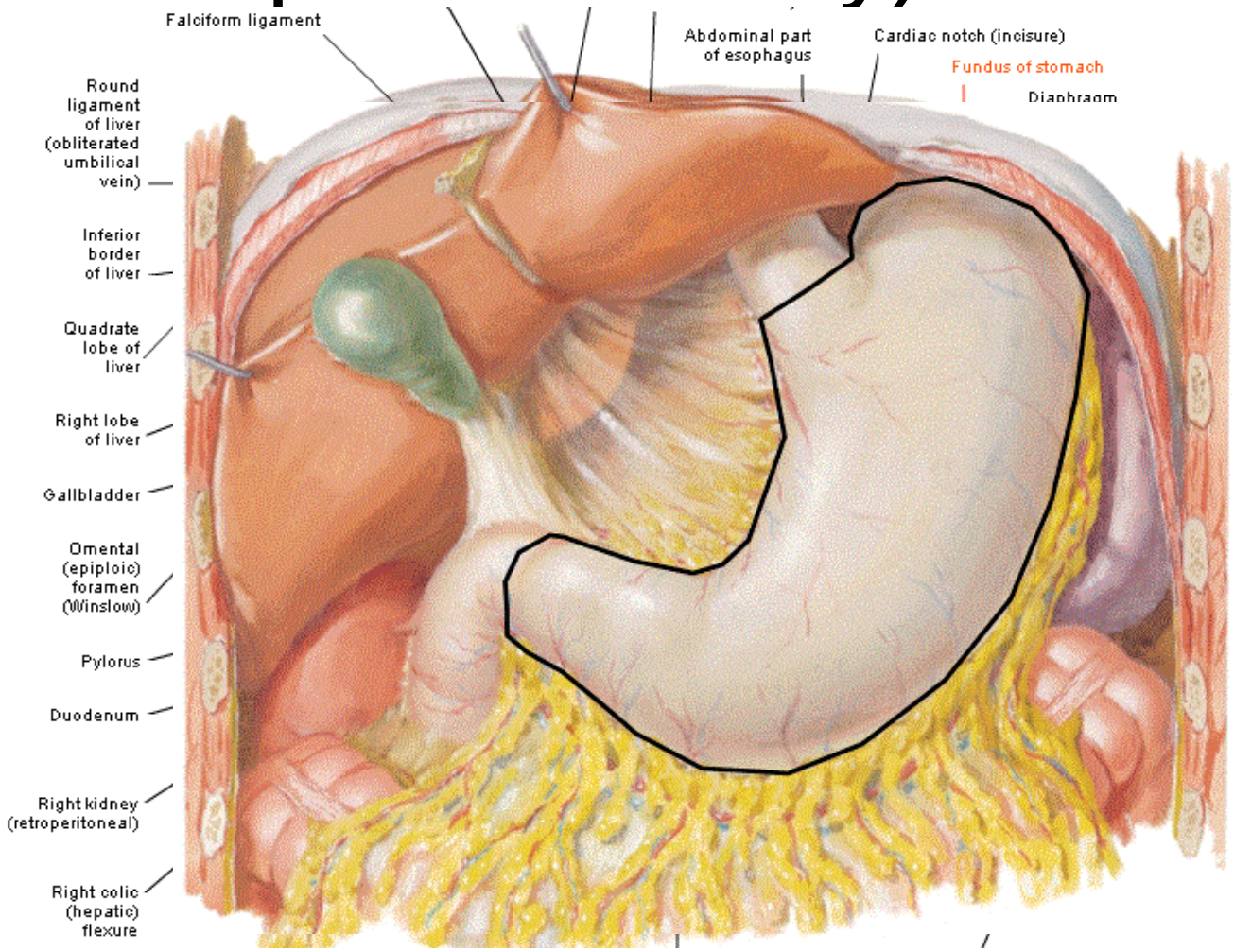
- mereological structure within a partition should not misrepresent the mereological relationships between the objects which the corresponding cells are projected onto
- **DS1**: $RS(z_1, z_2) \equiv$
  $\forall o_1, o_2 : (L(o_1, z_1) \wedge L(o_2, z_2) \wedge z_1 \subseteq z_2) \rightarrow o_1 \leq o_2)$
  representation of mereological structure between pairs of cells
- **DS2**: $RS(A) \equiv$
  $\forall\ z_1, z_2 : (Z(z_1, A) \wedge Z(z_2, A)) \rightarrow RS(z_1, z_2)$
  a partition is mereological structure preserving iff each pair of cells satisfies DS1
- **MB5**: all partitions are mereological structure preserving in the sense of DS2

domain of a partition

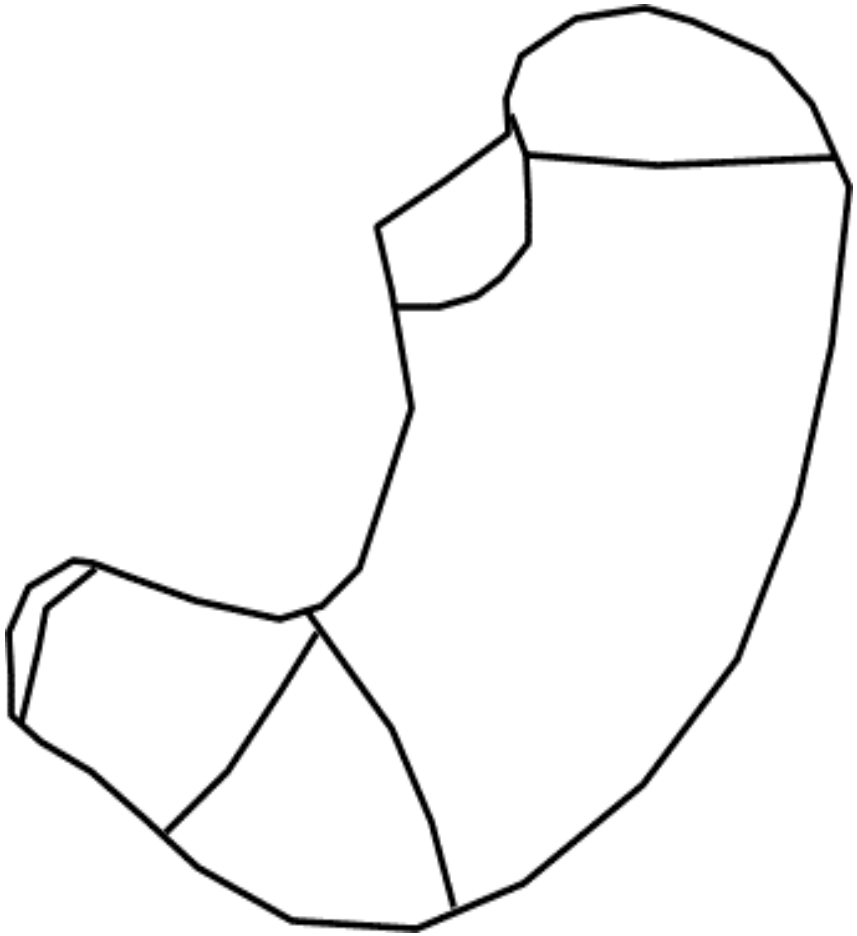
- **DD**: D(A) = p(r(A))
  the domain of a partition is the object the root cell projects onto
- **MB6**: $\exists x : x = D(A)$
  every partition has a non empty domain in the sense of DD

granular partitions of the stomach (macroscopical anatomy) I

- granularity: Organ – Stomach
- domain: Organ part
- domain: Stomach



granular partitions of the stomach (macroscopical anatomy) II

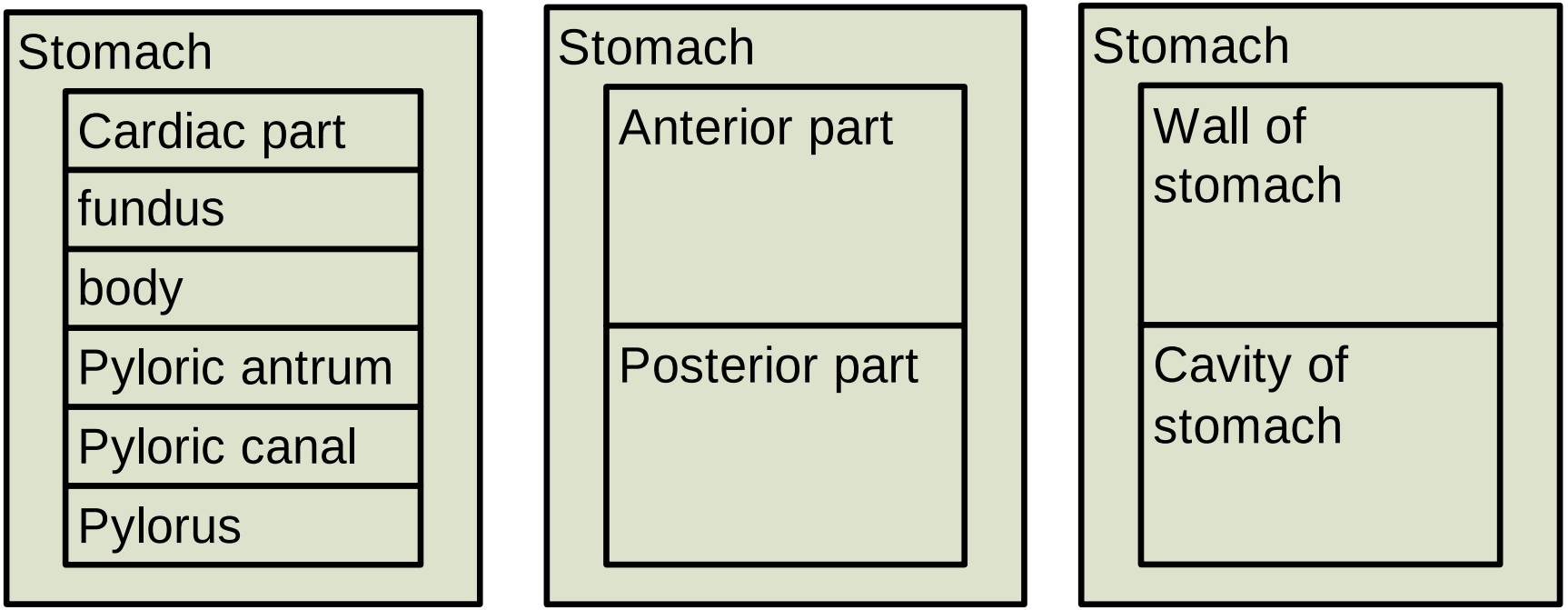


Stomach

- Cardiac part
- fundus
- body
- Pyloric antrum
- Pyloric canal
- Pylorus

granular partitions of the stomach (macroscopical anatomy) III

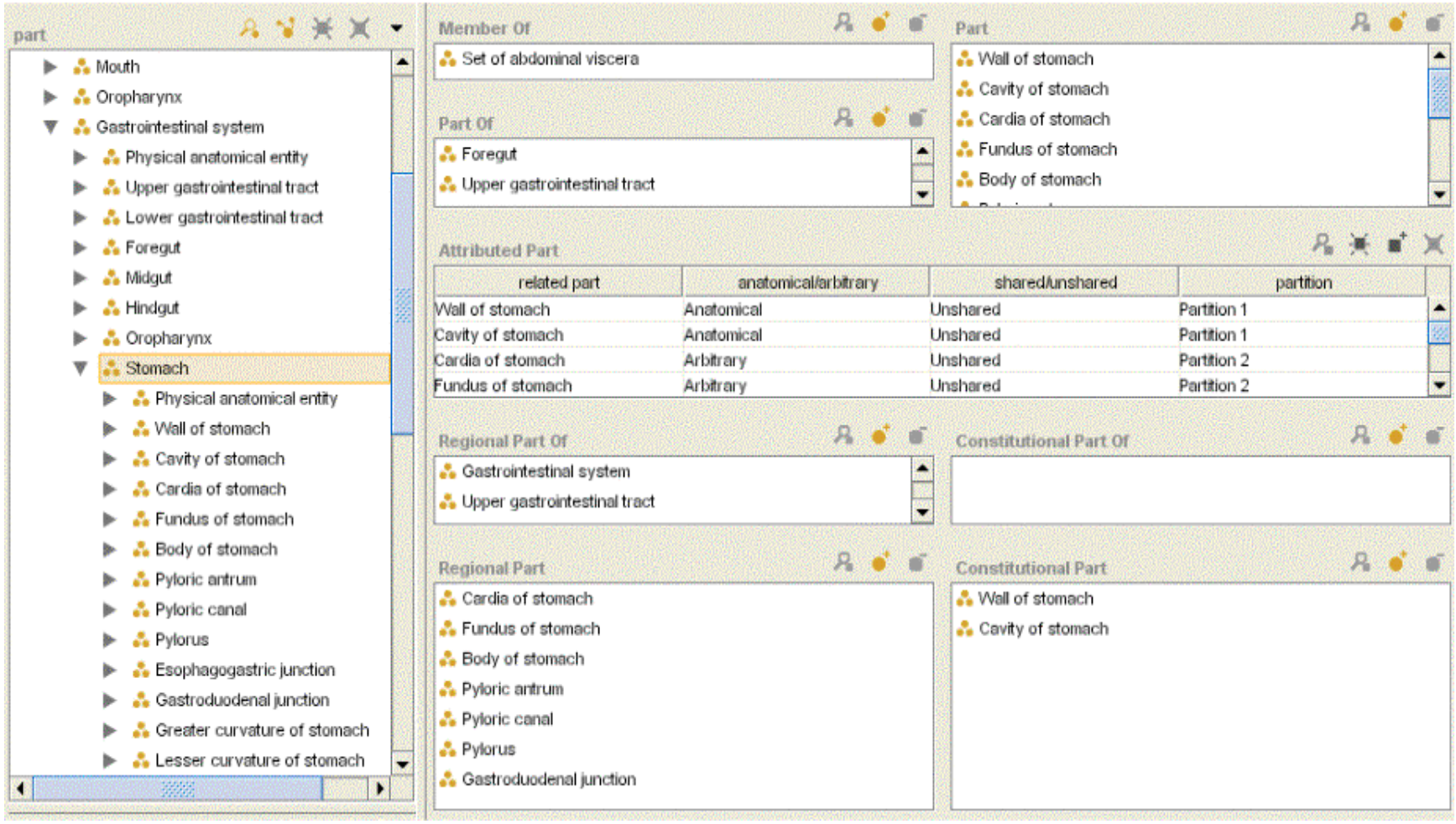
- mutual exclusive alternative granular partitions of the stomach
  - landmarked (arbitrary) regional parts
  - oriented regional part (axes, planes, relational)
  - constitutional parts
  - Systematic parts



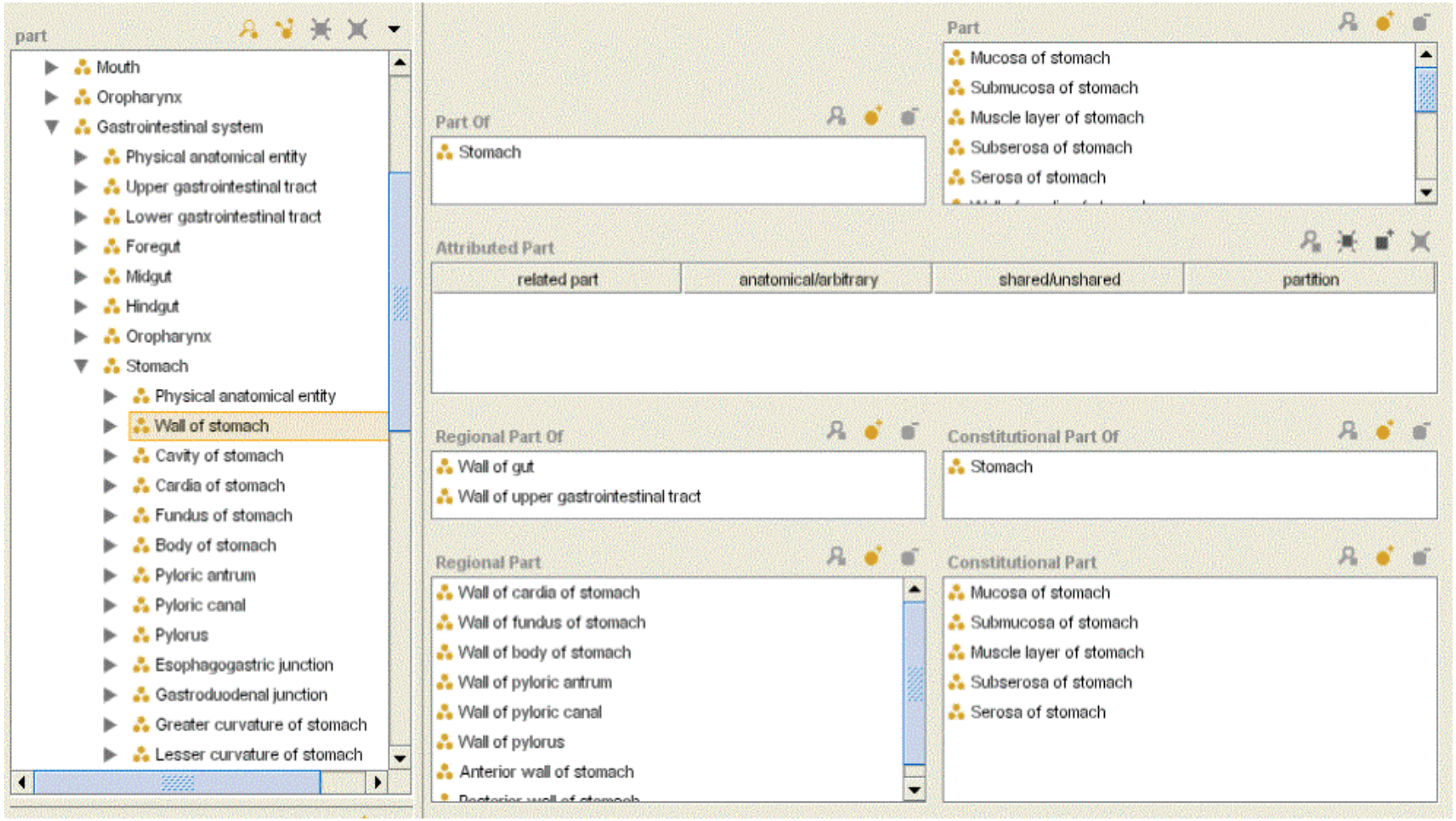
granular partitions in the FMA I

- mutual exclusive partitions of entities can be defined in the FMA (attributed_part)
- nested granular partitions are „supported“
  - FMA preserves mereological structure (MB5)
  - FMA differentiates types of mereological relations (MA4):
    - constitutional-part
    - regional-part
    - systematic-part
- inference of partitions is difficult
  - parts can overlap (MA4)

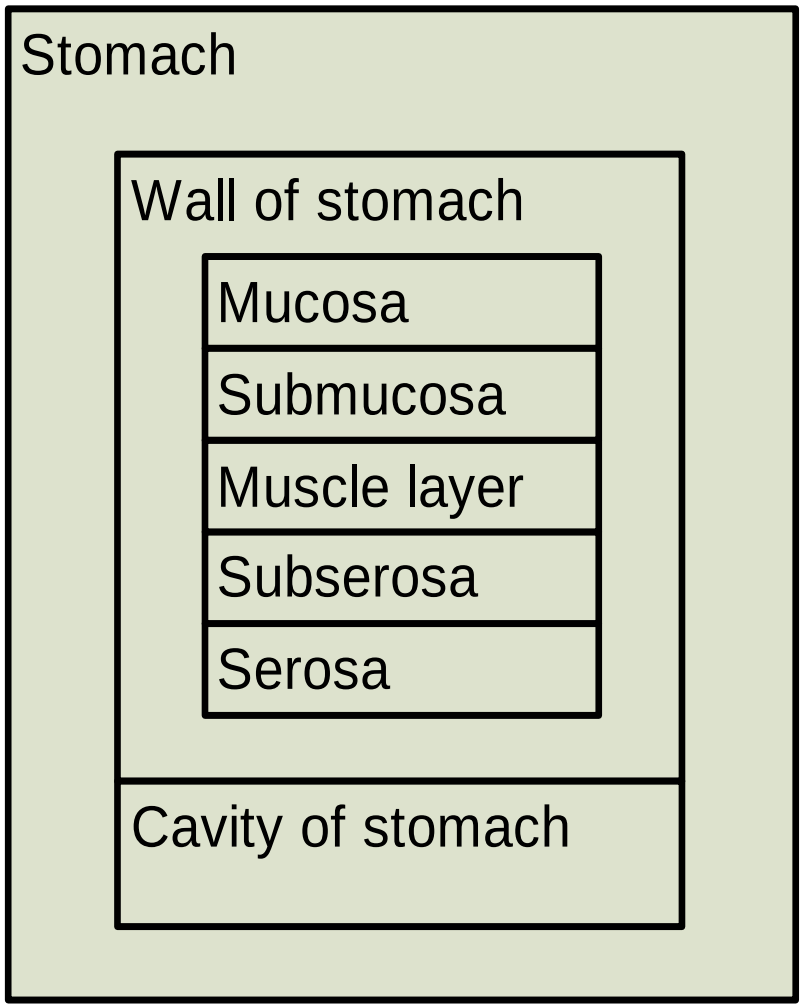
granular partitions in the FMA II



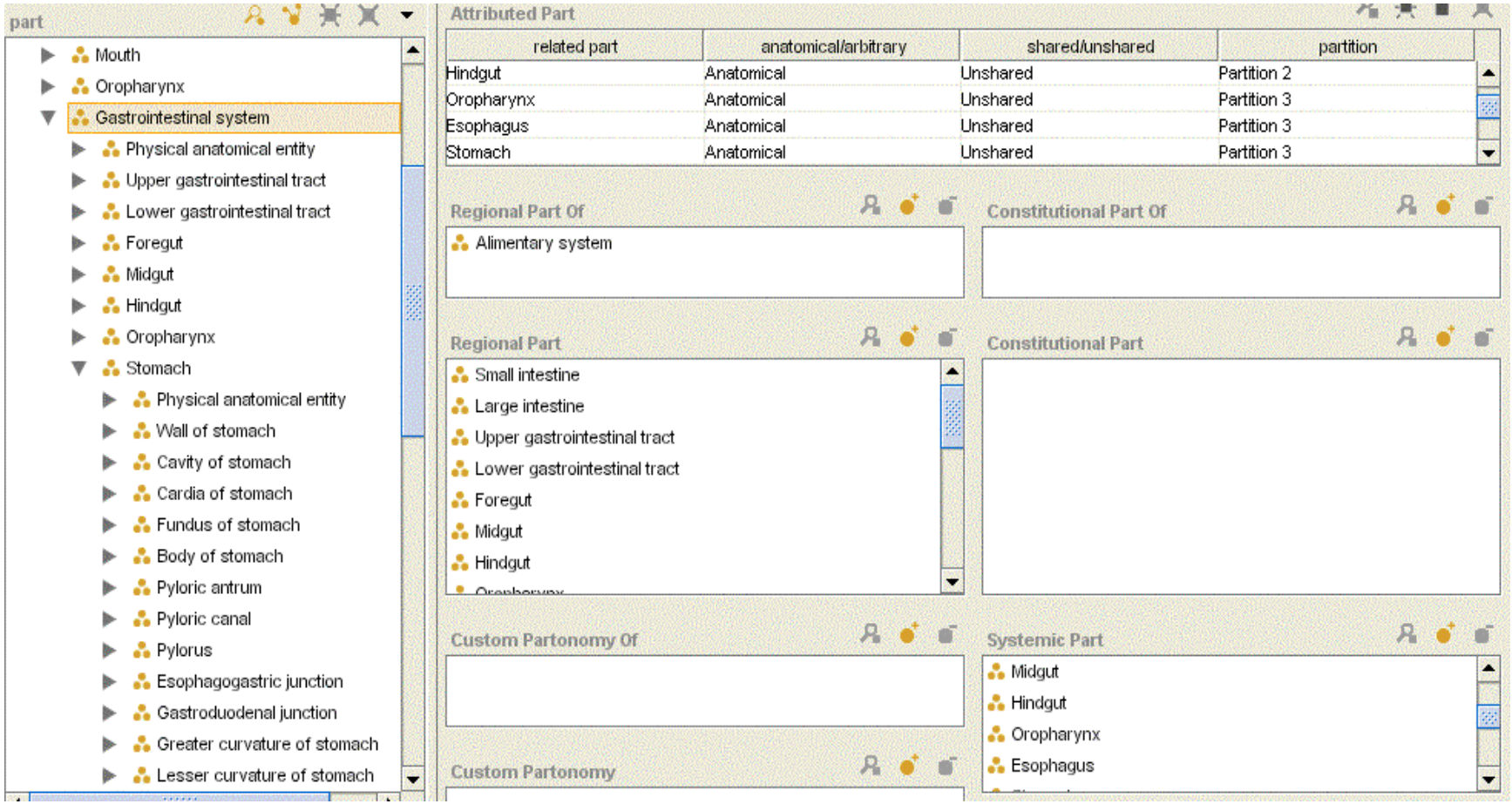
granular partitions in the FMA III



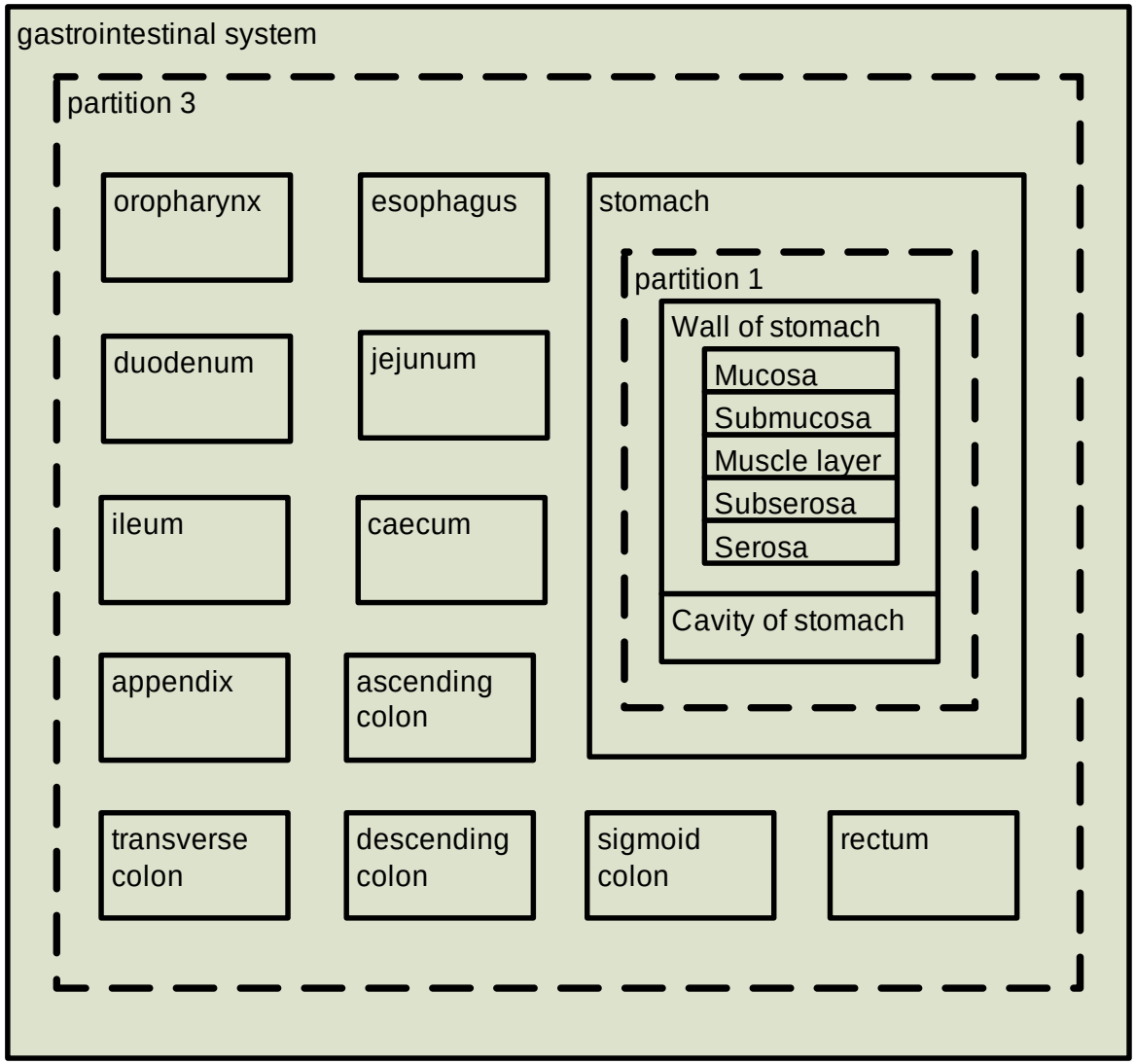
ontological zooming (in)



partitions in the FMA IV



ontological zooming (2)



summary

- A condition for the usability of biomedical ontologies in real world applications is the possibility to restrict the view onto reality to user-oriented domains
- granular partitions allow for defining different perspectives onto reality
- formal theory of granular partitions
  - partition system of cells
  - projective relation to reality
- FMA allows to define partitions
- FMA „supports“ the definition of granular partitions
  - mereology preserving (MB5)
  - subclassifies parthood (MA4)
    - but has still overlapping partitions defined by the subclassified parthood