15 - 20 min

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Boundaries and Natural Units

Lars Vogt

Roland Arhelger (1988) Berlin Wall, Niederkirchnerstraße. (WikiMedia Commons)

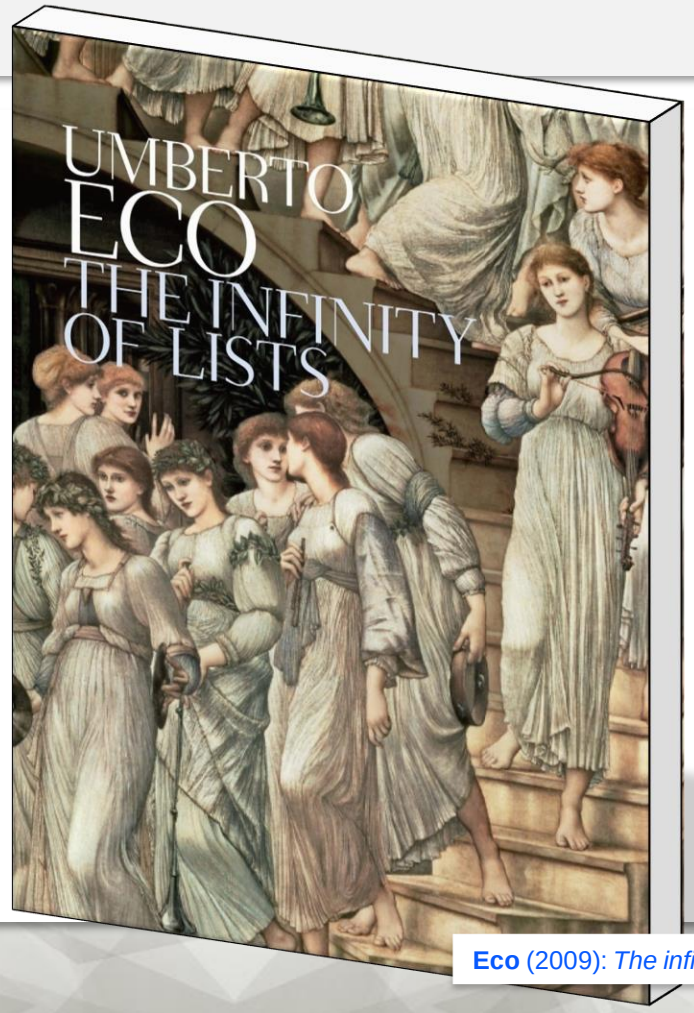
Educational Series on Applied Ontology *Webinar* November 9, 2021

Leibniz-Gemeinschaft

Humans make lists of objects

Making lists

We love to make all kinds of lists.



Eco (2009): *The infinity of lists*. Rizzoli, 408pp.

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Humans make lists of objects

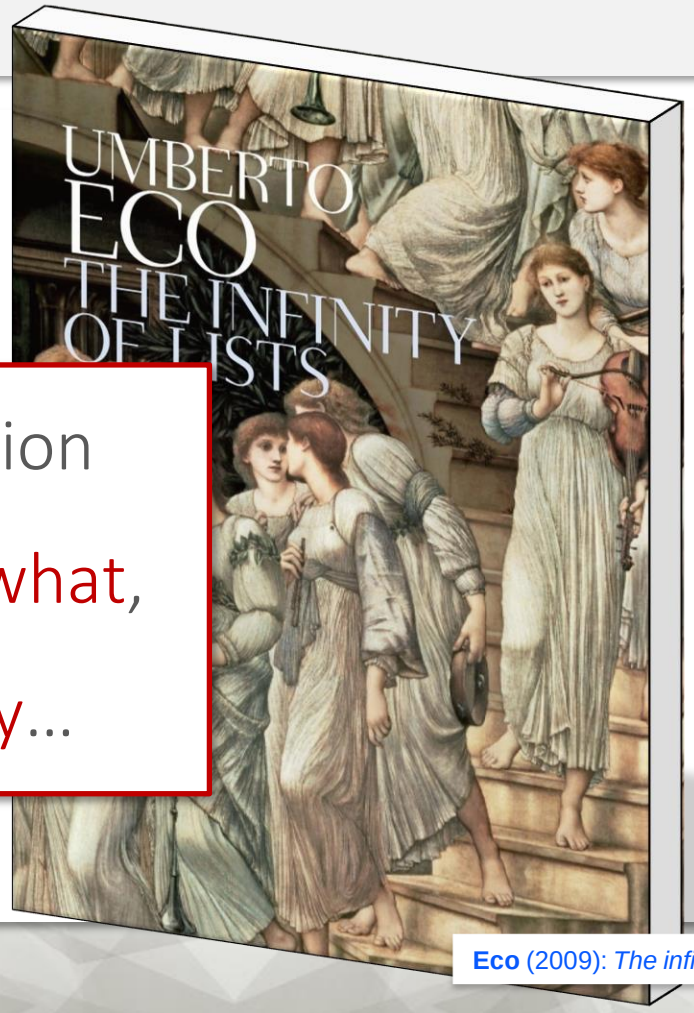
Making lists

We love to make all kinds of lists.

lists answer question

about who, when, what,

where, how many…



Eco (2009): *The infinity of lists*. Rizzoli, 408pp.

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Humans make lists of objects

Making lists

We love to make all kinds of lists.

Lists come in different forms:

written…

Wissenschaftlicher Name	Deutscher Name	Familie	kein akt. Nachweis	BNatSchG	BArtSchV	EG-VO 338/97	RL HESSEN	RL HESSEN SW
Abutilon theophrasti Medik.	Chinesische Samtpappel	Malvaceae					T	T
Acer campestre L.	Feld-Ahorn	Aceraceae						
Acer negundo L.	Eschen-Ahorn	Aceraceae					E	E
Acer platanoides L.	Spitz-Ahorn	Aceraceae						
Acer pseudoplatanus L.	Berg-Ahorn	Aceraceae						
Acer saccharinum L.	Silber-Ahorn	Aceraceae					T	T
Achillea millefolium L.	Gewöhnliche Wiesen-Schafgarbe	Asteraceae						
Achillea nobilis L.	Edle Schafgarbe	Asteraceae					3	3
Achillea pratensis J. Saukel & R. Länger	Echte Wiesen-Schafgarbe	Asteraceae						
Achillea ptarmica L.	Sumpf-Schafgarbe	Asteraceae						
Acinos arvensis (Lam.) Dandy	Steinquendel	Lamiaceae						
Aconitum lycoctonum L.	Gelber Eisenhut	Ranunculaceae					3	3
Acorus calamus L.	Kalmus	Acoraceae					E	E
Actaea spicata L.	Schwarzfrüchtiges Christophskraut	Ranunculaceae	x					
Adonis aestivalis L.	Sommer-Adonisröschen	Ranunculaceae	x				2	2
Adonis flammea Jacq.	Flammen-Adonisröschen	Ranunculaceae	x				0	0
Adoxa moschatellina L.	Moschuskraut	Adoxaceae						
Aegilops cylindrica Host	Zylinder-Walch	Poaceae					T	T
Aegopodium podagraria L.	Giersch	Apiaceae						
Aesculus hippocastanum L.	Gewöhnliche Rosskastanie	Hippocastanaceae					T	T
Aethusa cynapium L.	Hundspetersilie	Apiaceae						
Agastache rugosa Kuntze	Ostasiatischer Riesenysop	Lamiaceae						
Agrimonia eupatoria L.	Gewöhnlicher Odermennig	Rosaceae						
Agrimonia procera Wallr.	Wohlriechender Odermennig	Rosaceae						
Agrostemma githago L.	Kornrade	Caryophyllaceae	x				1	1
Agrostis canina L.	Hunds-Straußgras	Poaceae						
Agrostis capillaris L.	Rotes Straußgras	Poaceae						
Agrostis gigantea Roth	Riesen-Straußgras	Poaceae						
Agrostis stolonifera L.	Weißes Straußgras	Poaceae						
Agrostis vinealis Schreb.	Sand-Straußgras	Poaceae						
Ailanthus altissima (Mill.) Swingle	Götterbaum	Simaroubaceae					E	E
Aira caryophyllea L.	Nelken-Schmielenhafer	Poaceae					V	V
Aira praecox L.	Früher Schmielenhafer	Poaceae					2	3
Ajuga chamaepitys (L.) Schreb.	Gelber Günsel	Lamiaceae	x				2	2
Ajuga genevensis L.	Genfer Günsel	Lamiaceae						
Ajuga reptans L.	Kriechender Günsel	Lamiaceae						
Alcea rosea L.	Gewöhnliche Stockrose	Malvaceae					u	u
Alchemilla glabra Neygenf.	Kahler Frauenmantel	Rosaceae						
Alchemilla xanthochlora Rothm.	Gelbgrüner Frauenmantel	Rosaceae						
Alisma lanceolatum With.	Lanzett-Froschlöffel	Alismataceae						
Alisma plantago-aquatica L.	Gewöhnlicher Froschlöffel	Alismataceae						
Allanta petiolata (M. Bieb.) Caviara & Grande	Lauchhederich	Brassicaceae						
Allium angulosum L.	Kantiger Lauch	Liliaceae	x	b	b		2	2
Allium carinatum L.	Gekielter Lauch	Liliaceae	x				0	0
Allium cristophii Trautv.	Sternkugel-Lauch	Liliaceae					u	u
Allium oleraceum L.	Kohl-Lauch	Liliaceae						
Allium paradoxum (M. Bieb.) G. Don	Seltsamer Lauch	Liliaceae						
Allium schoenoprasum L.	Schnitt-Lauch	Liliaceae						
Allium scorodoprasum L.	Wilder Lauch	Liliaceae					E	E
Allium sphaerocephalon L.	Kugel-Lauch	Liliaceae						D
Allium tuberosum Sprengl.	Chinesischer Schnittlauch	Liliaceae	x					
Allium ursinum L.	Bär-Lauch	Liliaceae					3	3
Allium vineale L.	Weinberg-Lauch	Liliaceae					T	T
Alnus glutinosa (L.) Gaertn.	Schwarz-Erle	Liliaceae						
Alnus incana (L.) Moench	Grau-Erle	Betulaceae						
Alopecurus aequalis Sobol.	Rotgelbes Fuchsschwanzgras	Betulaceae						
Alopecurus geniculatus L.	Knick-Fuchsschwanzgras	Poaceae					T	T
Alopecurus myosuroides Huds.	Acker-Fuchsschwanzgras	Poaceae						V
Alopecurus pratensis L.	Wiesen-Fuchsschwanzgras	Poaceae						
Althaea hirsuta L.	Rauhhaariger Eibisch	Poaceae						
Althaea officinalis L.	Echter Eibisch	Malvaceae						
Alyssum alyssoides (L.) L.	Dünen-Steinkraut	Malvaceae					2	0
Alyssum montanum L. subsp. gmelinii (Jord. & Fourr.) Thell.	Sand-Steinkraut	Brassicaceae		b	b		3	3
Alyssum simplex Rudolphi	Kleines Steinkraut	Brassicaceae	x				V	
Amaranthus albus L.	Weißer Fuchsschwanz	Brassicaceae	x	b	b		1	1
Amaranthus blitoides S. Watson	Westamerikanischer Fuchsschwanz	Amaranthaceae	x				u	nv
Amaranthus blitum L.	Aufsteigender Fuchsschwanz	Amaranthaceae					E	E
Amaranthus bouchonii Thell.	Bouchons Fuchsschwanz	Amaranthaceae					E	E
Amaranthus caudatus L.	Garten-Fuchsschwanz	Amaranthaceae						
		Amaranthaceae					E	E
							u	u

1/25

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Humans make lists of objects

Making lists

We love to make all kinds of lists.

Lists come in different forms:

painting…

Altdorfer (1528): *Battle of Issus.* Pinakothek-Mus Munich.

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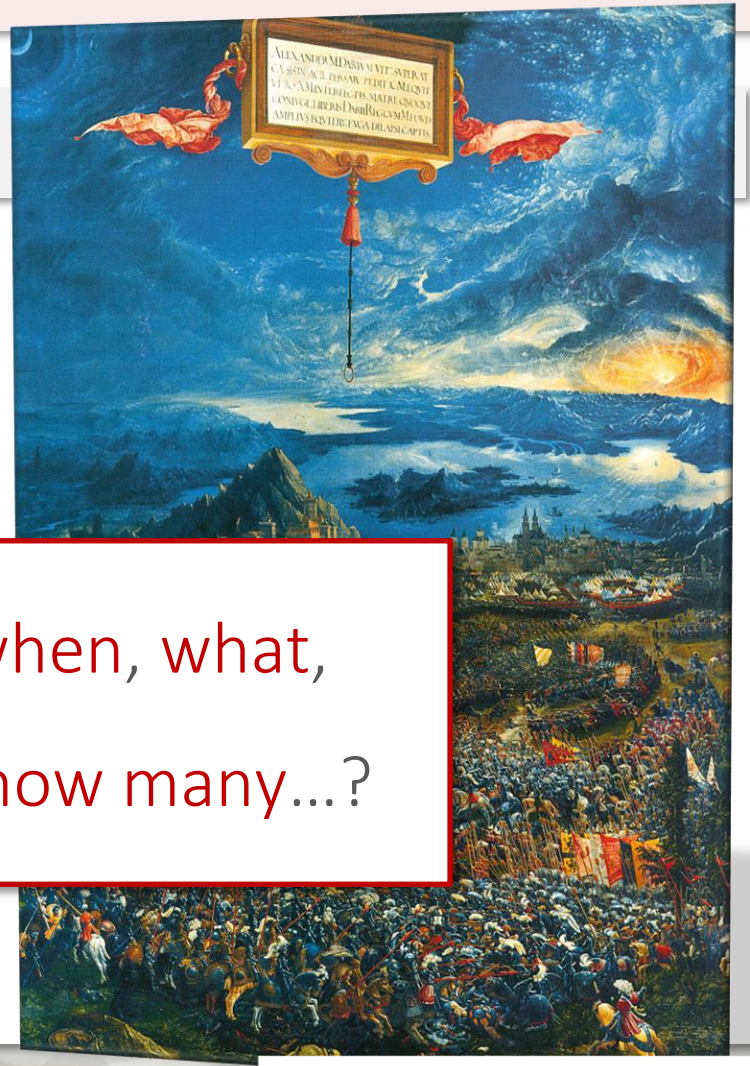
Humans make lists of objects

Making lists

We love to make all kinds of lists.

Lists come in different forms:

painting…



who, when, what,

where, how many…?

Altdorfer (1528): *Battle of Issus.* Pinakothek-Mus Munich.

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Humans make lists of objects

Making lists

We love to make all kinds of lists.

Lists come in different forms:

… or as a collection of objects.

Pannini (1759): *Gallery of Views of Modern Rome.* Louvre Mus Paris.

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Humans make lists of objects

Collections, classifications, and terminology

Collections

Anonymos (1599?): *Dell'Historia Naturale*. University Library Erlangen-Nürnberg.

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Humans make lists of objects

Collections, classifications, and terminology

Collections

Classifications

Drawer no.14 of James John Joicey collection. Haslemere Eduction Mus,Haslemere.

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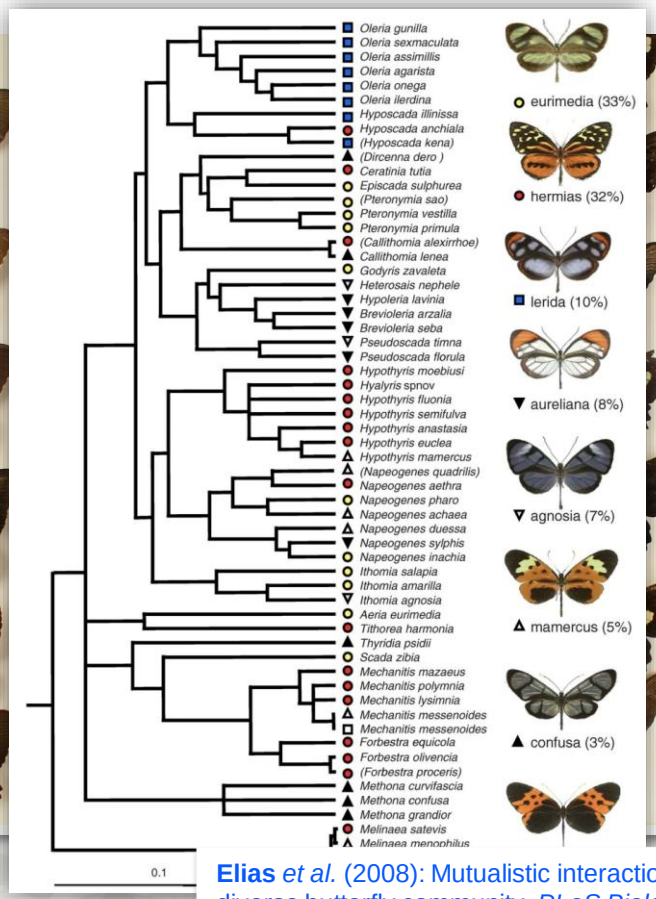
Humans make lists of objects

Collections, classifications, and terminology

Collections

Classifications



Elias *et al.* (2008): Mutualistic interactions drive ecological niche convergence in a diverse butterfly community. *PLoS Biology* **6**(12):e300.

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Humans make lists of objects

Collections, classifications, and terminology

Collections

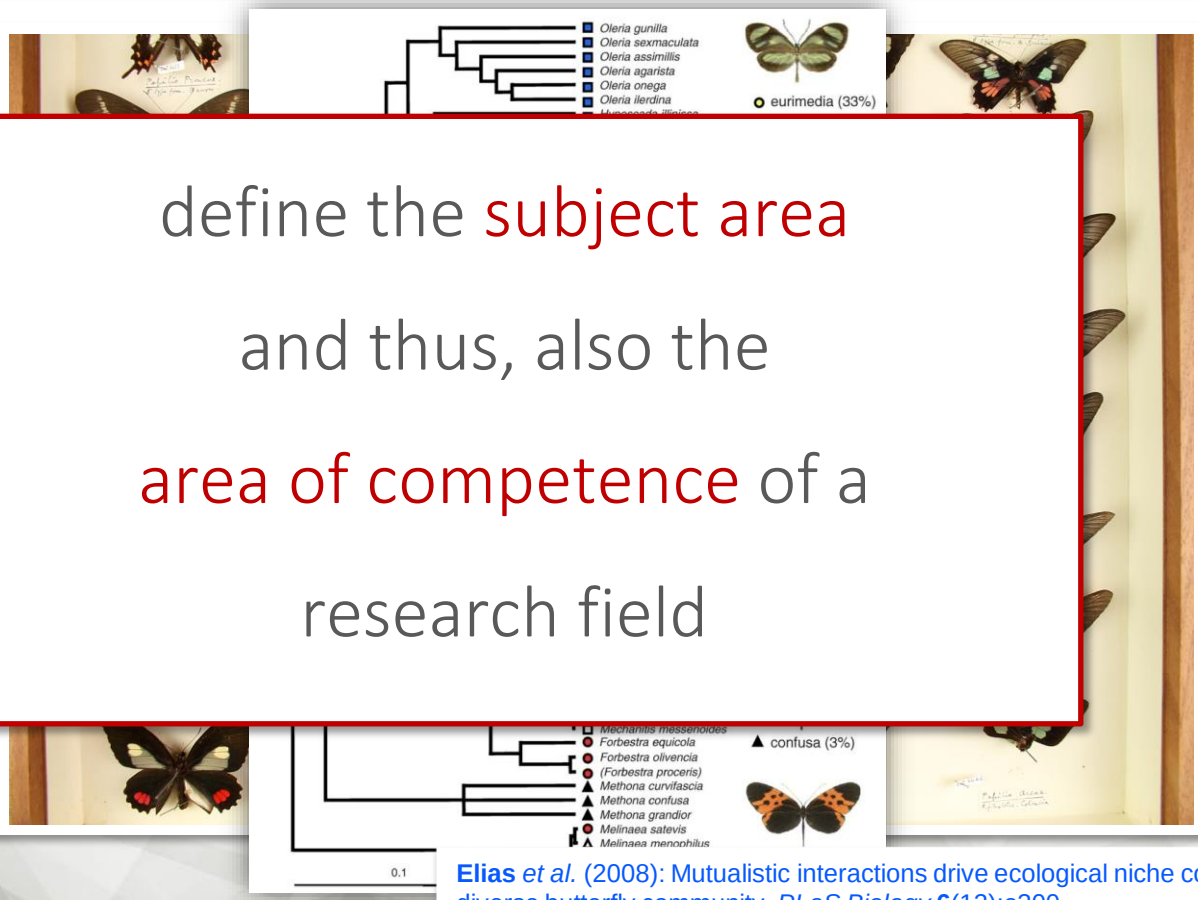
Classifications

define the subject area

and thus, also the

area of competence of a

research field



Elias *et al.* (2008): Mutualistic interactions drive ecological niche convergence in a diverse butterfly community. *PLoS Biology* **6**(12):e300.

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Humans make lists of objects

Collections, classifications, and terminology

Collections

Classifications

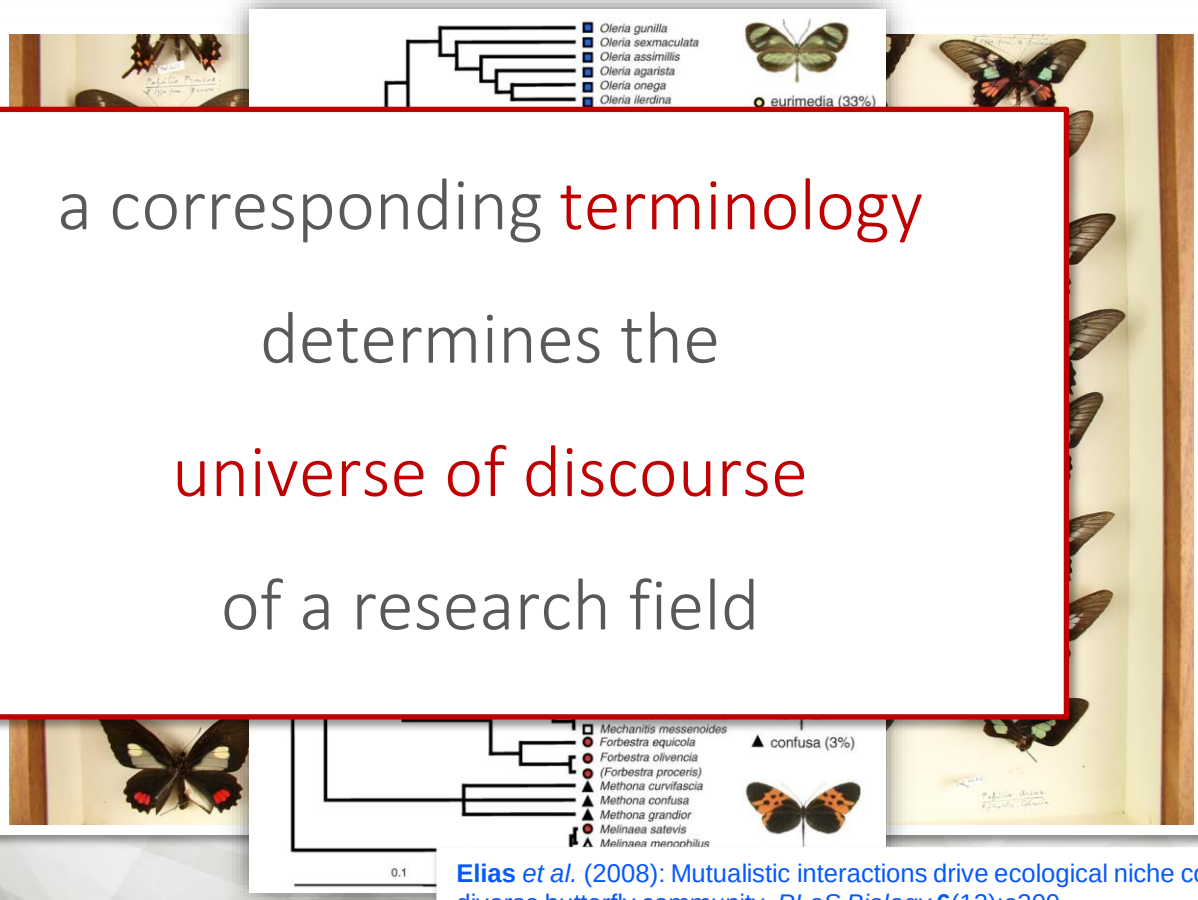
Terminology

a corresponding terminology

determines the

universe of discourse

of a research field



Elias *et al.* (2008): Mutualistic interactions drive ecological niche convergence in a diverse butterfly community. *PLoS Biology* **6**(12):e300.

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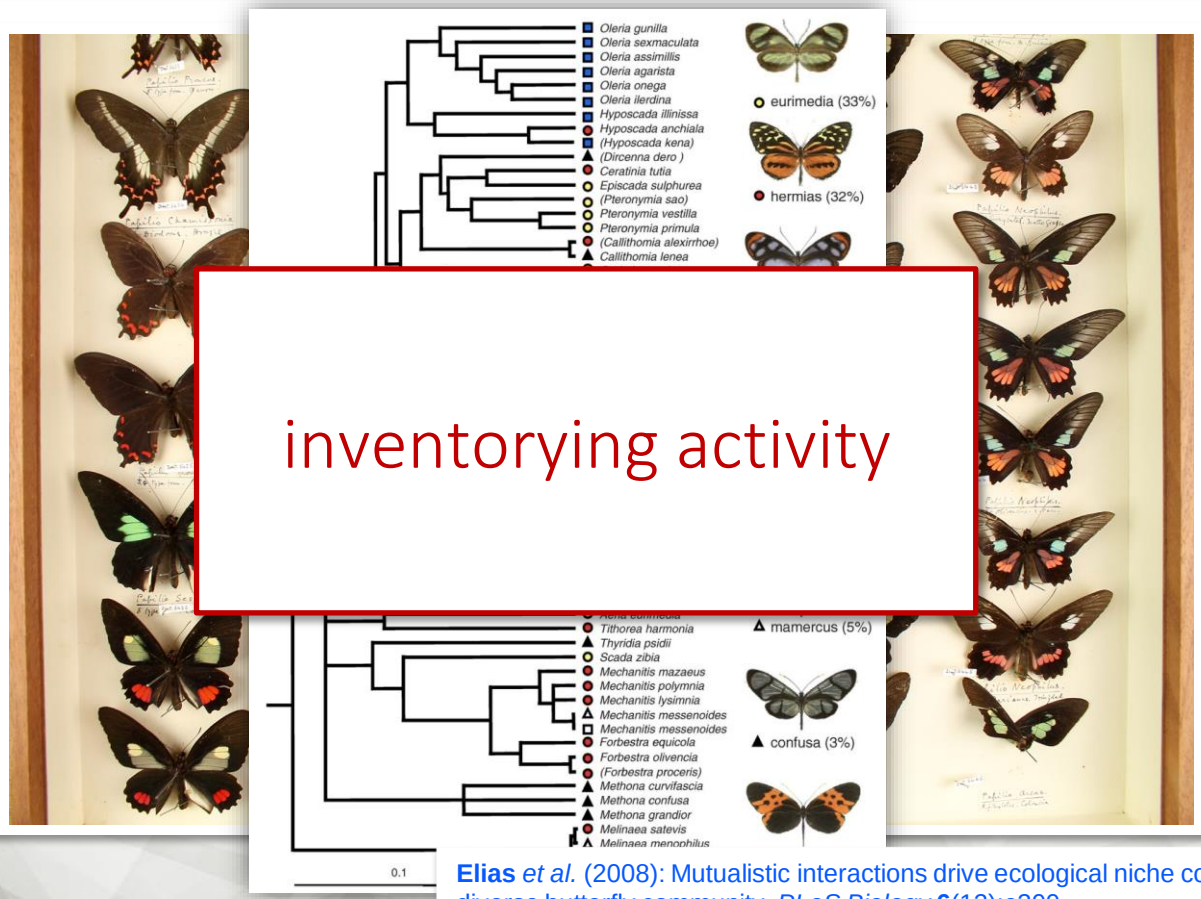
Humans make lists of objects

Collections, classifications, and terminology

Collections

Classifications

Terminology



inventorying activity

Elias *et al.* (2008): Mutualistic interactions drive ecological niche convergence in a diverse butterfly community. *PLoS Biology* **6**(12):e300.

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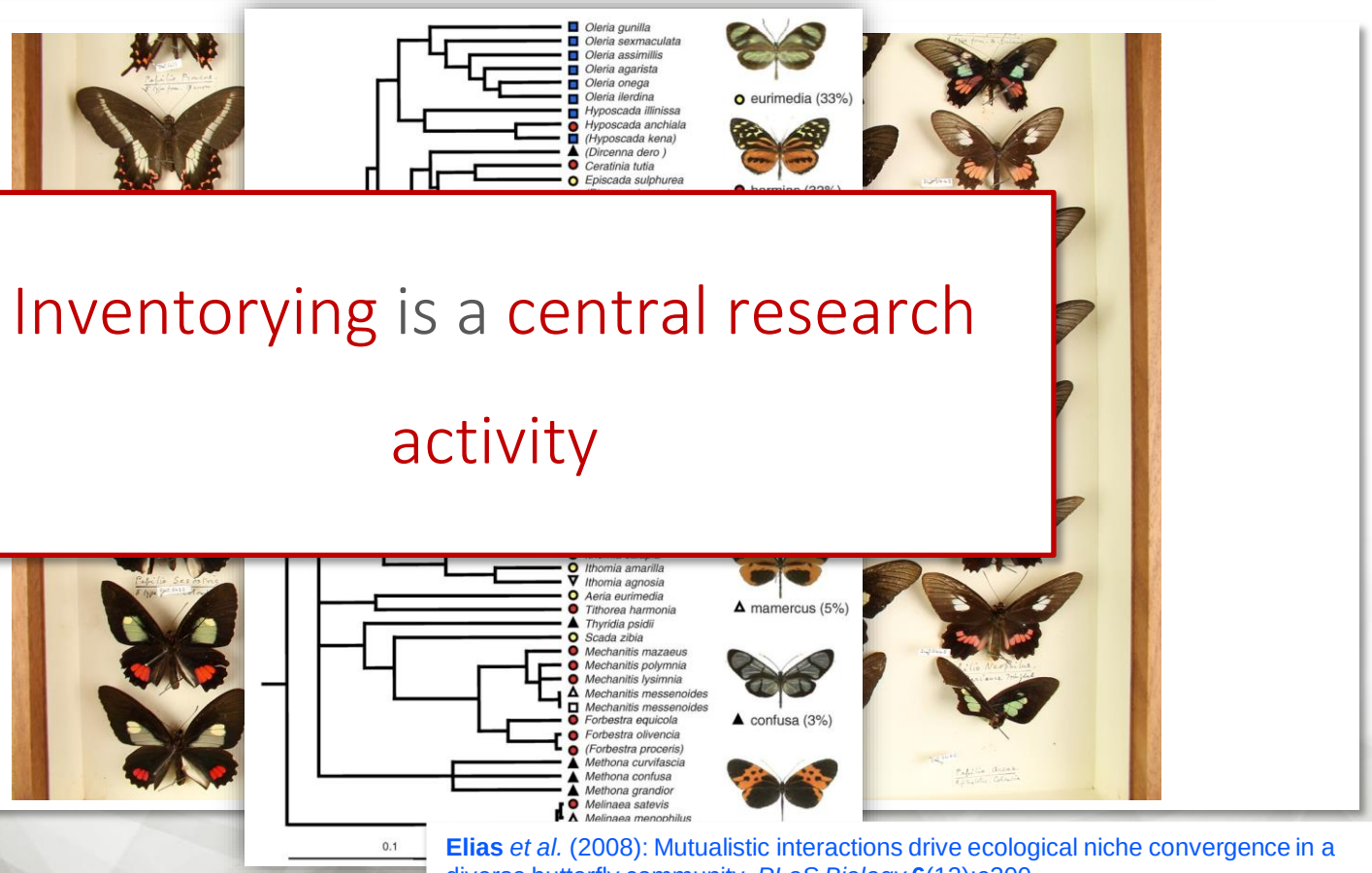
Humans make lists of objects

Collections, classifications, and terminology

Collections

Classifications

Terminology



Inventorying is a central research activity

Elias *et al.* (2008): Mutualistic interactions drive ecological niche convergence in a diverse butterfly community. *PLoS Biology* **6**(12):e300.

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Inventorying requires Partitioning

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Inventorying requires partitioning

Partitioning

Partitioning involves identifying and demarcating parts in a whole.

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Inventorying requires partitioning

Partitioning

Does the pollen have parts?

André Karwath (2005): Amaryllis stamen.

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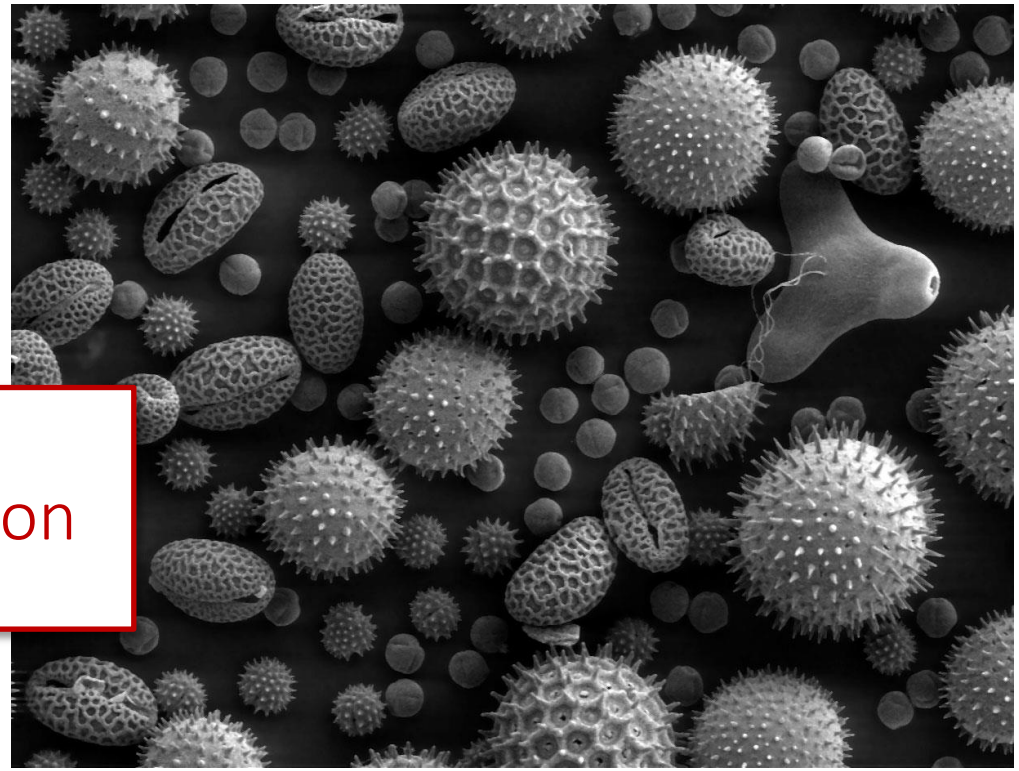
Inventorying requires partitioning

Partitioning

Yes, it has parts!

a matter of resolution



Pollen from a variety of common plants. *Darthmouth Electron Microscopy Facility*

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Different Kinds of Partitions

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Different kinds of partitions

Partitioning

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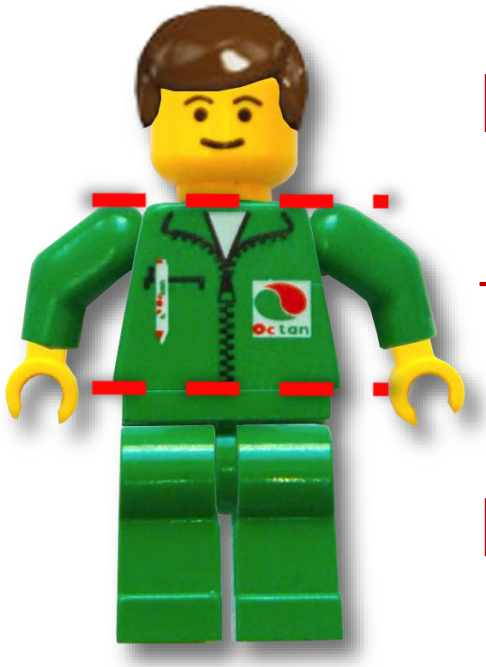
Different kinds of partitions

Partitioning

into regions



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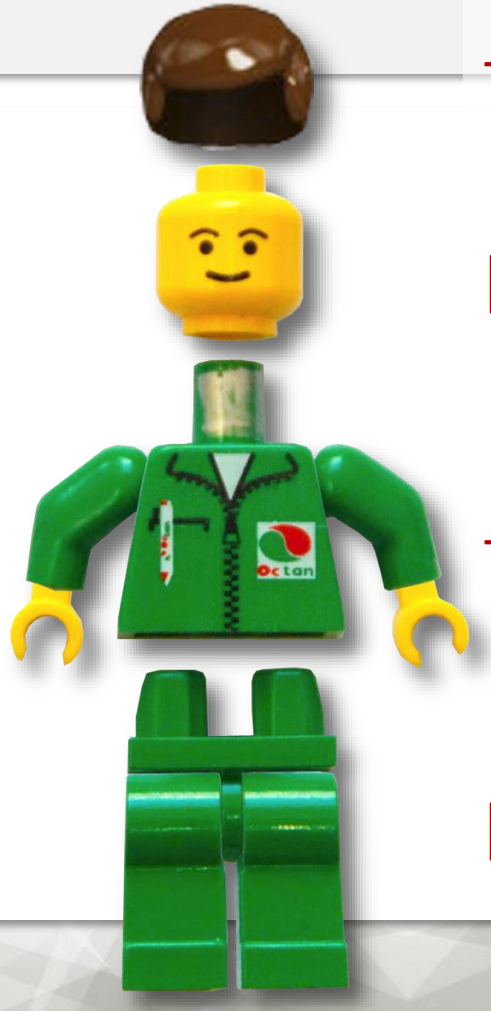
Different kinds of partitions

Partitioning

into objects



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Different kinds of partitions

Partitioning

into objects

finer grained

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From Partitions to Granularity Trees

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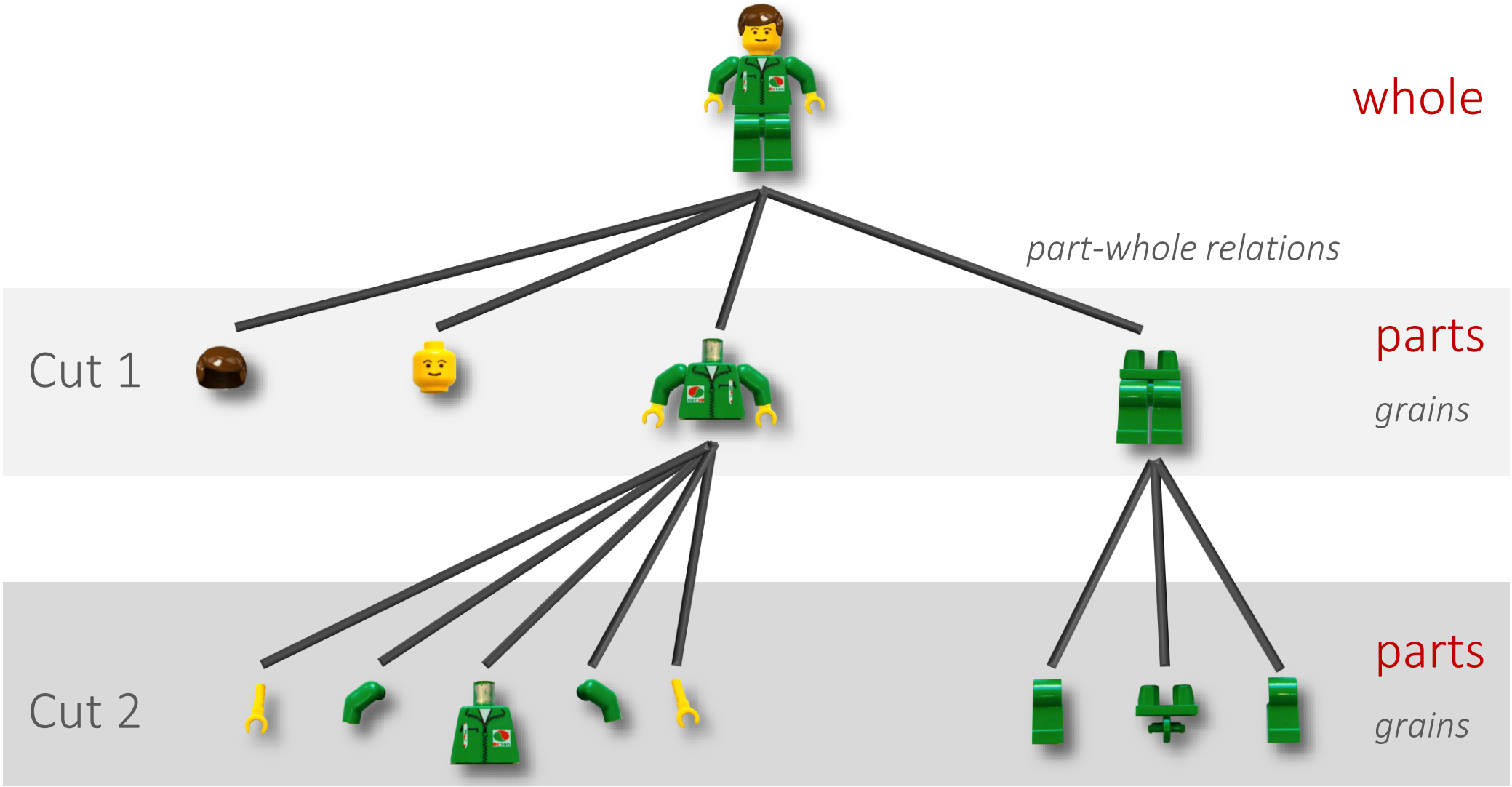
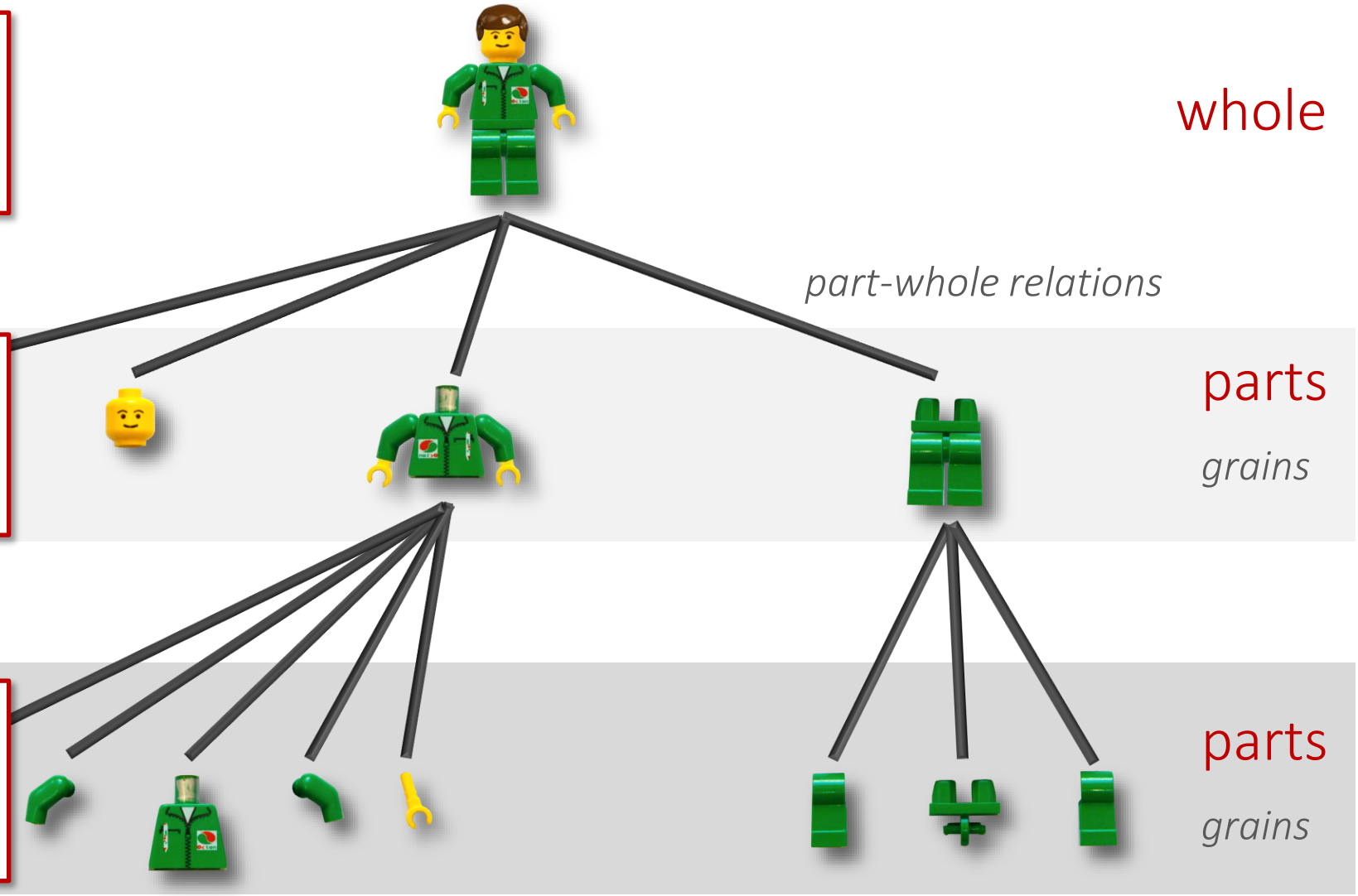


Rigaux & Scholl (1995) Multi-scale partitions: Applications to spatial and statistical databases. *Proceedings Fourth International Symposium SSD95*. pp. 170-183.
Bittner & Smith (2003) Granular spatio-temporal ontologies. *AAAI Spring Symposium Papers*. Pp. SS-03-03.
Vogt *et al.* (2012) Fiat or bona fide boundary—a matter of granular perspective. *PLoS One* 2012(7):e48603.
Vogt (2010) Spatio-structural granularity of biological material entities. *BMC Bioinformatics* 2010(11):289.

level of granularity

level of granularity

level of granularity



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Vogt (2010) Spatio-structural granularity of biological material entities. *BMC Bioinformatics* 2010(11):289.

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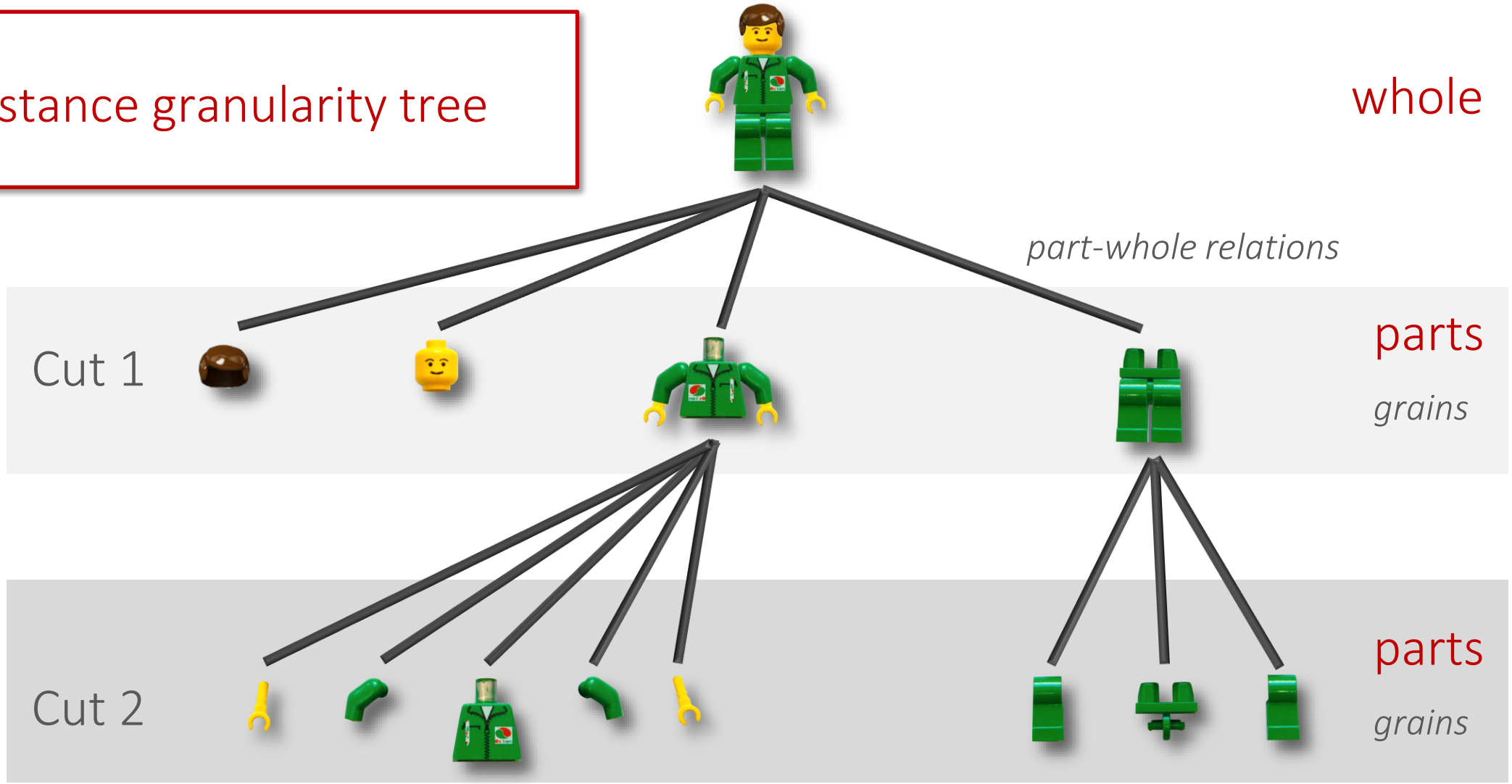
instance granularity tree



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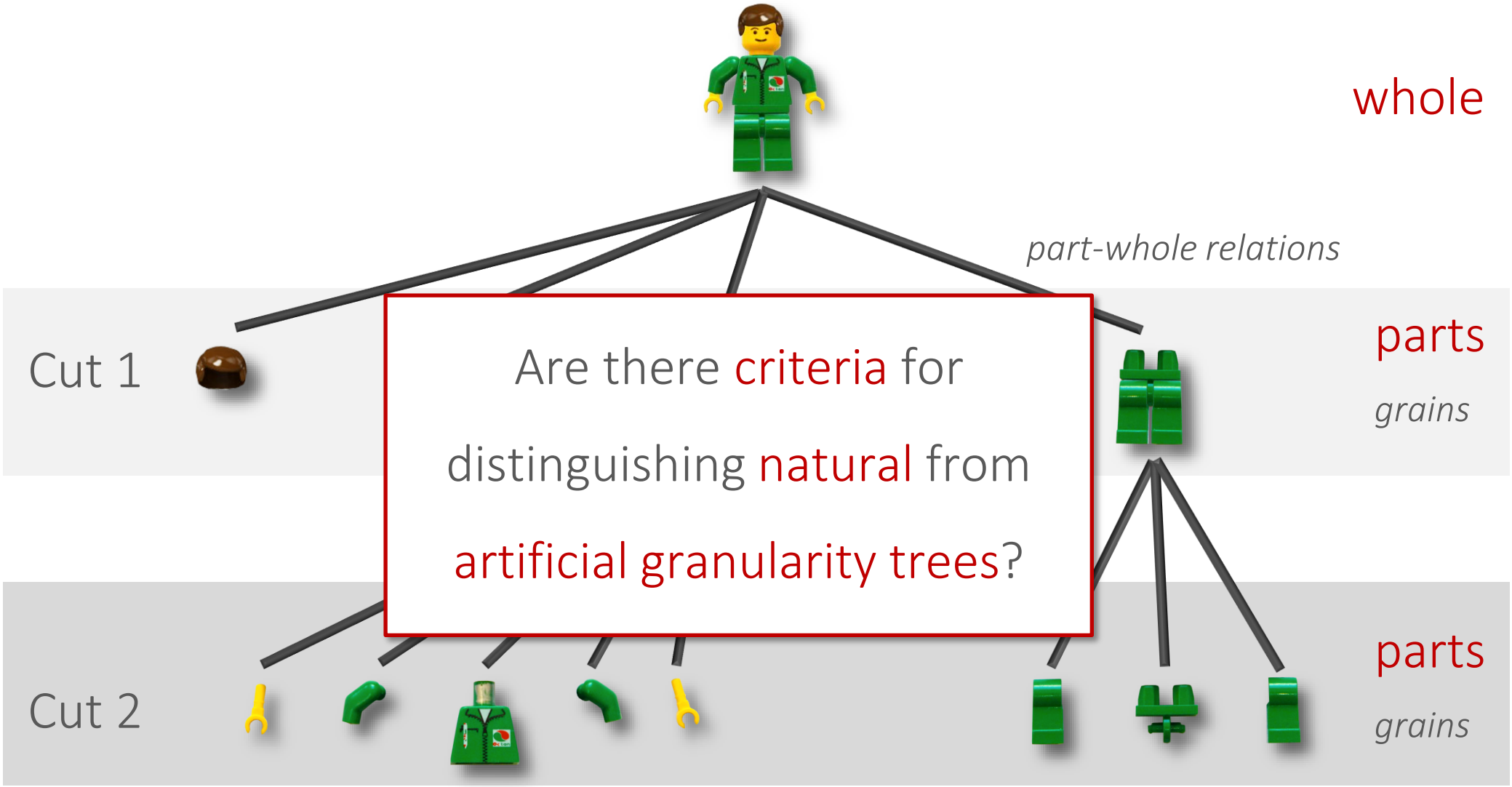

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Vogt (2010) Spatio-structural granularity of biological material entities. *BMC Bioinformatics* 2010(11):289.

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Levels of Organization

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Levels of organization

Published hierarchies

Levels of biological organization

Wimsatt (1976): Reconstructionism, levels of organization, and the mind-body problem. **In**: *Consciousness and the brain: A scientific and philosophic inquiry*. Plenum Press, 202-267.

Levels of complexity

Wimsatt (1994): The ontology of complex systems: Levels, Perspectives, and causal thickets. *Canadian Journal of Philosophy, Supp.Vol.* ***20***: 207-274.

Scalar hierarchy

Salthe (1985) *Evolving Hierarchical Systems: Their Structure and Representation.* New York: Columbia University Press.

Building block system

Jagers Op Akkerhuis & van Straalen (1998) Operators, the Legobricks of nature, evolutionary transitions from fermions to neural networks. *World Futures* **53**: 329–345.

Theory of the stratification of the world

Riedl (2000) *Strukturen der Komplexität - Eine Morphologie des Erkennens und Erklärens.* Berlin: Springer.

Levels of organization

Eldredge's Somatic Hierarchy

subatomic particle
atom
molecule
organelle
cell

different

demarcation criteria

structure

tissue

cluster & resolution

organ
organ system
individual organism

function

Eldredge (1985) *Unfinished Synthesis: Biological Hierarchies and Modern Evolutionary Thought*. New York: Oxford University Press.

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Levels of organization

Eldredge's Somatic Hierarchy

subatomic particle
atom
molecule
organelle
cell

this is a category error

structure

tissue

cluster & resolution

organ
organ system
individual organism

function

Eldredge (1985) *Unfinished Synthesis: Biological Hierarchies and Modern Evolutionary Thought*. New York: Oxford University Press.

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Boundaries provide Demarcation Criteria

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Boundaries provide demarcation criteria

Boundaries bound entities

- Only extended entities possess boundaries.

  processes in time, physical objects in space

Roland Arhelger (1988) Berlin Wall, Niederkirchnerstraße. (WikiMedia Commons)

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Boundaries provide demarcation criteria

Boundaries bound entities

Only extended entities possess boundaries.

processes in time, physical objects in space

Boundaries bound objects of a dimensionality one higher than their own.

e.g., three-dimensional entities are bound by two-dimensional entities.

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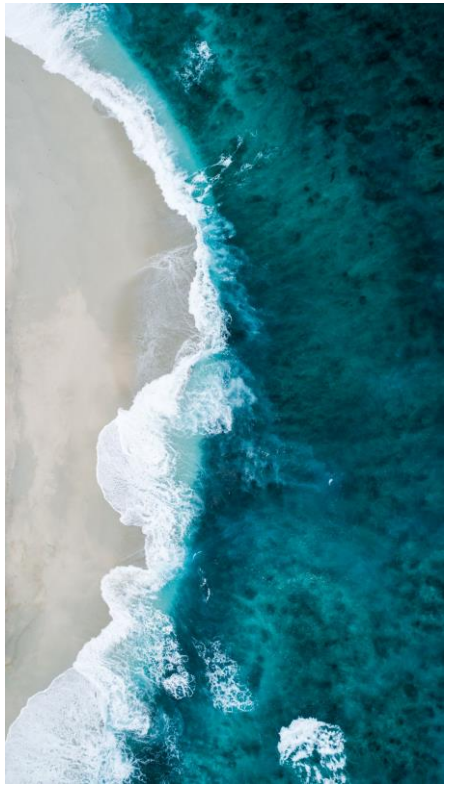
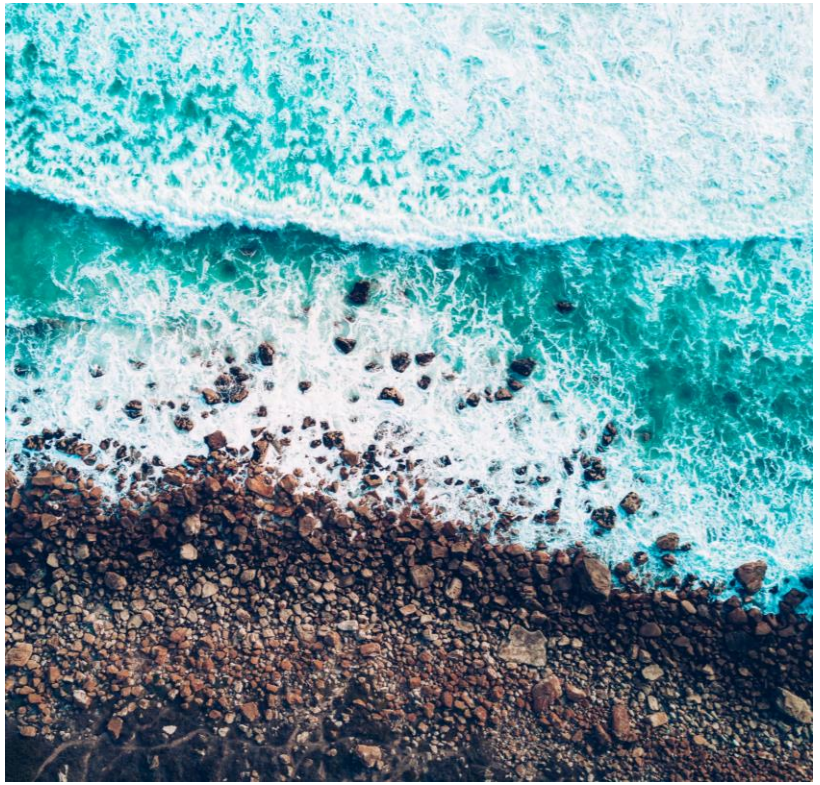
Boundaries provide demarcation criteria

Dynamic boundaries

The (relative) location of some boundaries is time-dependent.



Shifaaz shamoon (2017) Maldives



John O'Neal (2017) Cape Town, Western Cape, South Africa

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Boundaries provide demarcation criteria

Fuzzy boundaries

A ‘vague’ or ‘non-crisp’ boundary.

David Gavi (2017) *no title*

Pexels Closeup of sand on beach

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Boundaries provide demarcation criteria

Fuzzy boundaries

A ‘vague’ or ‘non-crisp’ boundary.

An entity that is delineated by boundary-like regions.

David Gavi (2017) *no title*

Pexels Closeup of sand on beach

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Boundaries provide demarcation criteria

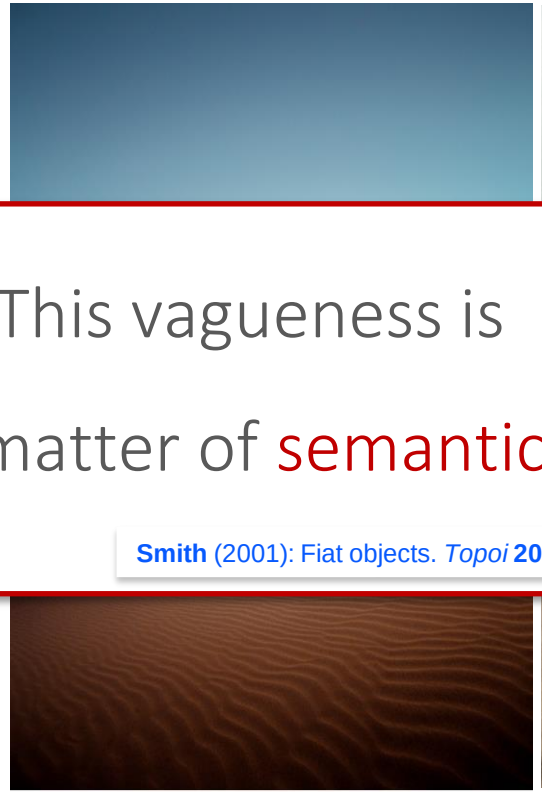
Fuzzy boundaries

A ‘vague’ or ‘non-cri
boundary.
An entity that is deli
by boundary-like reg

This vagueness is

a matter of semantics

Smith (2001): Fiat objects. *Topoi* **20**(2): 131–148



David Gavi (2017) *no title*

Pexels Closeup of sand on beach

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Bona Fide Boundaries and Natural Units

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Bona fide boundaries and natural units

Characterizing ‘bona fide boundary’

Natural or mind-independent boundaries [2,3], which are physical boundaries in the things themselves that exist independently from human perception [1-5].

Liam Gumley (2001) Satellite picture of the French island Corsica. University of Wisconsin-Madison

1. **Smith** (1994): Fiat objects. In: *Parts and Wholes: Conceptual Part-Whole Relations and Formal Mereology*. Amsterdam, pp. 15–23.
2. **Smith** (1995): On Drawing Lines on a Map. In: *Spatial Information Theory: Proceedings in COSIT ’95*. Berlin: Springer. pp. 475–484.
3. **Smith** (2001): Fiat Objects. *Topoi* 20(2): 131–148.
4. **Smith & Varzi** (1997): Fiat and Bona Fide Boundaries: Towards an Ontology of Spatially Extended Objects. In: *Spatial Information Theory: A Theoretical Basis for GIS*. Berlin: Springer. pp. 103–119.
5. **Smith & Varzi** (2000): Fiat and Bona Fide Boundaries. *Philosophy and Phenomenological Research* 60(2): 401–420.

Bona fide boundaries and natural units

Characterizing 'bona fide boundary'

Natural or mind-independent boundaries [2,3], which are physical boundaries in the things themselves that exist independently from human perception [1-5].

They can be demarcated on ground of "some interior physical discontinuity or some qualitative heterogeneity among the parts of the object (some sharp gradient of material constitution, color, texture, electric charge, etc.)"[3]

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They can be demarcated
discontinuity or some qua
parts of the object (some
constitution, color, textur

ontological criterion

natural = real, mind-independent

1. **Smith** (1994): Fiat objects. In: *Parts and Wholes: Conceptual Part-Whole Relations and Formal Mereology*. Amsterdam, pp. 15–23.
2. **Smith** (1995): On Drawing Lines on a Map. In: *Spatial Information Theory: Proceedings in COSIT ’95*. Berlin: Springer. pp. 475–484.
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Liam Gumley (2001) Satellite picture of the French island Corsica. University of Wisconsin-Madison

Bona fide boundaries and natural units

Characterizing 'bona fide boundary

Natural or mind-independent
physical boundaries in the thi
independently from human p

operational criterion

physical properties

discontinuity & heterogeneity

They can be demarcated on ground of "some interior physical discontinuity or some qualitative heterogeneity among the parts of the object (some sharp gradient of material constitution, color, texture, electric charge, etc.)"[3]

Liam Gumley (2001) Satellite picture of the French island Corsica. University of Wisconsin-Madison

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Bona fide boundaries and natural units

Characterizing ‘bona fide object’

A bona fide object is an entity with only

bona fide outer boundaries.

Liam Gumley (2001) Satellite picture of the French island Corsica. University of Wisconsin-Madison

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Fiat Boundaries and Fiat Entities

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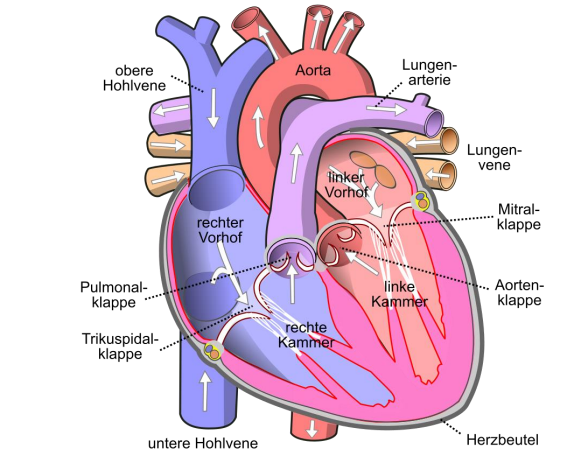
Fiat boundaries and fiat entities

Characterizing ‘fiat boundary’

Artificial (i.e., artifact of cognition) or mind-dependent boundaries, which are non-physical boundaries that depend on human decision and thus are the products of mental activities [1-4].

WikiMedia Commons (2005) Map of USA with state names



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Jakov (2008) Schema eines Menschlichen Herzen, WikiMedia Commons

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Fiat boundaries and fiat entities

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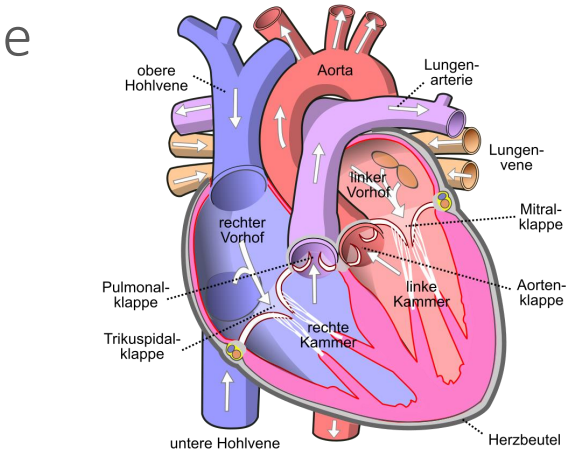

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Fiat boundaries and fiat entities

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maps”[4]

ontological criterion

artificial = mind-dependent

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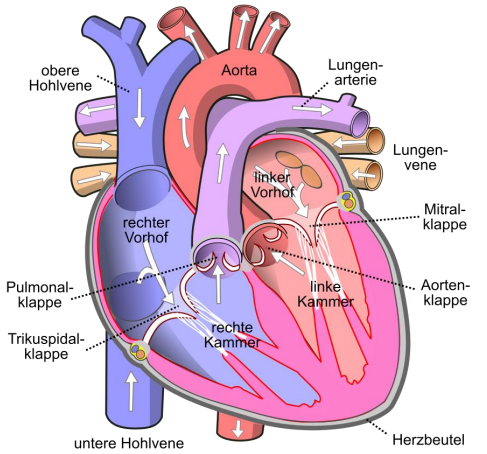

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Fiat boundaries and fiat entities

Characterizing ‘fiat boundary’

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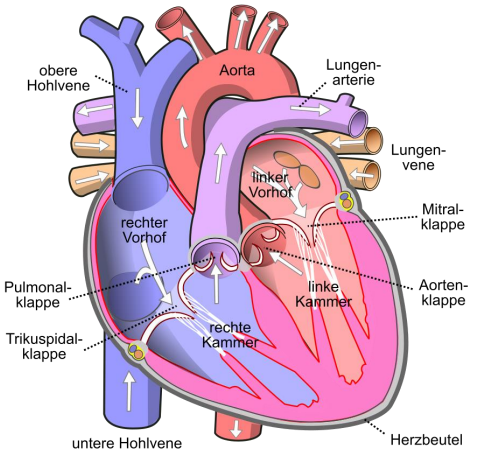

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Fiat boundaries and fiat entities

Characterizing ‘fiat object part’

A fiat object part is an entity with some

fiat outer boundary.

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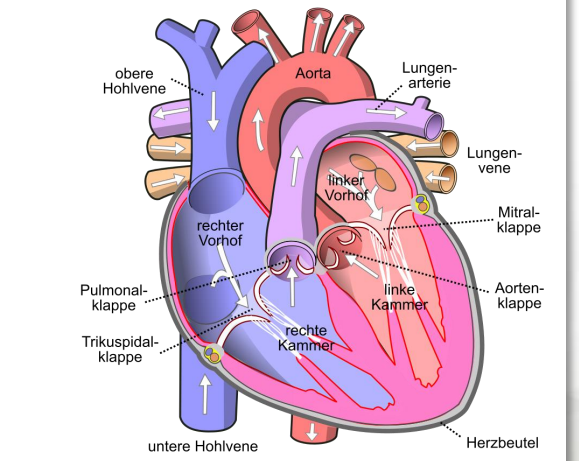

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Bona Fide Boundary ↔ Fiat Boundary

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Bona fide boundary ↔ fiat boundary

Characterizing 'bona fide boundary'

The distinction of fiat and bona fide boundaries is said to be absolute and categorial, i.e., disjunct and exhaustive.

Smith & Varzi (1997): Fiat and Bona Fide Boundaries: Towards an Ontology of Spatially Extended Objects. In: *Spatial Information Theory: A Theoretical Basis for GIS*. Berlin: Springer. pp. 103–119.

Bona fide boundary ↔ fiat boundary

Characterizing ‘bona fide boundary’

The distinctio … s is said to be absolut … exhaustive.

Is this really a categorial distinction?

Smith & Varzi (1997): Fiat and Bona Fide Boundaries: Towards an Ontology of Spatially Extended Objects. In: *Spatial Information Theory: A Theoretical Basis for GIS*. Berlin: Springer. pp. 103–119.

Bona fide boundary ↔ fiat boundary

Characterizing ‘bona fide boundary’

Are the two criteria, the ontological and the

operational criterion, really mutually dependent?

Smith & Varzi (1997): Fiat and Bona Fide Boundaries: Towards an Ontology of Spatially Extended Objects. In: *Spatial Information Theory: A Theoretical Basis for GIS*. Berlin: Springer. pp. 103–119.

Liam Gumley (2001) Satellite picture of the French island Corsica. University of Wisconsin-Madison

Bona Fide Boundary

Operational Criterion

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Bona fide boundary – operational criterion

A matter of scale and representation

Cell

at eye-sight scale, we cannot delimit single cells; instead, we refer to any aggregate of cells as a (fiat) portion of tissue.

Jon Sullivan (2013) Fresh meat (WikiMedia Commons)

WikiMedia Commons (2017) image skin texture

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Bona fide boundary – operational criterion

A matter of scale and representation

Cell

at the light- and electron-microscopic scale

often delimitable as a bona fide object.

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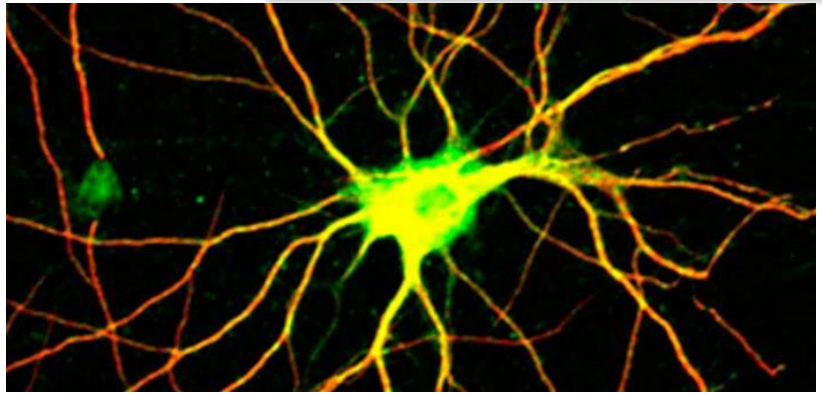

Mulletsrokk (2010) Cheek cells – nonkeratinized stratified squamous epithelium, 500x magnification

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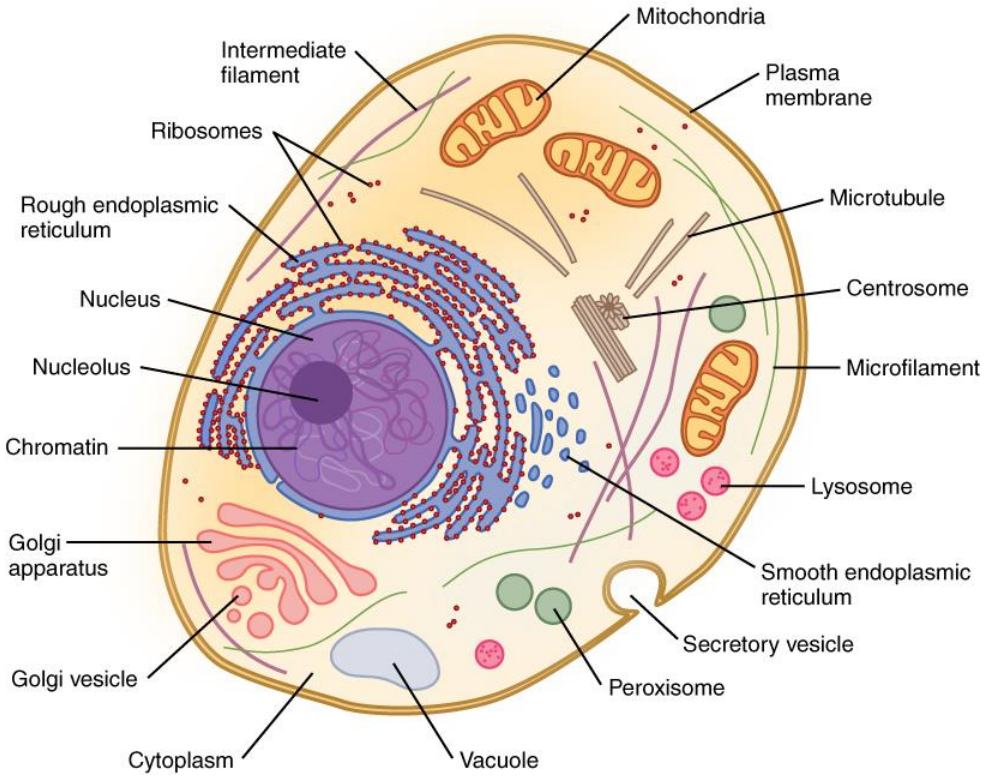
Bona fide boundary – operational criterion

Continua in biology

Cell

is at the cellular & organelle level

a bona fide object.



OpenStax (2016) Animal cell and components (WikiMedia Commons)

Vogt *et al.* (2012): Accommodating Ontologies to Biological Reality—Top-Level Categories of Cumulative-Constitutively Organized Material Entities. *PLoS ONE* 7(1): e30004

Vogt *et al.* (2012): Fiat or Bona Fide Boundaries – A Matter of Granular Perspective. *PLoS ONE* 7(12): e48603

Bona fide boundary – operational criterion

Continua in biology

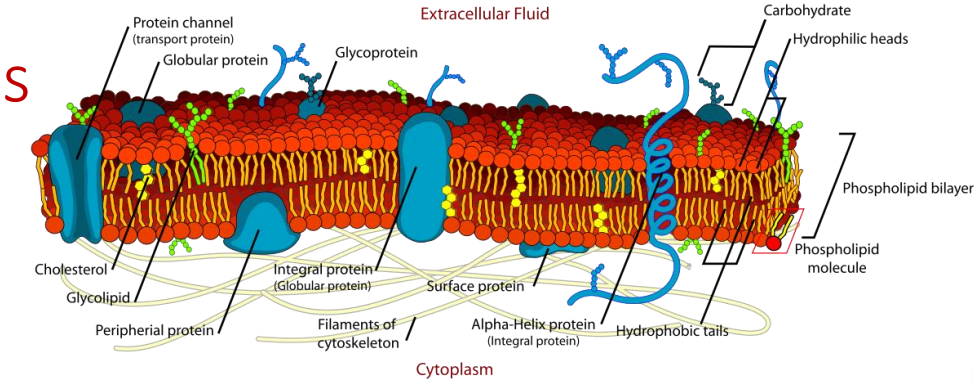
Cell

is at the molecular level a

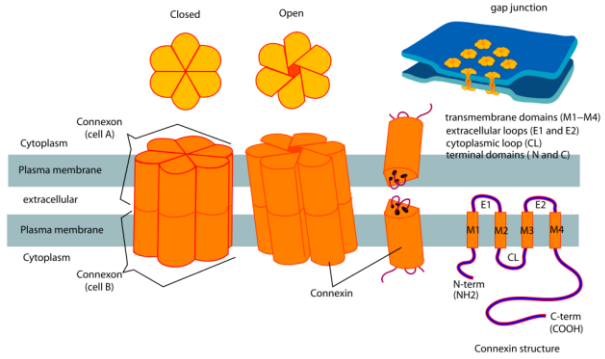
fiat object part.

channels

Mariana Ruiz (edited by Alokrpasad; 2008) Cell membrane detailed diagram edit 2 (Wikipedia)



gap junctions



Mariana Ruiz (2006) Connexon and connexin structure (WikiMedia Commons)

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Bona fide boundary – operational criterion

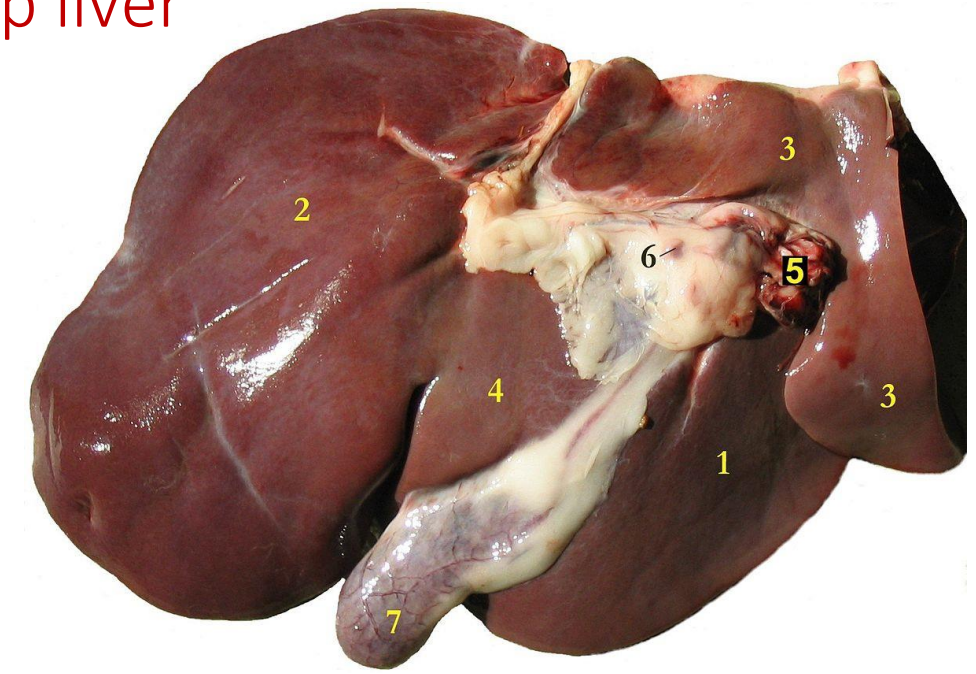
Continua in biology

Organ

is at the organ level a

bona fide object.

sheep liver



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Vogt *et al.* (2012): Fiat or Bona Fide Boundaries – A Matter of Granular Perspective. *PLoS ONE* 7(12): e48603

Uwe Gille (2005) Leber eines Schafes, Eingeweidefläche

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Bona fide boundary – operational criterion

Continua in biology

Organ

is at the cellular level a

fiat object part.

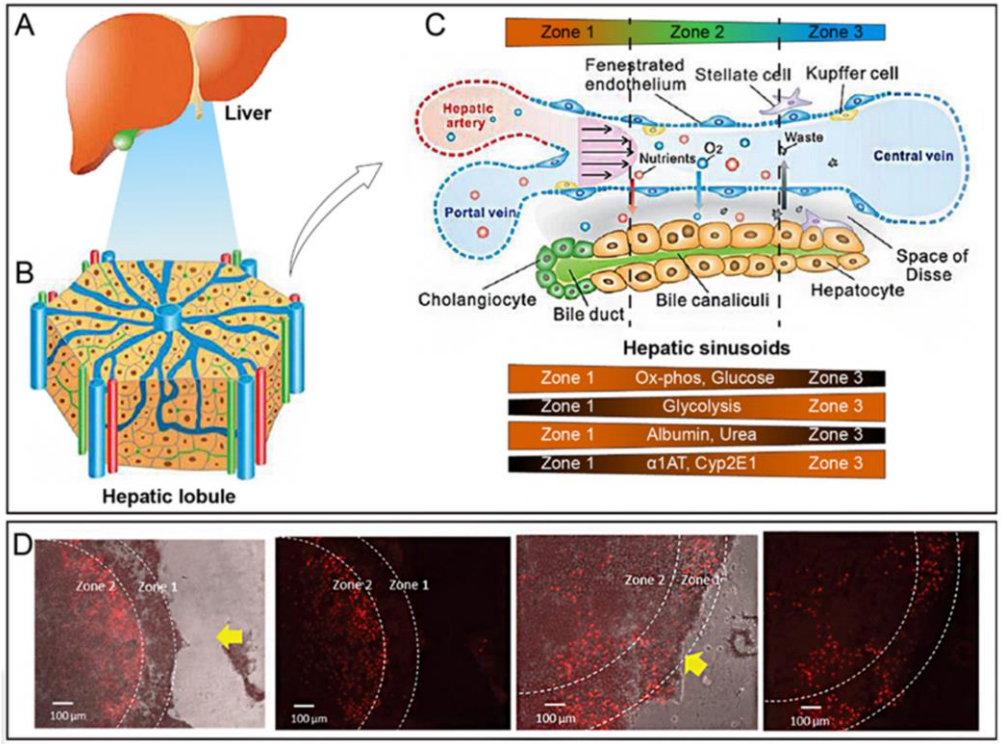

Fig.1 Cellular composition and anatomical microstructure of the liver;
Jeng *et al.* (2019) Engineered liver-on-a-chip platform to mimic liver functions and its biomedical applications: a review. *Micromachines* **10**(10), 676.

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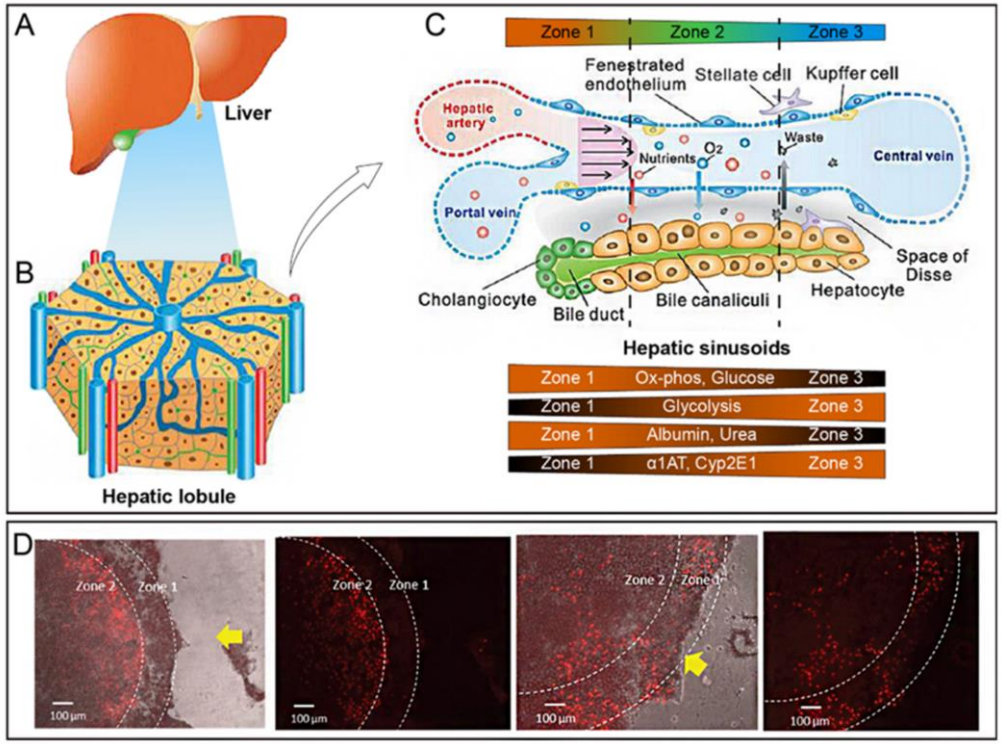
Bona fide boundary – operational criterion

Continua in biology

Physical Connectedness

At the cellular and supra-cellular levels, the parts of an organism are connected to their neighboring objects via various conduits, tunnels, vessels, ducts, nerve cords, intercellular spaces, pores, channels, and junctions.

Schulz & Johansson (2007): Continua in Biological Systems. *The Monist* **90**(4):499-522.



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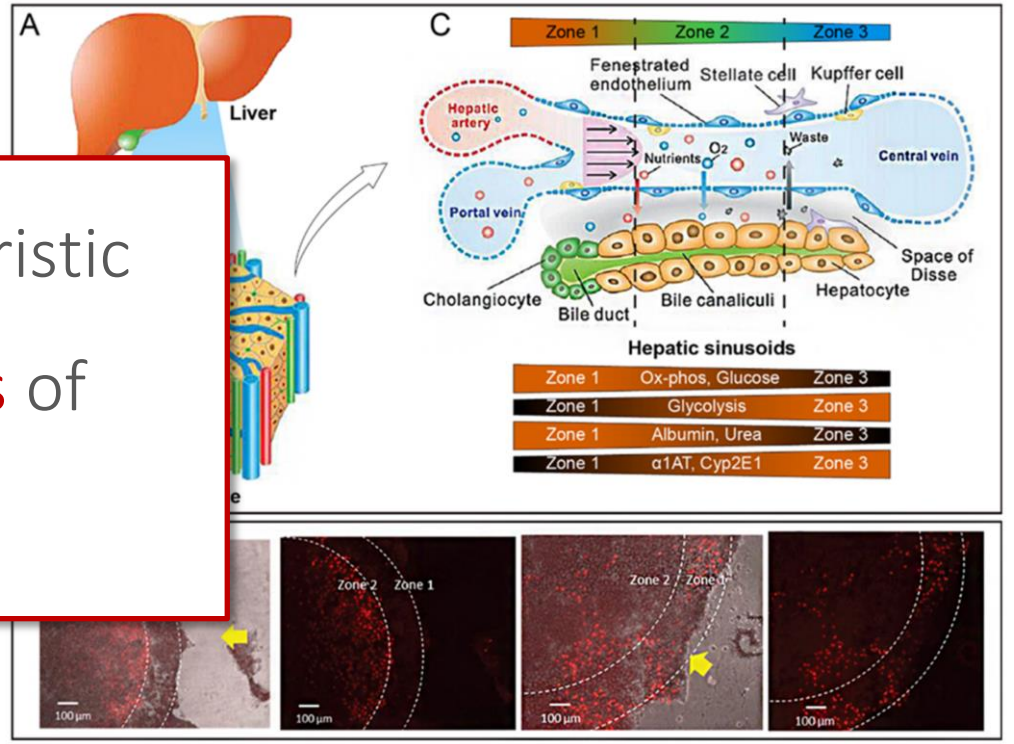
Bona fide boundary – operational criterion

Continua in biology

Physical Connectedness

At the
the pa
to the
condu
cords,
channels, and junctions.

Such connections are characteristic to complex biological systems of interacting subsystems



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Bona fide boundary – operational criterion

Characterizing 'bona fide boundary'

Natural or mind-independent bo
physical boundaries in the things
independently from human perc

Physical discontinuity

is

granularity-dependent

They can be demarcated on ground of "some interior physical discontinuity or some qualitative heterogeneity among the parts of the object (some sharp gradient of material constitution, color, texture, electric charge, etc.)"[3]

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Bona fide boundary – operational criterion

Continua in biology

Heterogeneity

No two cells are completely identical.

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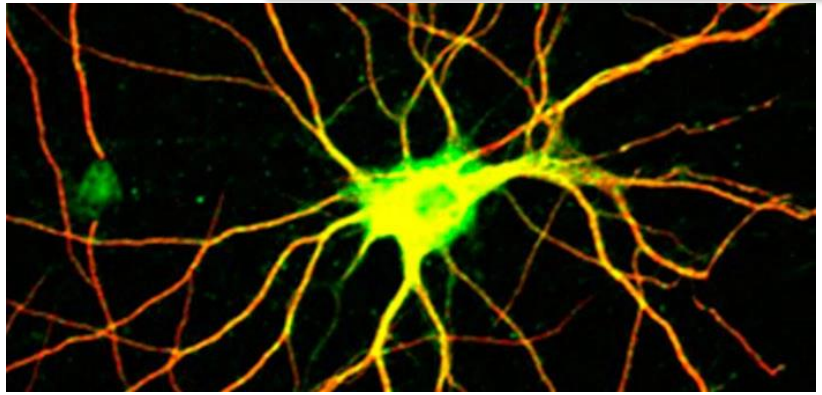

Mulletsrokk (2010) Cheek cells – nonkeratinized stratified squamous epithelium, 500x magnification

Vogt *et al.* (2012): Fiat or Bona Fide Boundaries – A Matter of Granular Perspective. *PLoS ONE* 7(12): e48603

Bona fide boundary – operational criterion

Continua in biology

Heterogeneity

No two cells are completely identical.

Each cell aggregate possesses qualitative heterogeneity between any two adjacent cells.

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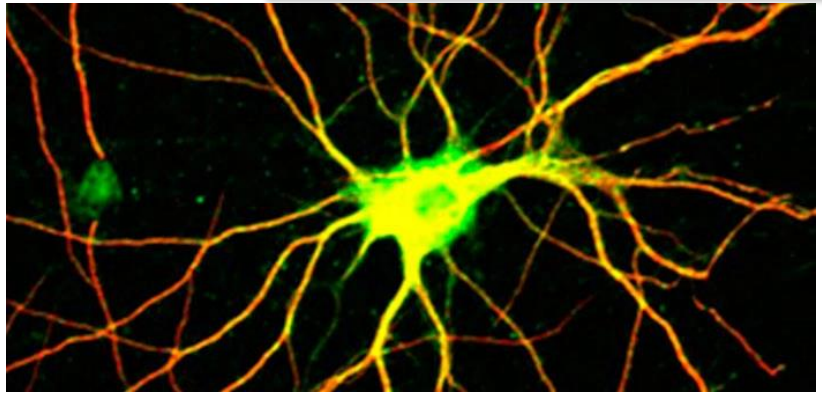

Mulletsrokk (2010) Cheek cells – nonkeratinized stratified squamous epithelium, 500x magnification

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Bona fide boundary – operational criterion

Continua in biology

Heterogeneity

No tv
ident

Each
quali
any two adjacent cells.

How much heterogeneity is required for a bona fide boundary?

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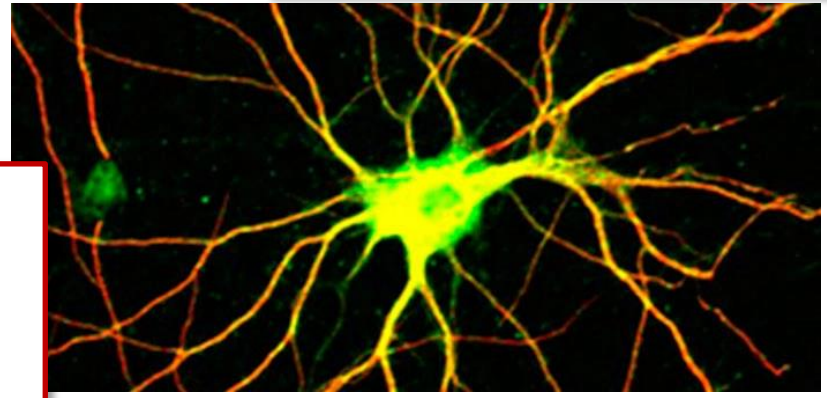

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Bona fide boundary – operational criterion

Qualitative Heterogeneity

is

granularity-dependent

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Bona fide boundary – operational criterion

Char

Ontological Continuum

Above the molecular level, the distinction of bona fide and fiat boundaries is fuzzy and granularity-dependent

Vogt *et al.* (2012): Accommodating Ontologies to Biological Reality—Top-Level Categories of Cumulative-Constitutively Organized Material Entities. *PLoS ONE* 7(1): e30004
Vogt *et al.* (2012): Fiat or Bona Fide Boundaries – A Matter of Granular Perspective. *PLoS ONE* 7(12): e48603

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Bona fide boundary – operational criterion

Characterizing 'bona fide boundary'

Natural or mind-independent boundaries [2,3], which are physical bo exist independe

They can b rior physical discontinui mong the parts of th ial constitution, color, texture, electric charge, etc.)"[3]

Are these two criteria really

mutually dependent?

Answer: No!

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Bona fide boundary – operational criterion

First Conclusion

First Conclusion

Either there are no natural units above the molecular level, or the criteria must be adopted to account for granularity-dependence.

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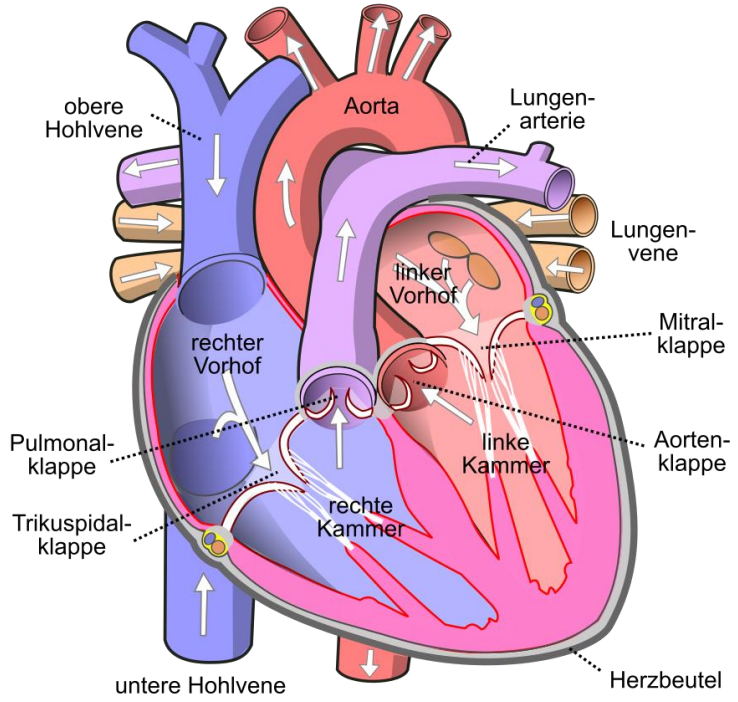
Bona fide boundary – operational criterion

Second Conclusion

Second Conclusion

If the two criteria are not mutually dependent, could there be mind-independent natural units with physically fiat boundaries?



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Bona fide boundary – operational criterion

Bona fide physical boundaries

Every natural unit must meet the ontological criterion.

Vogt *et al.* (2012): Fiat or Bona Fide Boundaries – A Matter of Granular Perspective. *PLoS ONE* 7(12): e48603

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Bona fide boundary – operational criterion

Bona fide physical boundaries

Every natural unit must meet the c

criterion.

ontological criterion

natural = real, mind-independent

Vogt *et al.* (2012): Fiat or Bona Fide Boundaries – A Matter of Granular Perspective. *PLoS ONE* 7(12): e48603

Bona fide boundary – operational criterion

Bona fide physical boundaries

Every natural unit must meet the c

criterion.

ontological criterion

natural = real, mind-independent

Every natural unit must meet the operational criterion, which depends on the granular perspective of interest, i.e., the frame of reference.

Vogt *et al.* (2012): Fiat or Bona Fide Boundaries – A Matter of Granular Perspective. *PLoS ONE* 7(12): e48603

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Bona fide boundary – operational criterion

Bona fide physical boundaries

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Every natural unit must meet the operational

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natural = real, mind-independent

operational criterion

???

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Bona fide boundary – operational criterion

Bona fide physical objects

Physical Objects	*structural biology*	**Structure**

operational criterion

physical properties

discontinuity & heterogeneity

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Examples for Non-Structural Natural Units from the Life Sciences

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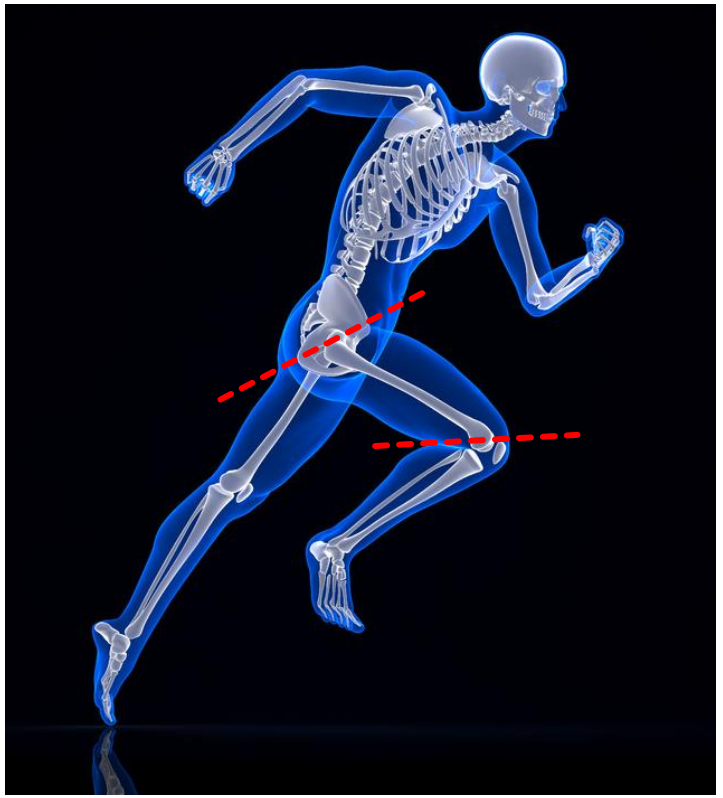
Examples for non-structural natural units from the life sciences

Example: Locomotion

Thigh as a natural unit

structurally bona fide?



https://www.slon.pics/product/running-skeleton-contains-clipping-path

Vogt *et al.* (2012): Fiat or Bona Fide Boundaries – A Matter of Granular Perspective. *PLoS ONE* 7(12): e48603

Examples for non-structural natural units from the life sciences

Example: Locomotion

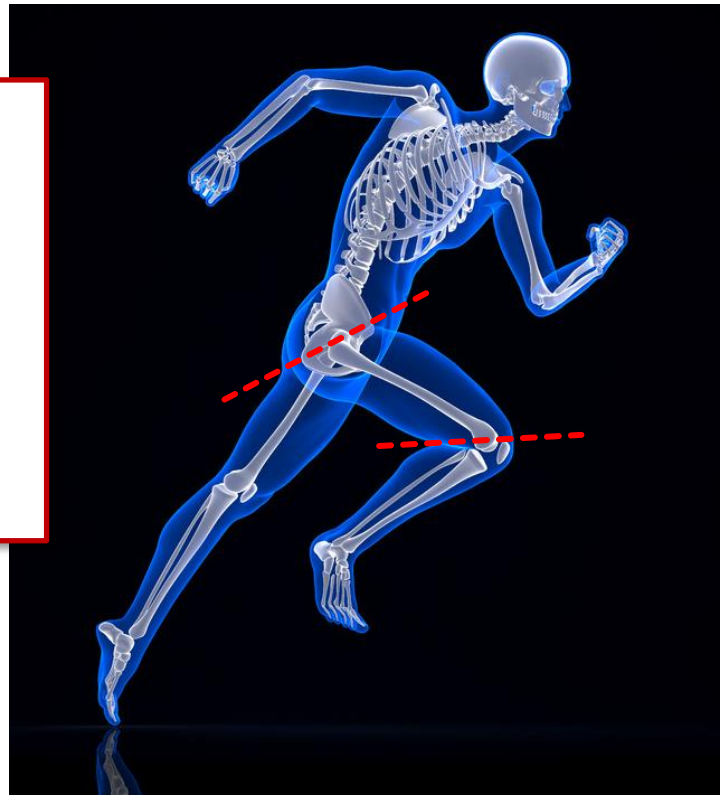
Thigh as a natura

structurally bona

operational criterion

physical properties

discontinuity & heterogeneity



Vogt *et al.* (2012): Fiat or Bona Fide Boundaries – A Matter of Granular Perspective. *PLoS ONE* 7(12): e48603

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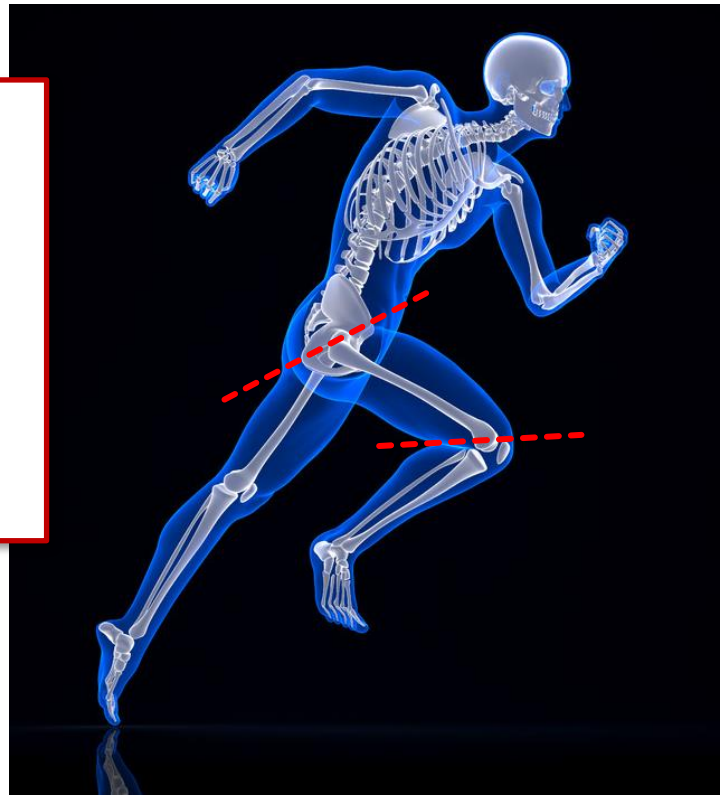

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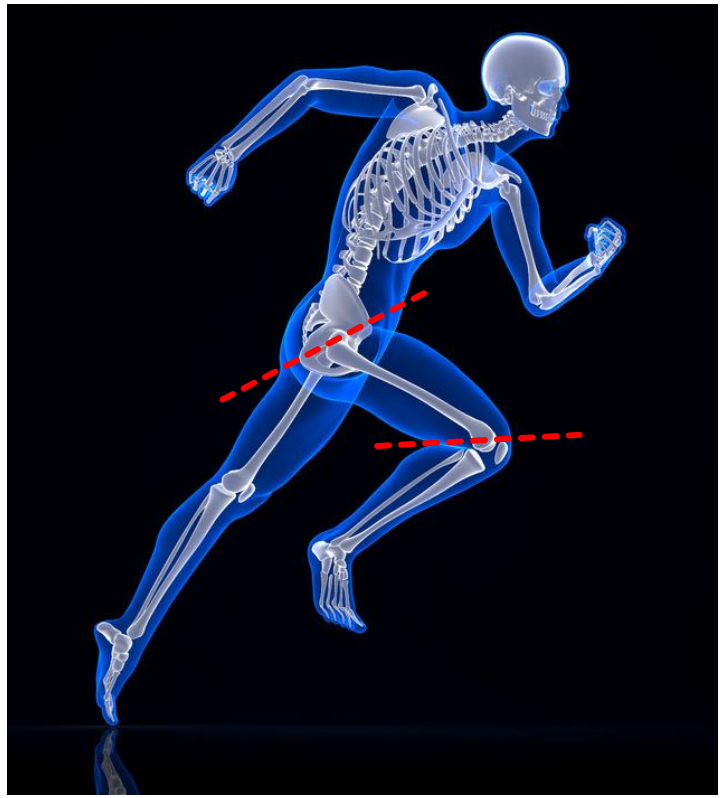
Examples for non-structural natural units from the life sciences

Example: Locomotion

Thigh as a natural unit

structurally: fiat object part



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Vogt *et al.* (2012): Fiat or Bona Fide Boundaries – A Matter of Granular Perspective. *PLoS ONE* 7(12): e48603

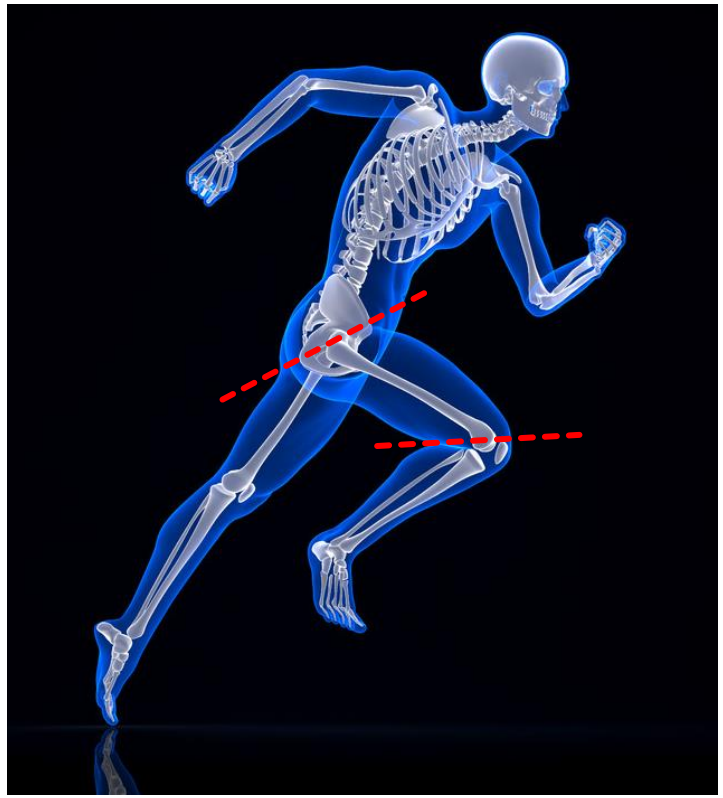
Examples for non-structural natural units from the life sciences

Example: Locomotion

Thigh as a natural unit

structurally: fiat object part

functionally natural unit?



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Vogt *et al.* (2012): Fiat or Bona Fide Boundaries – A Matter of Granular Perspective. *PLoS ONE* 7(12): e48603

Examples for non-structural natural units from the life sciences

Example: Locomotion

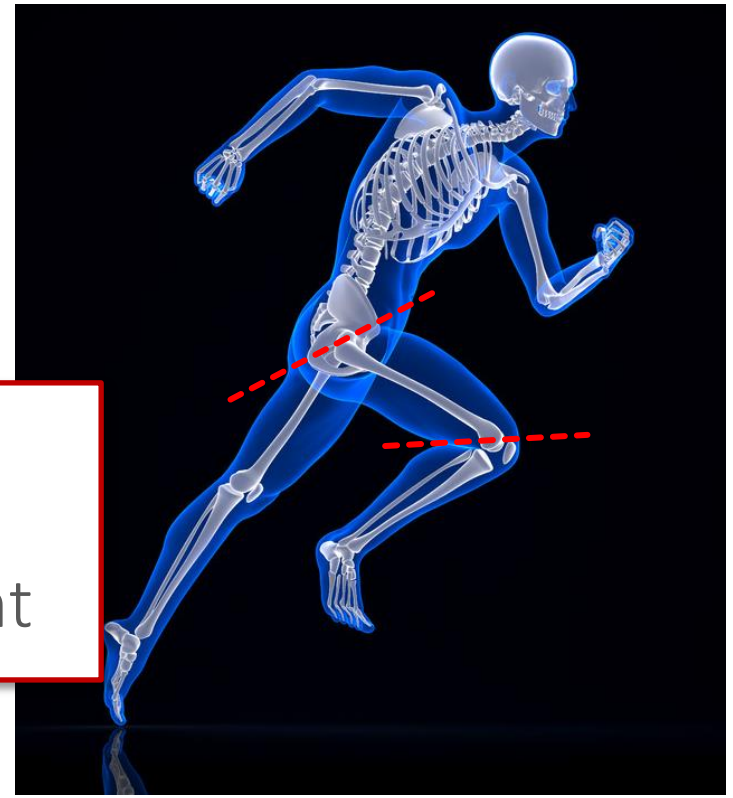
Thigh as a natural unit

structurally: fiat object part

functionally n

ontological criterion

natural = real, mind-independent



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Examples for non-structural natural units from the life sciences

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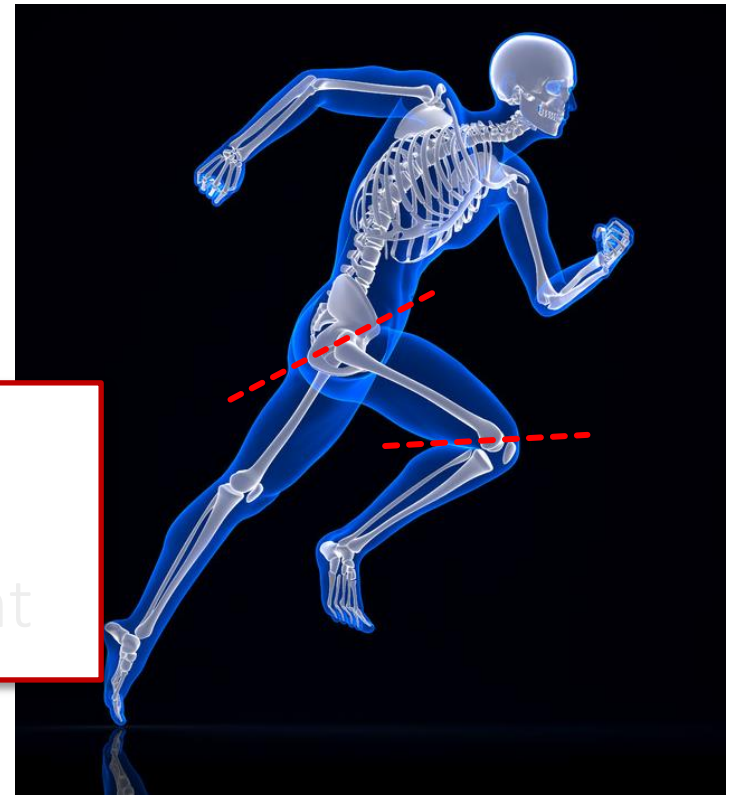

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Vogt *et al.* (2012): Fiat or Bona Fide Boundaries – A Matter of Granular Perspective. *PLoS ONE* 7(12): e48603

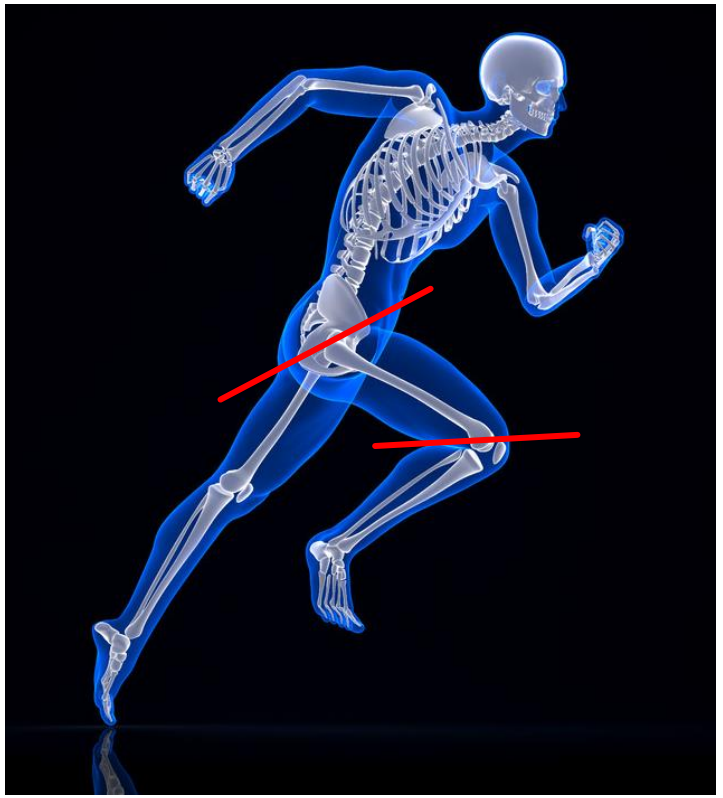
Examples for non-structural natural units from the life sciences

Example: Locomotion

Thigh as a natural unit

structurally: fiat object part

functionally: unit of locomotion



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Vogt *et al.* (2012): Fiat or Bona Fide Boundaries – A Matter of Granular Perspective. *PLoS ONE* 7(12): e48603

Examples for non-structural natural units from the life sciences

Example: Locomotion

Thigh as a natural unit

structurally: fiat object part

functionally: unit of locomotion, with

structurally bona fide landmarks

https://www.slon.pics/product/running-skeleton-contains-clipping-path

Vogt *et al.* (2012): Fiat or Bona Fide Boundaries – A Matter of Granular Perspective. *PLoS ONE* 7(12): e48603

Examples for non-structural natural units from the life sciences

Examples for bona fide entities and suggestions for corresponding operational criteria

Physical Objects	*structural biology*	**Structure**
Units of Locomotion	*functional biology*	**Function**
Units of Physiology		
Units of Ecology		
Units of Development		
Units of Reproduction and Propagation		

Vogt *et al.* (2012): Fiat or Bona Fide Boundaries – A Matter of Granular Perspective. *PLoS ONE* 7(12): e48603

Examples for non-structural natural units from the life sciences

Examples for bona fide entities and suggestions for corresponding operational criteria

Physical Objects	*structural biology*	**Structure**
Units of Locomotion Units of Physiology Units of Ecology Units of Development Units of Reproduction and Pro	*functional biology*	**Function**

operational criterion

‘universal causality’

bona fide landmarks & dispositions

Vogt *et al.* (2012): Fiat or Bona Fide Boundaries – A Matter of Granular Perspective. *PLoS ONE* 7(12): e48603

Examples for non-structural natural units from the life sciences

Examples for bona fide entities and suggestions for corresponding operational criteria

Physical Objects	*structural biology*	**Structure**
Units of Locomotion Units of Physiology Units of Ecology Units of Development Units of Reproduction and Propagation	*functional biology*	**Function**
Developmental Lineages Genealogical Lineages Evolutionary Lineages	*evolutionary biology*	**Common Origin**

Vogt *et al.* (2012): Fiat or Bona Fide Boundaries – A Matter of Granular Perspective. *PLoS ONE* 7(12): e48603

Examples for non-structural natural units from the life sciences

Examples for bona fide entities and suggestions for corresponding operational criteria

Physical Objects		
Units of Locomotion Units of Physiology Units of Ecology Units of Development Units of Reproduction and Pro		
Developmental Lineages Genealogical Lineages Evolutionary Lineages	*evolutionary biology*	**Common Origin**

operational criterion

'particular causality'

retrospective & historical

Vogt *et al.* (2012): Fiat or Bona Fide Boundaries – A Matter of Granular Perspective. *PLoS ONE* 7(12): e48603

Characterizing Natural Units in Reference to Causal Unity

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Characterizing natural units in reference to causal unity

A new attempt on characterizing (bona fide) objects

New approach

Objects are material entities that exist independent of human partition activities as causally relatively isolated entities that are both structured through and maximal relative to a certain type of causal unity.

Smith *et al.* (2015): Basic Formal Ontology 2.0. https://github.com/BFO-ontology/BFO/blob/master/docs/bfo2-reference/BFO2-Reference.pdf

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Characterizing natural units in reference to causal unity

A new attempt on characterizing (bona fide) objects

New approa

Objects are

activities as

through an

an partition

structured

ty.

The mathematical notion of a boundary is pertained, but the distinction between bona fide and fiat boundaries is dropped – all boundaries are considered to be fiat.

Smith *et al.* (2015): Basic Formal Ontology 2.0. https://github.com/BFO-ontology/BFO/blob/master/docs/bfo2-reference/BFO2-Reference.pdf

Characterizing natural units in reference to causal unity

3 types of causal unity

1) Causal unity via internal physical forces

e.g., covalent bonds, ionic bonds, fundamental forces of strong and weak interaction, etc
Objects: atoms, molecules, portions of solid matter, etc.

Smith *et al.* (2015): Basic Formal Ontology 2.0. https://github.com/BFO-ontology/BFO/blob/master/docs/bfo2-reference/BFO2-Reference.pdf

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2) Causal unity via physical covering

covering must serve as a barrier between inside and outside – e.g., a membrane
Objects: organelles, cells, tissues, organs

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2) Causal unity via pl

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Objects: organelles, cells, t

related to operational criterion

of bona fide boundaries

(physical properties of

discontinuity & heterogeneity)

Smith *et al.* (2015): Basic Formal Ontology 2.0. https://github.com/BFO-ontology/BFO/blob/master/docs/bfo2-reference/BFO2-Reference.pdf

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covering must serve as a barrier between inside and outside – e.g., a membrane
Objects: organelles, cells, tissues, organs

3) Causal unity via engineered assembly of components

parts are causally unified through screws, glues, etc.
Objects: cars, ballpoint pens, houses, etc.

Smith *et al.* (2015): Basic Formal Ontology 2.0. https://github.com/BFO-ontology/BFO/blob/master/docs/bfo2-reference/BFO2-Reference.pdf

Characterizing natural units in reference to causal unity

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e.g., covalent bonds, ion

Objects: atoms, molecul

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Objects: organelles, cells, tissues, organs

3) Causal unity via engineered assembly of components

parts are causally unified through screws, glues, etc.

Objects: cars, ballpoint pens, houses, etc.

2) and 3) existentially depend and thus

supervene on causal unity via physical forces

Vogt (2019): Bona fideness of material entities and their boundaries. **In** Davies (Ed.), *Natural and artifactual objects in contemporary metaphysics: exercises in analytical ontology* (pp. 103–120). Bloomsbury Academic.

Smith *et al.* (2015): Basic Formal Ontology 2.0. https://github.com/BFO-ontology/BFO/blob/master/docs/bfo2-reference/BFO2-Reference.pdf

Characterizing natural units in reference to causal unity

3 types of causal unity

1) Causal

e.g., covo ... *etc*

Objects: a

2) Causal

covering

Objects:

3) Causal

parts are

Objects: cars, ballpoint pens, houses, etc.

All three are associated with the

spatio-structural frame of reference, which

considers reality at a particular point in time,

filtering out its dynamic aspects.

Vogt (2019): Bona fideness of material entities and their boundaries. **In** Davies (Ed.), *Natural and artifactual objects in contemporary metaphysics: exercises in analytical ontology* (pp. 103–120). Bloomsbury Academic.

Smith *et al.* (2015): Basic Formal Ontology 2.0. https://github.com/BFO-ontology/BFO/blob/master/docs/bfo2-reference/BFO2-Reference.pdf

Characterizing natural units in reference to causal unity

3 types of causal unity

1) Causal

e.g., covo

Objects: a

2) Causal

covering

Objects:

3) Causal

parts are

Objects: cars, ballpoint pens, houses, etc.

All three are associated with th

spatio-structural frame of reference,

considers reality at a particular point

filtering out its dynamic aspects.

synchronic

What is given

Vogt (2019): Bona fideness of material entities and their boundaries. **In** Davies (Ed.), *Natural and artifactual objects in contemporary metaphysics: exercises in analytical ontology* (pp. 103–120). Bloomsbury Academic.

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Characterizing natural units in reference to causal unity

3 types of causal unity

1) Causal unity via internal physical forces

e.g., covalent bo

Objects: atoms, r

2) Causal unit

covering must se

Objects: organell

3) Causal unity via engineered assembly of components

parts are causally unified through screws, glues, etc.

Objects: cars, ballpoint pens, houses, etc.

This list of causal unities does not cover all types of natural units identified in the life sciences.

Vogt (2019): Bona fideness of material entities and their boundaries. **In** Davies (Ed.), *Natural and artifactual objects in contemporary metaphysics: exercises in analytical ontology* (pp. 103–120). Bloomsbury Academic.

Smith *et al.* (2015): Basic Formal Ontology 2.0. https://github.com/BFO-ontology/BFO/blob/master/docs/bfo2-reference/BFO2-Reference.pdf

Characterizing natural units in reference to causal unity

3 types of causal unity

Bicellular eyes form functional sensory units and exist as such independent of any human partitioning activity.

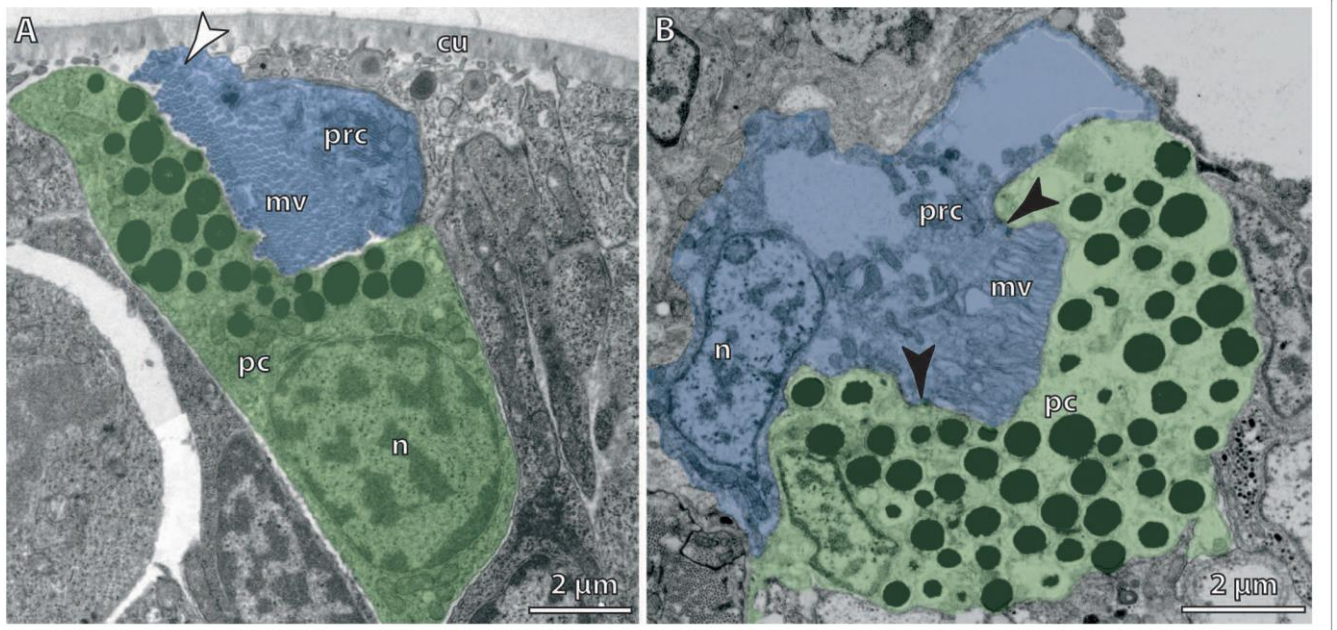


Figure 7 Bicellular eyes (ocelli). Receptor cells are labelled blue and supportive cells are labelled green. **A.** Larval eye in a trochophore of *Platynereis dumerilii* (Annelida). Eye cavity communicates with exterior via a small pore (arrowhead). [TEM micrograph. Manually labelled.] **B.** Adult eye of *Protodrilus oculifer* (Annelida) composed of two cells. Arrowheads point to junctional complexes sealing the extracellular cavity formed by the photoreceptor cell and the pigment cell. [TEM micrograph. Manually labelled.] Abbreviations: cu = cuticle; mv = microvilli; n = nucleus; pc = pigment cell; prc = photoreceptor cell. Originals: G. Purschke.

Vogt (2019): Bona fideness of material entities and their boundaries. **In** Davies (Ed.), *Natural and artifactual objects in contemporary metaphysics: exercises in analytical ontology* (pp. 103–120). Bloomsbury Academic.

Richter *et al.* (2010): Invertebrate neurophylogeny: suggested terms and definitions for a neuroanatomical glossary. *Frontiers in Zoology* **7**, 29. s

Characterizing natural units in reference to causal unity

Additional types of causal unity

Causal unity via bearing a specific function

unifies an entity through the function that the entity bears, with its functional component parts bearing sub-functions.

Vogt (2019): Bona fideness of material entities and their boundaries. **In** Davies (Ed.), *Natural and artifactual objects in contemporary metaphysics: exercises in analytical ontology* (pp. 103–120). Bloomsbury Academic.

Characterizing natural units in reference to causal unity

Additional types of causal unity

Causal un

unifies an

functiona

Functional units may lack physical connectedness, but they do exhibit functional connectedness.

s, with its

Vogt (2019): Bona fideness of material entities and their boundaries. **In** Davies (Ed.), *Natural and artifactual objects in contemporary metaphysics: exercises in analytical ontology* (pp. 103–120). Bloomsbury Academic.

Characterizing natural units in reference to causal unity

Additional types of causal unity

Causal un

unifies an **rs**, with its

functiona

Causal unity via bearing a specific function is associated with the functional frame of reference.

Vogt (2019): Bona fideness of material entities and their boundaries. **In** Davies (Ed.), *Natural and artifactual objects in contemporary metaphysics: exercises in analytical ontology* (pp. 103–120). Bloomsbury Academic.

Characterizing natural units in reference to causal unity

Additional types of causal unity

Causal un

unifies an

functiona

Causal unity via bearing a specific fu

associated with the

functional frame of reference.

dynamic, predictive

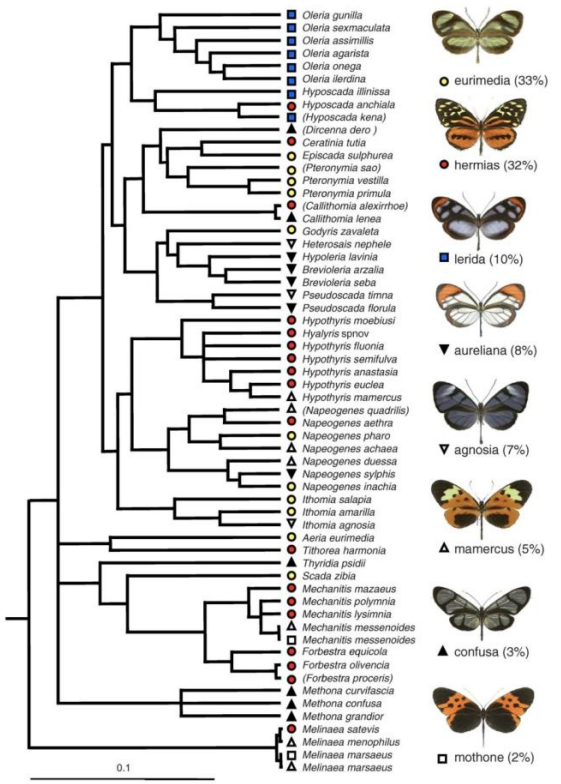
What can happen

Vogt (2019): Bona fideness of material entities and their boundaries. **In** Davies (Ed.), *Natural and artifactual objects in contemporary metaphysics: exercises in analytical ontology* (pp. 103–120). Bloomsbury Academic.

Characterizing natural units in reference to causal unity

Additional types of causal unity

All species of the genus *Oleria* share a common origin. They form an evolutionary unit that exists as such independent of any human partitioning activity.



Vogt (2019): Bona fideness of material entities and their boundaries. **In** Davies (Ed.), *Natural and artifactual objects in contemporary metaphysics: exercises in analytical ontology* (pp. 103–120). Bloomsbury Academic.

Elias *et al.* (2008): Mutualistic interactions drive ecological niche convergence in a diverse butterfly community. *PLoS Biology* **6**(12):e300.

Characterizing natural units in reference to causal unity

Additional types of causal unity

Causal unity via common historical/evolutionary origin

unifies an entity through the common historical/evolutionary origin of the entity's component parts. Historical/evolutionary units are demarcated so that all their component parts share the same historical/evolutionary origin, with no material entity not belonging to it sharing the same origin.

Vogt (2019): Bona fideness of material entities and their boundaries. **In** Davies (Ed.), *Natural and artifactual objects in contemporary metaphysics: exercises in analytical ontology* (pp. 103–120). Bloomsbury Academic.

Characterizing natural units in reference to causal unity

Additional types of causal unity

Causal unity via common historical/evolutionary origin

unifies an … nary origin of the entity … ts are demarcat… ame historical/… belonging to it sharing the same origin.

Historical/evolutionary units may lack physical connectedness, but they do exhibit historical/evolutionary connectedness.

Vogt (2019): Bona fideness of material entities and their boundaries. **In** Davies (Ed.), *Natural and artifactual objects in contemporary metaphysics: exercises in analytical ontology* (pp. 103–120). Bloomsbury Academic.

Characterizing natural units in reference to causal unity

Additional types of causal unity

Causal unity via common historical/evolutionary origin

unifies an … nary origin of the entity … ts are demarcat… ame historical/… belonging to it sharing the same origin.

Causal unity via common historical and evolutionary origin is associated with the historical/evolutionary frame of reference.

Vogt (2019): Bona fideness of material entities and their boundaries. **In** Davies (Ed.), *Natural and artifactual objects in contemporary metaphysics: exercises in analytical ontology* (pp. 103–120). Bloomsbury Academic.

Characterizing natural units in reference to causal unity

Additional types of causal unity

Causal unity via common historical/evolutionary origin

unifies an

the entity

demarcat

historical/

Causal unity via common historic

evolutionary origin is associated v

historical/evolutionary frame of reference.

dynamic, retrodictive

What has happend

ame

belonging to it

sharing the same origin.

Vogt (2019): Bona fideness of material entities and their boundaries. **In** Davies (Ed.), *Natural and artifactual objects in contemporary metaphysics: exercises in analytical ontology* (pp. 103–120). Bloomsbury Academic.

Conclusion

Boundaries and Natural Units

Conclusion

Natural Units

Natural units can be ontologically characterized in reference to different types of causal unity.

Vogt (2019): Bona fideness of material entities and their boundaries. **In** Davies (Ed.), *Natural and artifactual objects in contemporary metaphysics: exercises in analytical ontology* (pp. 103–120). Bloomsbury Academic.

Boundaries and Natural Units

Conclusion

Natural Units

Based on the different types of causal unity, we can distinguish at least three basic categories of natural units:

Physical, functional, and historical/evolutionary units.

Vogt (2019): Bona fideness of material entities and their boundaries. **In** Davies (Ed.), *Natural and artifactual objects in contemporary metaphysics: exercises in analytical ontology* (pp. 103–120). Bloomsbury Academic.

Boundaries and Natural Units

Conclusion

Natural Units

Each basic category of natural unit is associated with a corresponding frame of reference.

Vogt (2019): Bona fideness of material entities and their boundaries. **In** Davies (Ed.), *Natural and artifactual objects in contemporary metaphysics: exercises in analytical ontology* (pp. 103–120). Bloomsbury Academic.

Boundaries and Natural Units

Conclusion

Boundaries

Boundaries remain to be important, also because they are relevant in practical research: to partition an entity into its parts, a researcher needs a diagnostic framework that provides operational criteria for identifying instances of natural units.

Vogt (2019): Bona fideness of material entities and their boundaries. **In** Davies (Ed.), *Natural and artifactual objects in contemporary metaphysics: exercises in analytical ontology* (pp. 103–120). Bloomsbury Academic.

Characterizing bona fide objects in reference to causal unity

A new attempt on characterizing (bona fide) objects

In the end, it often depends on identifying some interior physical discontinuity or qualitative heterogeneity among the parts of the object as weak criteria that must be complemented with other criteria and decided on a case-by-case basis.

Vogt (2019): Bona fideness of material entities and their boundaries. **In** Davies (Ed.), *Natural and artifactual objects in contemporary metaphysics: exercises in analytical ontology* (pp. 103–120). Bloomsbury Academic.

15 - 20 min

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Boundaries and Natural Units

Lars Vogt

Thank you for your attention!

Roland Arhelger (1988) Berlin Wall, Niederkirchnerstraße. (WikiMedia Commons)

Relations Across Causal Unit Types:

Building Blocks and a General Domain Granularity Scheme

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Building Blocks and a General Domain Granularity Scheme

Building Blocks

Building Blocks

- are maximal relative to all three basic causal unity types;
- possess a physical covering and are thus physical objects;
- are self-organizing and self-maintaining functional units;
- originate from (cosmic) evolution as evolutionary units;
- coarser level building blocks existentially depend on finer level building blocks and form granularity trees.

Vogt (2019) Levels and building blocks—toward a domain granularity framework for the life sciences. *Journal of Biomedical Semantics* 2019(10): 1–29

Building Blocks and a General Domain Granularity Scheme

Building Blocks and their interfaces

Physical covering takes the role of an interface for a building block.

Jagers Op Akkerhuis (2001) Extrapolating a hierarchy of building block systems towards future neural network organisms. *Acta Biotheoretica* **49**: 171–190.

Jagers Op Akkerhuis & van Straalen (1998) Operators, the Lego-bricks of nature, evolutionary transitions from fermions to neural networks. *World Futures* **53**: 329–345.

Vogt (2019) Levels and building blocks—toward a domain granularity framework for the life sciences. *Journal of Biomedical Semantics* **2019**(10): 1–29

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Interfaces are surfaces for interacting with the environment.

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Building Blocks and a General Domain Granularity Scheme

Building Blocks and their interfaces

Physical covering takes the role of an interface for a building block.

Interfaces are surfaces for interacting with the environment.

Interfaces are barriers that separate the internal milieu from the environment.

Jagers Op Akkerhuis (2001) Extrapolating a hierarchy of building block systems towards future neural network organisms. *Acta Biotheoretica* **49**: 171–190.

Jagers Op Akkerhuis & van Straalen (1998) Operators, the Lego-bricks of nature, evolutionary transitions from fermions to neural networks. *World Futures* **53**: 329–345.

Vogt (2019) Levels and building blocks—toward a domain granularity framework for the life sciences. *Journal of Biomedical Semantics* **2019**(10): 1–29

Building Blocks and a General Domain Granularity Scheme

3 types of interfaces

1) Electron Cloud

Atom
Molecule – *atoms sharing an electron cloud*

2) Bio-Membrane

organelle, prokaryote
eukaryote cell – *bio-membrane in bio-membrane*

3) Epithelium

epithelially delimited compartments
multicellular organism with epidermis

Vogt (2019) Levels and building blocks—toward a domain granularity framework for the life sciences. *Journal of Biomedical Semantics* **2019**(10): 1–29

Building Blocks and a General Domain Granularity Scheme

Building Block Granularity Perspective

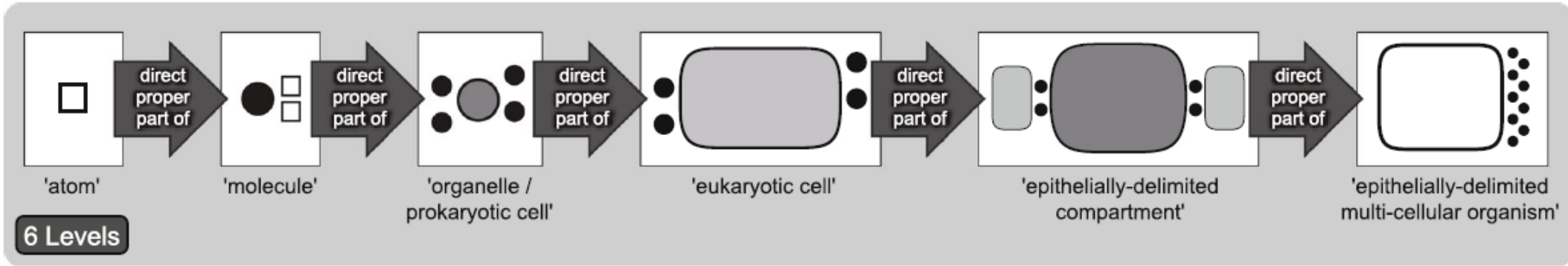

Fig. 4 Compositional Building Block (CBB) Granular Perspective. The different building blocks are granulated according to the direct proper parthood granulation relation (the large dark arrows). The granulation is of the non-scale dependent single-relation-type granularity type (*nrG* [61]), and uses the combination of the granulation relation together with the common properties of all categories of the building block type as its granulation criterion. Due to the cumulative constitutive organization, finer-level building block entities can be considered to be parts associated with coarser-level building block entities, for instance, ECM being an associated part of a eukaryotic cell

Vogt (2019) Levels and building blocks—toward a domain granularity framework for the life sciences. *Journal of Biomedical Semantics* **2019**(10): 1–29

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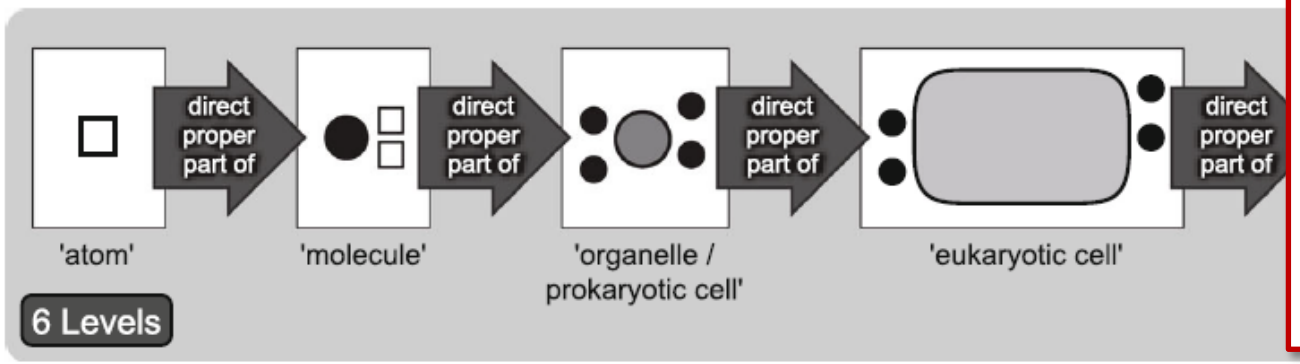
Building Blocks and a General Domain Granularity Scheme

Building Block Granularity Perspective



bona fide

granularity perspective

Fig. 4 Compositional Building Block (CBB) Granular Perspective. The different building blocks are granulated according to the direct proper parthood granulation relation (the large dark arrows). The granulation is of the non-scale dependent single-relation-type granularity type (*nrG* [61]), and uses the combination of the granulation relation together with the common properties of all categories of the building block type as its granulation criterion. Due to the cumulative constitutive organization, finer-level building block entities can be considered to be parts associated with coarser-level building block entities, for instance, ECM being an associated part of a eukaryotic cell

Vogt (2019) Levels and building blocks—toward a domain granularity framework for the life sciences. *Journal of Biomedical Semantics* **2019**(10): 1–29

Building Blocks and a General Domain Granularity Scheme

Domain Granularity Scheme

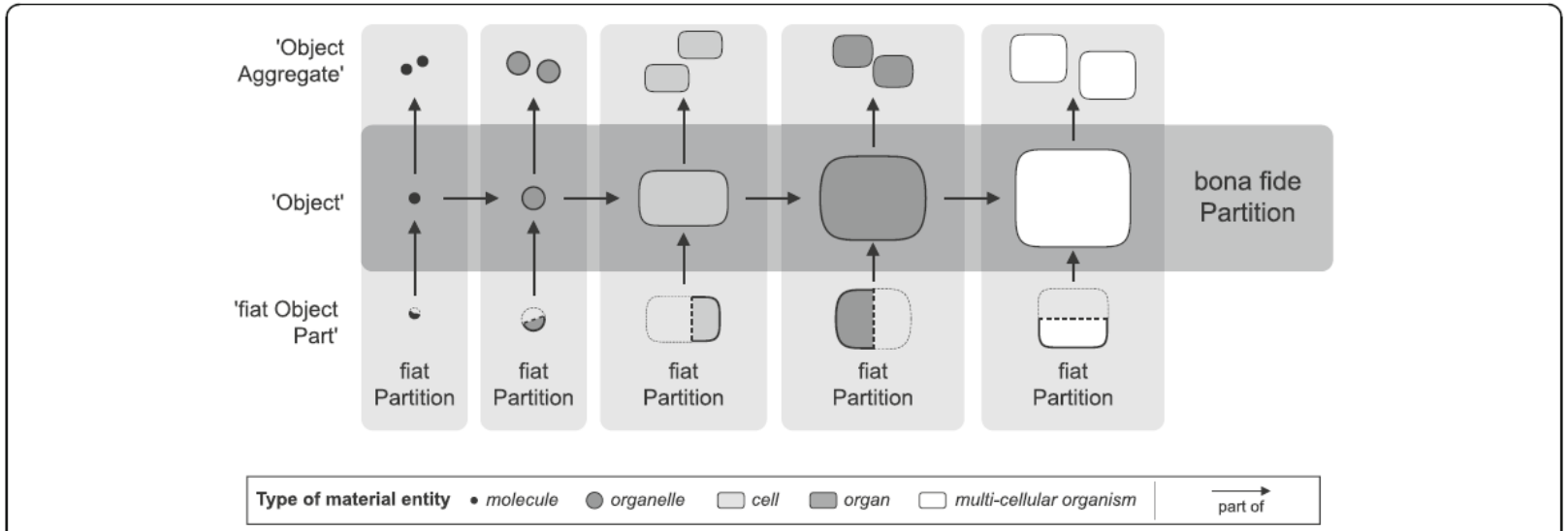


Fig. 3 BFO's Basic Granularity Framework. A bona fide partition from a multi-cellular organism to a molecule represents the center of BFO's granularity framework and reflects direct subclasses of BFO's 'object' for the biological domain. According to BFO, each level of the corresponding bona fide granularity tree must be modeled by its own domain reference ontology (i.e., a molecule ontology, a cell ontology, etc.). Within each such level-specific ontology, BFO's top-level distinction of 'object', 'fiat object part', and 'object aggregate' indicates a basic fiat partition that orthogonally crosses the bona fide partition. The bona fide partition can therefore be understood as an integrating cross-granular backbone for the different ontologies of a given domain together with their implicit fiat partitions

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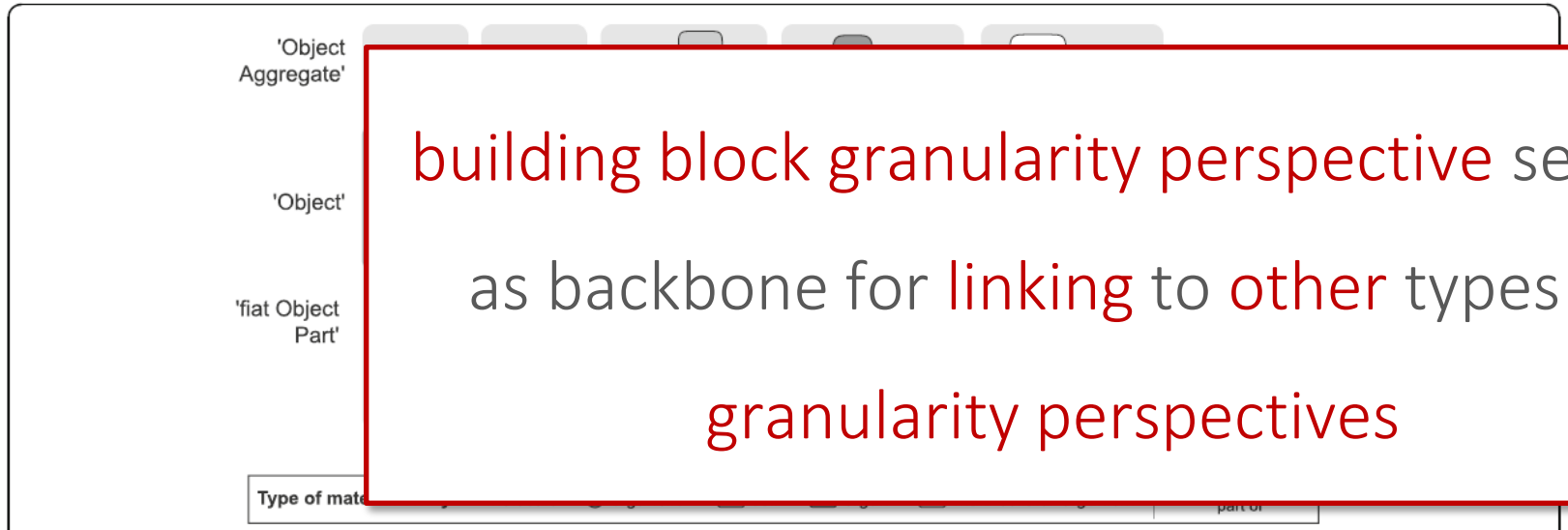

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building block granularity perspective serves as backbone for linking to other types of granularity perspectives

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Domain Granularity Scheme

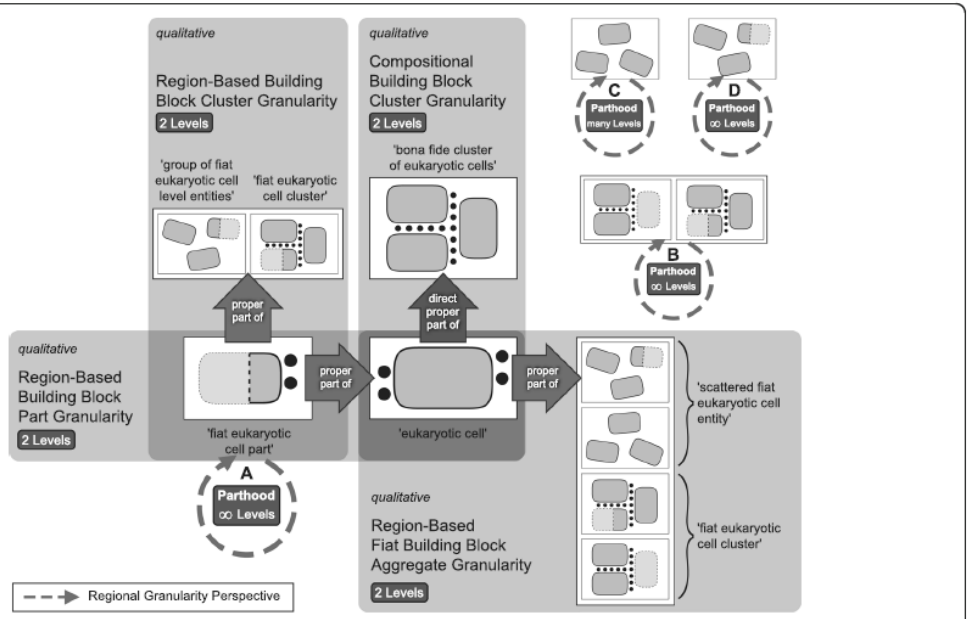

Fig. 5 Set of Granular Perspectives within a given spatio-structural Frame of Reference. The figure shows all qualitative granular perspectives that the domain granularity framework for the life sciences distinguishes for any given spatio-structural frame of reference and thus any corresponding CBB granularity level (here, the set of perspectives for the eukaryotic cell level as an example). The large dark arrows indicate the granulation relation and the white boxes contain the granulated entity types. **a** = Region-Based Fiat Building Block Part Granularity Perspective; **b** = Region-Based Fiat Building Block Cluster Granularity Perspective; **c** = Region-Based Group of Building Block Level Objects Granularity Perspective; **d** = Region-Based Group of Fiat Building Block Level Entities Granularity Perspective (see also Table 1)

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Building Blocks and a General Domain Granularity Scheme

Domain Granularity Scheme

- Provides a meta-layer that organizes and structures a knowledge graph;

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Building Blocks and a General Domain Granularity Scheme

Domain Granularity Scheme

- Provides a meta-layer that organizes and structures a knowledge graph;
- can be used for navigating and exploring knowledge graphs, providing semantically meaningful filters in the form of defined granularity perspectives;

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Building Blocks and a General Domain Granularity Scheme

Domain Granularity Scheme

- Provides a meta-layer that organizes and structures a knowledge graph;
- can be used for navigating and exploring knowledge graphs, providing semantically meaningful filters in the form of defined granularity perspectives;
- for evaluating similarity/identity between knowledge graphs.

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Characterizing bona fide objects in reference to causal unity

Additional types of causal unity

"A part is a component in a mechanism if one can change the behavior of the mechanism as a whole by intervening to change the component and one can change the behavior of the component by intervening to change the behavior of the mechanism as a whole."

(Craver 2007, p. 141)

Craver (2007): Explaining the Brain. *Oxford University Press*.