Interdisciplinary Ontology. Proceedings of the Third Interdisciplinary Ontology Meeting, Tokyo: Keio University Press, 2012, 1-13.

On Classifying Material Entities in Basic Formal Ontology

Barry Smith

Department of Philosophy and National Center for Ontological Research, University at Buffalo
126 Park Hall, Buffalo, NY 14260, USA
phismith@buffalo.edu
http://ontology.buffalo.edu/smith

ABSTRACT. Basic Formal Ontology (BFO) was created in 2002 as an upper-level ontology to support the creation of consistent lower-level ontologies, initially in the subdomains of biomedical research, now also in other areas, including defense and security. BFO is currently undergoing revisions in preparation for the release of BFO version 2.0. We summarize some of the proposed revisions in what follows, focusing on BFO's treatment of material entities, and specifically of the category *object*.

1 Introduction

BFO is one of three leading public domain upper-level ontologies used in scientific and other contexts,[1] alongside DOLCE (the Domain Ontology for Linguistic and Cognitive Engineering) [Gangemi et al. 2002] and SUMO (the Suggested Upper Merged Ontology) [Niles and Pease 2001]. BFO differs from the latter, however, in being a strict upper level ontology. Unlike DOLCE and SUMO, it does not contain its own representations of physical, chemical, biological, psychological, or other types of entities which would properly fall within the domains of the special sciences. BFO is therefore, in contrast to these other ontologies, very small, and thus more manageable as an artifact designed for purposes of ontological engineering. As will become clear, however, even a small ontology can bring large challenges from a logico-metaphysical point of view.

BFO is concerned only with what exists (which means in practice: only with those sorts of entities for which we have good – for example empirical-scientific reason to believe that they exist; thus not with unicorns, sprites, or absent fingers). BFO then adopts an approach to ontology which sees what exists as being divided along three orthogonal dimensions.

First, BFO recognizes a dichotomy between *occurrents* and *continuants*. The former are either processual entities (events, actions, procedures ...) which unfold over a

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[1] The BFO website at http://www.ifomis.org/bfo/ contains a list of some 98 projects and research groups using BFO as a top-level ontology to support semantic interoperability.

span of time from their beginning to their ending, or they are the beginnings and endings themselves (their process boundaries) or the spans of time (and of spacetime) which such entities occupy. The latter are the participants in such processes, entities that endure during the period of their existence, and the spatial boundaries of such entities, as well as the spatial regions in which they are located.

Second, BFO recognizes a dichotomy between *independent* and *dependent* entities. Cells and organs are independent continuants; a quality of a cell (for example: its mass or volume) is a dependent continuant – this mass and this volume are dependent on the cell in the sense that, should the latter cease to exist, then so also would the former.

Third, BFO rests on a distinction between *instances* (individuals, tokens, particulars) and *universals* (generals, types, kinds). It furnishes formal specifications for the high-level formal universals (called 'categories' in what follows) which can be defined in terms of these three dichotomies, and also of a set of relations which link them [Smith et al. 2005]. The terms in BFO and in the domain ontologies based on BFO consist of preferred labels representing what is general in reality. Universals are most clearly illustrated by considering the general terms – such as 'electron' or 'cell' – employed by scientific theories in the formulation of general truths [Smith and Ceusters 2010]. However, universals include also the general entities referred to by general terms employed in domains such as engineering, commerce, administration and intelligence analysis. BFO was designed to work with entities within the province of the natural sciences, especially biology, its coverage domain embraces also social and psychological entities such as military units and counterinsurgency operations, mortgage contracts and relations of ownership, poems and experimental protocols.

We use 'universal' and 'type' in what follows as synonyms. Universals exist at various levels of generality, starting at the most general and domain-neutral level treated of by BFO, and proceeding from there to less general universals such as *person*, *vehicle*, *disease*, and so forth.

2 Continuant

A *continuant* is an entity that persists, endures, or continues to exist through time while maintaining its identity. Continuants can preserve their identity even while gaining and losing material parts. If *a* is a *continuant*, then there is some temporal interval (referred to below as a *one-dimensional temporal region*) during which *a* exists.

Continuants are contrasted with occurrents, which unfold themselves in successive temporal phases. Continuants have only continuants as parts, just as occurrents have only occurrents as parts. Continuants, as BFO understands them, are three-dimensional entities (entities extended in three spatial dimensions); occurrents are four-dimensional entities (entities extended also in the dimension of time).

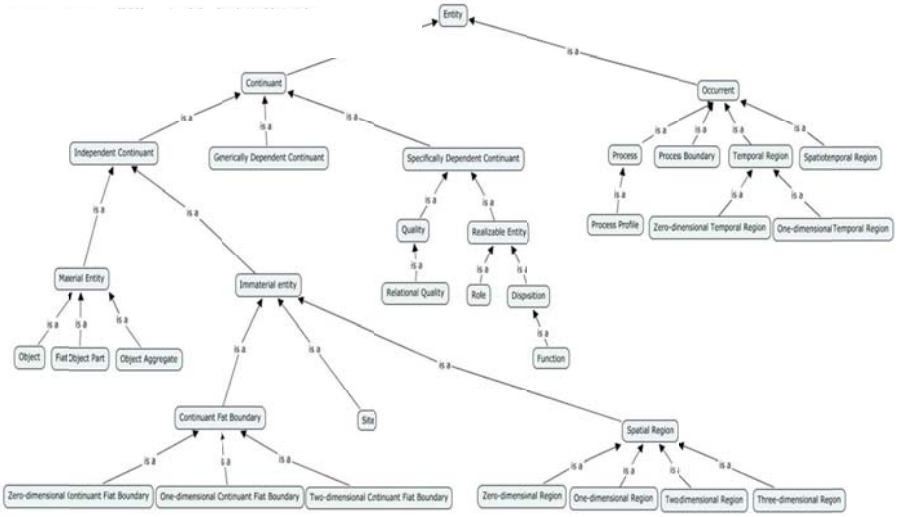

Fig. 1. BFO 2.0 *is_a* Hierarchy

In embracing the dichotomy between continuant and occurrent ontologies as the central organizing axis of the BFO ontology we follow Zemach, who distinguishes between

– non-continuant entities (NCs), which Zemach calls 'events', and which are defined by the fact that they can be sliced along any spatial and temporal dimensions to yield parts (for example the first year of the life of your table; the entire life of your table top – as contrasted with the life of your table legs – and so forth).

and

– continuant entities which can be sliced to yield parts only along the spatial dimension, yielding for example the parts of your table which we call its legs, its top, its nails. 'My desk stretches from the window to the door. It has spatial parts, and can be sliced (in space) in two. With respect to time, however, a thing is a continuant.' [Zemach 1970]

Thus you, for example, are a continuant, and your arms and legs are parts of you; your childhood, however, is not a part of you; rather, it is a part of your life. Continuants, as matter of definition, are entities which have no parts along the time axis; in this sense continuants are extended only along the three spatial dimensions, not however along the temporal dimension.

Continuants can preserve their identity even while gaining and losing material parts. Each continuant is such that all its parts are continuants, and also such that there is some temporal interval, however short, during which it exists.

3 Material entity

The most important sub-category of continuants, for BFO, is that of material entities, which are continuants that include some portion of matter as part, where 'portion of matter' is understood in the broadest possible sense to include also undetached portions of matter such as your head and scattered portions of matter such as the Buffalo Symphony Orchestra. Every material entity is localized in space. Every material entity can move in space. Every entity which has a material entity as part is a material entity.

A portion of matter is anything that includes elementary particles among its proper or improper parts: quarks and leptons, including electrons, as the smallest particles thus far discovered; baryons (including protons and neutrons) at a higher level of granularity; atoms and molecules at still higher levels, forming the cells, organs, organisms and other material entities studied by biologists, the portions of rock studied by geologists, the fossils studied by paleontologists, and so on.

BFO allows material entities to have immaterial entities as parts; for example the interior (or 'lumen') of your small intestine is a part of your body, your left nasal cavity is a part of your nose, the interior of the railway carriage is a part of the train.

In what follows we define three children of 'material entity' – namely 'object', 'object aggregate'; and 'fiat object part'. This is intended not as an exhaustive classification of material entities, but rather as a selection of three subtypes of particular importance in many areas of natural and social science.

4 Object

4.1 Natural and engineered units of matter

BFO rests on the presupposition that at multiple micro-, meso- and macroscopic scales reality exhibits certain stable, spatially separated or separable material units, combined, or combinable, into aggregates of various sorts (for example organisms into what are called 'populations'). Such units play a central role in almost all domains of natural science from particle physics to cosmology. Many scientific laws govern the units in question, employing general terms (such as 'molecule' or 'planet') referring to the types and subtypes of units, and also to the types and subtypes of the processes through which such units develop and interact. The division of reality into such *natural units* is at the heart of biological science. So too is the fact these units may form higher-level units (as cells form multicellular organisms) and that they may also form *aggregates* of units, for example, as cells form portions of tissue and organs form families, herds, breeds, species, and so on.

At the same time, the division of certain portions of reality into *engineered units* (manufactured artifacts) is the basis of modern industrial technology, which rests on the distributed mass production of engineered parts through division of labor and on their

assembly into larger, compound units such as cars and laptops. The division of portions of reality into units is one starting point for the phenomenon of *counting*.

Examples of units of special importance for the purposes of natural science include: atom, molecule, organelle, cell, organism, grain of sand, planet, star. These *material entities* are candidate examples of what are called 'objects' in BFO 2.0. Such units are sometimes referred to as 'grains' [Jansen and Schulz 2011], and are associated with specific 'levels of granularity' in what is seen as a layered structure of reality, with units at lower and more fine-grained levels being combined as parts into grains at higher, coarse-grained levels. Our proposals here are consistent with, but are formulated independently of such granularity considerations.

4.2 Three focal examples

The following elucidation documents a set of conditions to be used when deciding whether entities of a given type should be represented as *objects* in the BFO sense. It rests on three candidate groups of focal examples, namely:

1. organisms, cells and biological entities of certain other sorts, including organs
2. portions of solid matter such as rocks and lumps of iron
3. engineered artifacts such as watches and cars.

Material entities under all of these headings are all *causally relatively isolated entities* in Ingarden's sense [Ingarden 1970, Smith and Brogaard 2003]. This means that they are both *structured* through a certain type of causal unity and *maximal* relative to this type of causal unity.

We first characterize causal unity in general. We then distinguish three types of causal unity corresponding to the three candidate families of objects listed above (cells and organisms, solid portions of matter, machines and other engineered artifacts). We then describe what it is for an entity to be maximal relative to one or other of these types, and formulate in these terms an elucidation of what BFO means by 'object'.

> *a* is *causally unified* means: *a* is a material entity such that its material parts are tied together in such a way that, in environments typical for *entities* of the type in question,
>
> - if *b* is a part *a* in the interior of *a* at *t* that is larger than a certain threshold size (which will be determined differently from case to case, depending on factors such as porosity of external cover) and if *b* is moved in space to be at *t′* at a location on the exterior of the spatial region that had been occupied by *a* at *t*, then *either a*'s other parts will be moved in coordinated fashion *or a* will be damaged (be affected, for example, by breakage or tearing) in the interval between *t* and *t′*.
> - causal changes in one part of *a* can have consequences for other parts of *a* without the mediation of any entity that lies on the exterior of *a.*

Material entities with no proper material parts (some smallest microparticle) would satisfy these conditions trivially. Candidate examples of types of causal unity for material entities of more complex sorts are as follows (this is not intended to be an exhaustive list):

CU_1: Causal unity via physical covering

Here the parts in the interior of the unified entity are combined together causally through a common membrane or other physical covering – what the FMA refers to as a 'bona fide anatomical surface' [Rosse and Mejino 2007]. The latter points outwards toward and may serve a protective function in relation to what lies on the exterior of the entity.

Note that the physical covering may have holes (for example pores in your skin, shafts penetrating the planet's outer crust, sockets where conduits to other entities are connected allowing transport of electric current or of liquids or gases). The physical covering is nonetheless *connected* in the sense that (a) between every two points on its surface a continuous path can be traced which does not leave this surface, and also (b) the covering serves as a barrier preventing entities above a certain size threshold from entering from the outside or escaping from the inside.

Some organs in the interior of complex organisms manifest a causal unity of this type. Organs can survive detachment from their surroundings, for example in the case of transplant, with their membranes intact. The FMA defines 'organ' as follows:

> An anatomical structure which has as its direct parts portions of two or more types of tissue or two or more types of cardinal organ part which constitute a maximally connected anatomical structure demarcated predominantly by a bona fide anatomical surface. Examples: femur, biceps, liver, heart, skin, tracheobronchial tree, ovary. [Rosse and Mejino 2007]

CU_2: Causal unity via internal physical forces

Here the material parts of a material entity are combined together causally by sufficiently strong physical forces, for example, by fundamental forces of strong and weak interaction, by covalent or ionic bonds, by metallic bonding, or more generally by forces of a type which makes the overall sum of forces strong enough to act in such a way as to hold the object together relative to the strength of attractive or destructive forces in its ordinary environmental neighborhood. (Few solid portions of matter in our everyday environment would survive very long on the face of a neutron star, but luckily that is not our everyday environment.) In the case of larger portions of matter the constituent atoms are tightly bound to each other in a geometric lattice, either regularly (as in the case of portions of metal) or irregularly (as in an amorphous solid such as a portion of glass). Examples: *atoms, molecules, grains of sand, lumps of iron.*

CU_3: Causal unity via engineered assembly of components

Here the material parts of a material entity are combined together via mechanical assemblies joined for example through screws or other fasteners. The assemblies often

involve parts which are reciprocally engineered to fit together, as in the case of dovetail joints, balls and bearings, nuts and bolts. A causal unity of this sort can be interrupted for a time, as when a watch is disassembled for repair, and then recreated in its original state. The parts of an automobile, including the moving parts, constitute an object because of their relative rigidity: while these parts may move with respect to each other, a given gear cannot move e.g., 10 ft., while the other parts do not.

We can now elucidate what it means for a material entity to be *maximal* relative to one or other of these three types of causal unity as follows:

To say that *a* is *maximal* relative to some criterion of causal unity CU_n means:

> *a* is causally unified relative to CU_n at *t*
> & if (for some *t* and *b*, *a* is a part of *b* at *t* & *b* is causally unified relative to the same CU_n) then (*a* and *b* are identical)

Examples of maximality relative to the causal unity criterion CU_1 are: a cell or organism is maximal; your lower torso falls short of maximality; a pair of cells exceeds maximality; relative to CU_2: a continuous dumbbell-shaped lump of iron is maximal; the connecting portion falls short of maximality; a pair of such dumbbell-shaped lumps exceeds maximality; and relative to CU_3: an armored vehicle is maximal; the portions of armor of an armored vehicle falls short of maximality; a pair of armored vehicles exceeds maximality.

4.3 Objects can have other objects as parts

We cannot define 'object' in BFO simply by asserting that an entity is an object if and only if it is maximal relative to some causal unity criterion, however. This is because objects under all three of the identified headings may have other, smaller objects as parts. A spark plug is an object; when inserted into a car to replace a defective plug, it remains an object, but ceases to be maximal. Importantly, however, the spark plug as installed still instantiates a universal many instances of which are maximal. This suggests that we define object as follows:

> *a* is an *object* =Def. *a* is a *material entity* which
> manifests causal unity of one or other of the types CU_n listed above
> & is of a type instances of which are maximal relative to this criterion of causal unity.

Objects can be joined to other objects, not only through engineering but also in biology, as for example in Fig. 2.

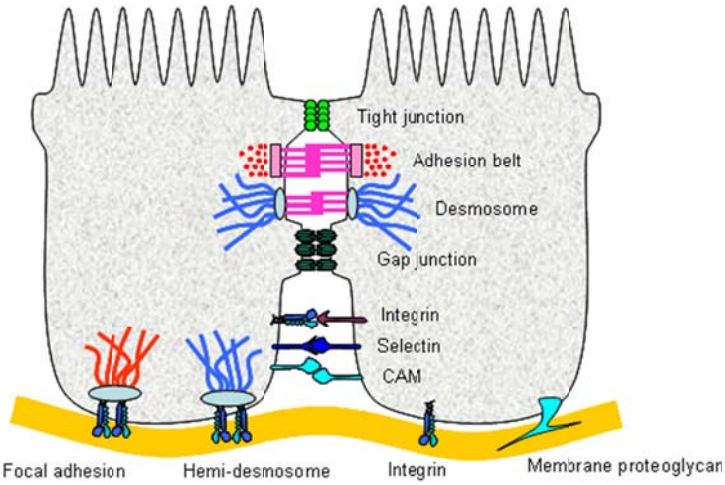

Fig. 2. An example of cell adhesion[2]

Each *object* is such that there are *entities* of which we can assert unproblematically that they lie in its interior, and other *entities* of which we can assert unproblematically that they lie in its exterior. This may not be so for *entities* lying at or near the boundary between the interior and exterior. This means that two objects – for example the two cells depicted in Fig. 2 – may be such that there are material entities crossing their boundaries which belong determinately to neither cell. Something similar obtains in certain cases of conjoined twins (see below).

Some instances of any given BFO:*object* universal – for example *cell* or *organism* or *laptop* – are separated by spatial gaps from other instances of this same *object* universal. The spatial gaps may be filled by a medium, for example of air or water. (There are cells not attached to other cells; there are spatially separated organisms, such as you and me. Peas in a pea pod are initially attached to the interior of the pea pod covering. Sperm initially float freely from each other; some sperm become fused with oocytes through a membrane fusion process.)

Objects may contain other objects as part, for example:

- by containing atoms and molecules as parts;
- by containing cells as parts, for instance the collection of blood cells in your body;
- by containing objects which are bonded to other objects of the same type in such a way that they cannot (for the relevant period of time) move separately, as in the case of the cells in your epithelium or the atoms in a molecule;

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[2] http://php.med.unsw.edu.au/cellbiology/index.php?title=File:Cell_adhesion_summary.png

- by containing objects which are connected by conduits or tracts which may themselves have covering membranes.

4.4 Conjoined twins

Some objects may change type from one time to the next (a fetus becomes a baby, which in turn becomes a child). Objects may also fuse or be separated. Two boats may be combined to form a single multihulled boat. Conjoined twins may be successfully separated.

Whether each one of a pair of conjoined twins is or is not an object is not a trivial question, and the treatment of this case ontologically should be viewed as an experimental matter, with different alternatives tested to see which yield the most coherent solution for different sorts of cases. Different types of conjoined twins will need to be treated differently, and in cases where twins do not share vital organs an identification of each one of the pair as an object will yield a workable solution. Certainly, the maximal CU_1-causally unified material entity here is the whole which they together form; accepting each twin as an object even prior to separation – thus as an instance of the material universal *human being* – is, however, consistent with our elucidation of BFO:*object*.

5 Object aggregate

An *object aggregate* is a *material entity* consisting exactly of a plurality of *objects* as continuant parts.

More formally:

> If *a* is an *object aggregate*, then if *a* exists at *t*, there are *objects* $o_1, \ldots, o_n$ at *t* such that:
> for all *x* (*x* part of *a* at *t* iff *x* overlaps some o_i at *t*)

An entity *a* is an object aggregate if and only if there is a mutually exhaustive and pairwise disjoint partition of *a* into objects [Bittner and Smith 2008]. Examples are: a symphony orchestra, the aggregate of bearings in a constant velocity axle joint, the nitrogen atoms in the atmosphere, a collection of cells in a blood biobank.

The objects which form the proximal parts of an aggregate – those parts which determine the aggregate as an aggregate – are called its member parts (sometimes referred to as 'granular parts').

Different sorts of examples will satisfy further conditions, for example an organization is an aggregate whose member parts have *roles* of specific types (for example in a jazz band, a chess club, a football team); a swarm of bees is an aggregate of members who are linked together through natural bonds.

Object aggregates may be defined through physical attachment (the aggregate of atoms in a lump of granite), or through physical containment (the aggregate of molecules

of carbon dioxide in a sealed container, the aggregate of blood cells in your body). Object aggregates may be defined by fiat – for example in the case of the aggregate of members of an organization, or via attributive delimitations such as: the patients in this hospital, the restaurants in Palo Alto, your collection of Meissen ceramic plates.

[Bittner et al. 2004] provide a formal treatment of aggregates (there called 'collections') that is consistent with the above. However, the formalization provided assumes that membership in a collection is fixed over time. As is true for all material entities (for example: you), object aggregates may gain and lose parts while remaining numerically identical (one and the same individual) over time, and for some aggregates, especially in cases where membership is determined by fiat (for example a baseball team, a congressional committee) membership may change with time.

6 Fiat object part

Clearly not all material entities form separated or separable natural units in the way described above [Smith and Mark 2003], and so there is – in dealing with limbs demarcated within a body, mountains demarcated within mountain ranges, and so forth – a need for some way to do justice to those material entities here called fiat object parts.

Fig. 3. Mount Everest from space

We define:

> *a* is a *fiat object part* = Def. *a* is a *material entity* that is a proper part of an *object* and that is not itself an *object.*

Examples are: the upper and lower lobes of the left lung, the dorsal and ventral surfaces of the body, the Western hemisphere of the Earth, the FMA:*regional parts* of an intact human body.

Since *fiat object parts* are *material entities*, they are also extended in space in three dimensions (in contrast to *fiat continuant boundaries*, introduced below).

Fiat object parts are contrasted with bona fide object parts, which are themselves objects (for example: a cell is a bona fide object part of a multi-cellular organism), and are marked by bona fide boundaries, or in other words, by *physical discontinuities* (for example: between the surface of your skin, or your laptop, and the surrounding body of air) [Smith 2001]. Most examples of fiat object parts are associated with theoretically drawn divisions (for example: the division of the brain into regions or the division of the planet into hemispheres), or with divisions drawn by cognitive subjects for practical reasons, such as the division of a cake (before slicing) into (what will become) slices (member parts of an *object aggregate*). However, this does not mean that fiat object parts are dependent for their existence on divisions or delineations effected by cognitive subjects. If, for example, it is correct to conceive geological layers of the Earth as fiat object parts of the Earth, then even though these layers were first delineated in recent times, still they existed long before such delineation and what holds of these layers (for example that the oldest layers are also the lowest layers) did not begin to hold because of our acts of delineation.

7 Treatment of Problem Cases

Examples viewed by some as problematic cases for the trichotomy of *fiat object part*, *object*, and *object aggregate* include:

> a mussel on (and attached to) a rock, a slime mold, a pizza, a cloud, a galaxy, a railway train with engine and multiple carriages, a clonal stand of quaking aspen[3], a bacterial community (biofilm), a broken femur.

Note that, as Aristotle already clearly recognized, such problematic cases – which lie at or near the penumbra of instances defined by the categories in question – need not invalidate these categories. The existence of grey objects does not prove that there are not objects which are black and objects which are white; the existence of mules does not prove that there are not objects which are donkeys and objects which are horses. It does, however, show that the examples in question need to be addressed carefully in order to show how they can be fitted into the proposed scheme – that the scheme requires additional subdivisions or amendments of other sorts. Where users of BFO need to annotate

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[3] http://scienceblogs.com/evolvingthoughts/2007/08/what_is_an_individual.php

data pertaining to such problematic cases, then they may in every case use BFO:*material entity* in formulating the corresponding annotations.

Already it is clear that BFO or its conformant domain-ontologies will in due course need to recognize also other sub-universals of *material entity*, in addition to *object*, *object aggregate* and *fiat object part* – for instance: *aggregate of fiat object parts* [Vogt 2010, Vogt et al. 2012].

Thus the treatment of *material entity* in BFO 2.0 should not be associated with any closure axiom pertaining to the three distinguished categories, and the existing treatment of the three identified sub-universals should not be associated with any claim to exhaustivity.

Acknowledgments

Many persons have contributed to the development of BFO since its inception, and I would like to thank Mauricio Almeida, Mathias Brochhausen, Werner Ceusters, Randall Dipert, Fabian Neuhaus, Albert Goldfain, Pierre Grenon, Janna Hastings, William Hogan, Ingvar Johansson, Chris Mungall, Bjoern Peters, Robert Rovetto, Mark Ressler, Stefan Schulz, Darren Natale, Holger Stenzhorn, Kerry Trentelman, and especially, Alan Ruttenberg for invaluable assistance

References

[Bittner et al. 2004] Thomas Bittner, Maureen Donnelly and Barry Smith, "Individuals, Universals, Collections: On the Foundational Relations of Ontology", Achille Varzi and Laure Vieu (eds.), *Formal Ontology in Information Systems. Proceedings of the Third International Conference (FOIS 2004)*, Amsterdam: IOS Press, 2004, 37–48.

[Bittner and Smith 2008] Thomas Bittner and Barry Smith, "A Theory of Granular Partitions", in K. Munn and B. Smith (eds.), *Applied Ontology: An Introduction*, Frankfurt/Lancaster: ontos, 2008, 125-158.

[Gangemi et al. 2002] Aldo Gangemi, Nicola Guarino, Claudio Masolo, Alessandro Oltramari, and Luc Schneider, Sweetening ontologies with DOLCE, *Knowledge Engineering and Knowledge Management: Ontologies and the Semantic Web* (LNCS 2473), 223–233.

[Ingarden 1983] Roman Ingarden, *Man and Value*, Munich: Philosophia, 1983.

[Jansen and Schulz 2011] Ludger Jansen and Stefan Schulz, "Grains, components and mixtures in biomedical ontologies", *Journal of Biomedical Semantics* 2011, 2(Suppl 4):S2.

[Niles and Pease 2001] Ian Niles, and Adam Pease, Towards a standard upper ontology. In: C. Welty and B. Smith, editors, *Proceedings of the 2nd International Conference on Formal Ontology in Information Systems* (FOIS), ACM Press, pages 2–9, 2001.

[Rosse and Mejino 2007] Cornelius Rosse and J. L. V. Mejino Jr., "The Foundational Model of Anatomy Ontology", in A. Burger, D. Davidson, and R. Baldock, eds., *Anatomy Ontologies for Bioinformatics: Principles and Practice*, London: Springer, 2007, 59-117.

[Smith 2001] Barry Smith, "Fiat Objects", *Topoi*, 20: 2 (September 2001), 131–148.

[Smith and Brogaard 2003] Barry Smith and Berit Brogaard, "Sixteen Days", *The Journal of Medicine and Philosophy*, 28 (2003), 45–78.

[Smith and Ceusters 2010] Barry Smith and Werner Ceusters, "Ontological Realism as a Methodology for Coordinated Evolution of Scientific Ontologies", *Applied Ontology*, 5 (2010), 139–188.

[Smith and Mark 2003] Barry Smith and David M. Mark, "Do Mountains Exist? Towards an Ontology of Landforms", *Environment and Planning B* (*Planning and Design*), 30(3) (2003), 411–427.

[Smith et al. 2005] Barry Smith, Werner Ceusters, Bert Klagges, Jacob Köhler, Anand Kumar, Jane Lomax, Chris Mungall, Fabian Neuhaus, Alan Rector and Cornelius Rosse, "Relations in Biomedical Ontologies", *Genome Biology* (2005), 6 (5), R46.

[Vogt 2010] Lars Vogt, "Spatio-structural granularity of biological material entities", *BMC Bioinformatics*, Vol. 11, Issue 1, May 2010.

[Vogt et al. 2012] Lars Vogt, Peter Grobe, Björn Quast, Thomas Bartolomaeus, "Accommodating Ontologies to Biological Reality – Top-Level Categories of Cumulative-Constitutively Organized Material Entities" , *PLoS One*, 2012; 7(1): e30004.

[Zemach 1970] Eddy Zemach, "Four Ontologies", *Journal of Philosophy* 23 (1970), 231-247.