**BFO 2.0 Reference**

**Draft**

**11/6/2011**

In what follows we document the conditions which must be satisfied by entities in reality if they are properly to be categorized as instantiating the different universals recognized by Basic Formal Ontology. Thus it is a guide for those using BFO as an upper-level ontology to support the creation of domain ontologies containing domain-level terms referring to particulars of different sorts in reality. To specify these conditions we will utilize a semi-formalized English that has approximately the expressivity of first-order logic (FOL) with identity. In a future document we will provide a formalized treatment of these specifications using FOL and also in a version using OWL DL.

# 1. Entity

Elucidation: Anything that exists.

Entities may be either universal or particular.

The categories which follow are in every case categories of particulars (there extensions are sets of particularsin reality).

Question: How does ‘Entity’ differ from OWL ‘Thing’?

If we have ‘entity’, then to avoid attributive classes that conflict with the BFO ontology we need to insist that all attributive classes are sub-classes of classes lower down than entity

## Relations of parthood

*a* **part\_of** *b*

*a* **part\_of** *b* at *t*

defined in terms of part-of:

*a***has\_part** *b* =Def. *b* **part\_of** *a*

*a***has\_part** *b***at** *t* =Def. *b* **part\_of** *a* **at***t*

# 2. Continuant

Elucidation: A *continuant* is an entity thatpersists, endures, or continues to exist through time while maintaining its identity.

We provide elucidations (rather than definitions) for those terms which are primitives, in the sense that there is no way of defining them in a non-circular fashion.

Note: Continuants may persist for very short periods of time (as for example in the case of a highly unstable isotope; even here, however, an atom of the given sort might persist for much longer than its momentary half-life).

Axiom: if *a* is a continuant and *b* is part of *a* then *b* is a continuant (continuants have no temporal parts).

## Relation of specific dependence

*a* **s**-**depends on** *b* **at** *t*1 *=*Def. *a* exists **at** *t*1and necessarily(if *a* exists **at***t* then *b* exists **at** *t*)

Question: Do we need **at** *t*? is **at** *t* inappropriate when *a* is an occurrent?

## 2.1 Independent continuant

*a* is an *independent continuant* =Def. *a* is a *continuant* which is such that there is no *b* such that *a* **s-depends on** *b*

(examples: an atom, a molecule, an organism, a heart, a clay statue, a symphony orchestra, a chair, the bottom right portion of a human torso, a leg; the surface of a person’s body; a person’s mouth)

Axiom: Every independent continuant is such that there are entities which **inhere** in it (for example qualities).

### 2.1.1 Material entity

Elucidation: A *material entity* is an *independent continuant* that has some portion of matter as part. Thus every material entity is extended in 3 spatial dimensions.

Axiom: Every *entity* which has a *material entity* as part is a *material entity*

(Examples: persons, undetached arms of persons, aggregates of persons)

‘Matter’ here is intended in the sense of physics, as something which includes elementary  
particles among its parts: quarks and leptons at the most fundamental level of granularity; protons, neutrons and electrons 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 and others.

Material entities may have non-material parts – identified below as sites; for example the interior (or ‘lumen’) of your small intestine is a part of you.

#### 2.1.1.1 Object

BFO rests on the presupposition that the material universe is built to a large degree in terms of separate or separable units, combined into aggregates called groups, populations, or collections. Many scientific laws govern the units in question, and the units play a central role in almost all domains of natural science.

Examples of such units include, at least: atom, molecule, organelle, cell, organism, planet. These entities are called in BFO ‘*objects*’. Each of the listed *object*  universals is marked by the fact that it has very large numbers of instances.

An *object* is a material entity that is of a type that serves as a unit in the structure of reality. Such units are often referred to also as ‘grains’, and are associated with specific ‘levels of granularity’. It is important, however, that an entity that is properly categorized as an *object* instantiates the BFO *object* universal independently of any granularity considerations.

The following elucidation is provided not as part of the BFO formal theory, but as a set of conditions to be used when deciding whether entities of a given type should be represented as *objects* in the BFO sense.

Elucidation: *Object* universals satisfy the following interdependent conditions:

1. Each *object* includes material entities as parts.

1. Hence: Each *object* is spatially extended in three dimensions.
2. Some *objects* have immaterial parts (the lumen of your gut, the hull of your ship)
3. 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.
4. Each instance of an *object* universal is causally unified, in the sense that its material parts are tied together in such a way that, in environments typical for *objects* of the type in question,
   1. if one part of the *object* is moved in space then *either* its other parts will be moved in coordinated fashion *or* the *object* will be destroyed by breakage or tearage
   2. causal changes in one part of the *object* can have consequences for other parts of the *object* without the mediation of any entity that lies on the exterior of the *object*
5. The causal unity described in (5) holds for one or more of the following reasons:
   1. The parts are combined together causally by sufficiently strong physical forces (for example, in the case of molecules, by covalent bonds; in the case of planets, by gravity)
   2. The parts are combined together causally through a common membrane or physical covering pointing outwards toward the exterior of the *object*. This membrane may have holes (for example pores, or holes for transport via conduits to other entities), but it is connected nonetheless in the sense that, between every two points on its surface a continuous path can be traced which does not leave this surface. (Organ is an *object* universal in the sense described above since organs can survive detachment from their surroundings, for example in the case of transplant, with their membranes intact.)
   3. The parts are combined together through conduits or tracts which may themselves have covering membranes and which lie in the interior of the *object*
6. Some instances of any given *object* universal are separated by spatial gaps from other instances of this same *object* universal. The spatial gaps may be filled by a lower-density medium, for example of air or water. (There are free atoms; there are cells not adjacent to or attached to other cells; there are spatially separated organisms.)
7. Instances of *object* universals are in this sense *maximal*: that, for each of the three criteria listed under (6), above, for each instance o of an *object* universal O satisfying this criterion, there is no instance of O also satisfying this criterion which includes o as proper part. Thus where conjoined twins share organs they are, prior to separation, one single *object*.

Other entities are BFO:*objects* because they satisfy these conditions even though they are not seen by natural science as ‘units of reality’. Examples are: a raindrop, a lump of cheese, a slice of cake, a pencil, a laptop, a railway carriage, a space ship, a pizza.

Objecthood is most easily assigned in the case of portiosn of solid, rigid matter (a chair carved out of a single block of wood or stone). The parts, including the moving parts, of an automobile 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. Thus a raindrop on the car is not part of it (nothing prevents it from being moved many feet away from the car) while the oil in the crankcase, and various gears, are parts of the car.

#### 2.1.1.2 Object aggregate

*a* is an *object aggregate* =Def. *a* is a *material entity* consisting exactly of two or more *objects* as **parts**.

#### 2.1.1.3 Fiat object part

*a* is a *fiat object part* =Def. *a* is a a *material entity* satisfying (5) that is a **proper part** of an *object*.

 (examples: upper and lower lobes of the left lung, the dorsal and ventral surfaces of the body, the east side of Copenhagen, your head) (FMA: regional part)

Note that there are many other sub-universals of *material entity*, in addition to *object aggregate* and *fiat object part*. For instance: aggregate of *fiat object parts*. Thus *material entity* should not be associated with any closure axiom.

Portions of matter are not extra entities

BFO is non-multiplicative; it does not distinguish between an object and its constituting matter. The statue is not a second object; it is the portion of clay during the period when it plays the statue role. (The clay may have parts which are not clay; it may have immaterial parts. These are parts of the statue also.)

### 2.1.2 Immaterial entity

*a* is an immaterial entity =Def. *a* is an independent continuant that has no material entities as parts.

Immaterial entities are divided into two subgroups; those which are tied to material entities (for example: your nasal passage), and which can thus change size, shape and location as their material hosts move; and those – called ‘spatial regions’ which exist independently of material entities, and which thus do not change.

## Relation of boundary-dependence for continuants

*a* is **boundary\_dependent\_on** *b* **at** *t =*Def. *b* is a *material entity* & *a* **proper part\_of** *b* **at** *t* & *a* is necessarily such that it cannot exist unless either (*b* exists or there exists some **part** of *b* which includes *a* as **part)**

The idea is that the parts of *b* tend towards *a* and become identical with *a* in the limit.

(Boundary dependence is a close cousin of generic dependence)

Note: *object boundaries* and *sites* are distinguished from the spatial region which they occupy at any given time in the sense that (1) the former move when their material host moves, and they change shape or size when their material host changes shape or size; (2) the latter must be specifiable in terms of some system of coordinates, and they are by definition at rest relative to this coordinate frame.

#### 2.1.2.1 Object boundary

Elucidation: *a* is an *object boundary =*Def. *a* is an *immaterial entity* that is a lower-dimensional **part\_of** some *material entity*

This can be converted into a definition only when we have a definition of ‘dimension’. See [here](http://ontology.buffalo.edu/smith/articles/chisholm/chisholm.pdf).

##### 2.1.2.1.1 Zero-dimensional object boundary (object point)

Examples (fiat): the North Pole, the quadripoint where the boundaries of Colorado, Utah, New Mexico, and Arizona meet.

##### 2.1.2.1.2 One-dimensional object boundary (object line)

Examples (fiat): The Equator, all geopolitical boundaries, all lines of latitude and longitude.

##### 2.1.2.1.3 Two-dimensional object boundary (object plane)

Here again, clear examples are fiat boundaries, for example FMA: saggital midplane of body

Candidate examples of bona fide *object boundaries* are: the surface of skin, the surface of the earth, the outer surface of a cell) (BFO is not committed to any of these examples)

|  |
| --- |
| Table 1. Fragment of Foundational Model of Anatomy |
| [http://fme.biostr.washington.edu:8080/FME/images/minus.gif](http://fme.biostr.washington.edu:8080/FME/menu.jsp?id=9&ec=0#9)[Anatomical boundary entity](http://fme.biostr.washington.edu:8080/FME/body.jsp?sel=Anatomical+boundary+entity&selID=9" \t "body)                     [http://fme.biostr.washington.edu:8080/FME/images/minus.gif](http://fme.biostr.washington.edu:8080/FME/menu.jsp?id=11&ec=0#11)[Anatomical surface](http://fme.biostr.washington.edu:8080/FME/body.jsp?sel=Anatomical+surface&selID=11" \t "body)                          [http://fme.biostr.washington.edu:8080/FME/images/plus.gif](http://fme.biostr.washington.edu:8080/FME/menu.jsp?id=14&ec=1#14)[Bona fide anatomical surface](http://fme.biostr.washington.edu:8080/FME/body.jsp?sel=Bona+fide+anatomical+surface&selID=14" \t "body)                          [http://fme.biostr.washington.edu:8080/FME/images/minus.gif](http://fme.biostr.washington.edu:8080/FME/menu.jsp?id=15&ec=0#15)[Anatomical plane](http://fme.biostr.washington.edu:8080/FME/body.jsp?sel=Anatomical+plane&selID=15" \t "body)                               [http://fme.biostr.washington.edu:8080/FME/images/minus.gif](http://fme.biostr.washington.edu:8080/FME/menu.jsp?id=16&ec=0#16)[Anchored anatomical plane](http://fme.biostr.washington.edu:8080/FME/body.jsp?sel=Anchored+anatomical+plane&selID=16" \t "body)                                    http://fme.biostr.washington.edu:8080/FME/images/leaf.gif[Craniocervical plane](http://fme.biostr.washington.edu:8080/FME/body.jsp?sel=Craniocervical+plane&selID=18" \t "body)                                    http://fme.biostr.washington.edu:8080/FME/images/leaf.gif[Cervicothoracic plane](http://fme.biostr.washington.edu:8080/FME/body.jsp?sel=Cervicothoracic+plane&selID=19" \t "body)                                    http://fme.biostr.washington.edu:8080/FME/images/leaf.gif[Thoraco-abdominal plane](http://fme.biostr.washington.edu:8080/FME/body.jsp?sel=Thoraco-abdominal+plane&selID=20" \t "body)                                    http://fme.biostr.washington.edu:8080/FME/images/leaf.gif[Occipital plane](http://fme.biostr.washington.edu:8080/FME/body.jsp?sel=Occipital+plane&selID=21" \t "body)                                    http://fme.biostr.washington.edu:8080/FME/images/leaf.gif[Interspinous plane](http://fme.biostr.washington.edu:8080/FME/body.jsp?sel=Interspinous+plane&selID=22" \t "body)                                    [http://fme.biostr.washington.edu:8080/FME/images/plus.gif](http://fme.biostr.washington.edu:8080/FME/menu.jsp?id=23&ec=1#23)[Plane of anatomical orifice](http://fme.biostr.washington.edu:8080/FME/body.jsp?sel=Plane+of+anatomical+orifice&selID=23" \t "body)                                    [http://fme.biostr.washington.edu:8080/FME/images/plus.gif](http://fme.biostr.washington.edu:8080/FME/menu.jsp?id=24&ec=1#24)[Anatomical transverse plane](http://fme.biostr.washington.edu:8080/FME/body.jsp?sel=Anatomical+transverse+plane&selID=24" \t "body)                                    [http://fme.biostr.washington.edu:8080/FME/images/plus.gif](http://fme.biostr.washington.edu:8080/FME/menu.jsp?id=25&ec=1#25)[Plane of anatomical junction](http://fme.biostr.washington.edu:8080/FME/body.jsp?sel=Plane+of+anatomical+junction&selID=25" \t "body)                                    http://fme.biostr.washington.edu:8080/FME/images/leaf.gif[Sagittal midplane of body](http://fme.biostr.washington.edu:8080/FME/body.jsp?sel=Sagittal+midplane+of+body&selID=26" \t "body)                     [http://fme.biostr.washington.edu:8080/FME/images/plus.gif](http://fme.biostr.washington.edu:8080/FME/menu.jsp?id=12&ec=1#12)[Anatomical line](http://fme.biostr.washington.edu:8080/FME/body.jsp?sel=Anatomical+line&selID=12" \t "body)                     [http://fme.biostr.washington.edu:8080/FME/images/plus.gif](http://fme.biostr.washington.edu:8080/FME/menu.jsp?id=13&ec=1#13)[Anatomical point](http://fme.biostr.washington.edu:8080/FME/body.jsp?sel=Anatomical+point&selID=13" \t "body) |

##### 2.1.2.1.4 Site

*a* is a *site* =Def. *a* is a three-dimensional *immaterial entity* that is (partially or wholly) bounded by a *material entity*.

Examples: a hole in the interior of a portion of cheese, a rabbit hole, the interior of this room, the Grand Canyon, the Piazza San Marco, a kangaroo pouch, your left nostril, the hull of a ship, the lumen of your gut, the trunk of your car)

Note: *Sites* may be bounded in part by fiat boundaries, as for instance the Mont Blanc Tunnel is bounded by fiat boundaries at either end. Each site coincides at any given time with some spatial region, but which spatial region this is may vary with time, for instance as the ship moves through space, or as your nostril expands and dilates.



Figure 1: Four Basic Types of Examples of Sites

1: the interior of an egg; 2: the interior of a snail’s shell; 3: the environment of a pasturing cow

#### 2.1.2.3 Spatial region

Uses of ‘spatial region’ by users of BFO demand specification of a coordinate frame, which can be associated with a Newtonian or a relativistic frame of reference. The reference frame might be relative to a moving object such as the earth, in which case the corresponding spatial regions move with the movement of the earth. However, they are at rest relative to their coordinate frame. Lines of latitude and longitude are two-dimensional object boundaries which can move; however, they are by definition at rest relative to the coordinate frame which they determine.

Elucidation:

Spatial regions have no qualities except shape, size and relative location.

##### 2.1.2.3.1 Zero-dimensional spatial region (aka spatial point)

Def. a spatial region of zero dimensions.

(example: a point in space)

##### 2.1.2.3.2 One-dimensional spatial region (aka spatial line)

Def. a spatial region of one dimension.

(examples: a line stretching from one point in space to another, an edge of a cube-shaped portion of space)

##### 2.1.2.3.3 Two-dimensional spatial region (aka spatial volume)

Def. a spatial region of two dimensions.

(examples: the surface of a cube-shaped part of space, the surface of a sphere-shaped part of space, an infinitely thin plane in space)

##### 2.1.2.3.4 Three-dimensional spatial region (aka spatial volume)

Def. a spatial region of three dimensions.

(examples: a cube-shaped region of space, a sphere-shaped region of space)

## Location relations

**Located\_at**

Elucidation: a**located\_at**r**at**t This is a primitive relation between an independent continuant, a spatial region which it occupies, and a time.

Trivially, every region is located in itself.

**Located\_in**

a**located\_in** b **at**t =Def. a and b are material entities, and the region occupied by a is a (proper or improper) **part** of the region occupied by b.

## Relation of containment

*a* **contained\_in** *b* **at** *t =*Def. *a* is a material entity & *b* is a site & for all spatial regions *r*1*,* *r*2, if *a* **located\_in** *r*1  **at** *t* and *b* **located\_in** *r*2 **at** *t*,then *r*1  **part\_of** the convex hull of*r*2.

A site is something in which a material entity can be contained.

Note that there are many other sub-universals of *immaterial entity*, in addition to *site*, *object boundary* and *spatial region*. (For instance *aggregate of sites*.)

## 2.2 Specifically dependent continuant

*a* is a *specifically dependent continuant =*Def. *a* is a continuant which **s-depends** on some entity.

(examples: the mass of this tomato, the color of this tomato, the smell of this portion of mozzarella, the disposition of this fish to decay, the role of being a doctor, the function of the heart to pump blood, John’s love for Mary)

*a* **inheres in** *b* **at***t*1 *=*Def. *a* is a dependent continuant & *b* is an independent continuant &  *a* **s-depends on** *b* **at** *t*1& for all *c* (if *a* **s-depends on** *c* **at** *t*1 then overlap(*b*, *c*))’

*a* **bearer\_of** *b* **at***t =*Def. *b* **s-depends on** *a* **at** *t* or *b* **g-depends\_on** *b***at** *t*

Axiom: A specifically dependent continuant cannot inhere in distinct bearers at distinct times.

### 2.2.1 Quality

Elucidation: a *quality* is an s-dependent continuant that, in contrast to roles and dispositions, does not require any further process in order to be realized.

(examples: the color of a tomato, the ambient temperature of a portion of air, the circumference of a waist, the shape of a nose, the mass of a piece of gold, the weight of a chimpanzee)

Thus, solubility is not manifested in some solid pieces of salt or sugar, while their crystalline quality is.

*a* **quality\_of** *b* **at** *t =*Def. *a* is a quality & *b* is a material entity & *a* **s-depends\_on** *b* **at** *t*

For some qualities, e.g. color, dependence may be not on bearer but on surface of bearer. (See discussion of boundary dependence above.)

Qualities of spatial regions are restricted to qualities of size, shape and position and qualities definable in terms of these.

There are relation qualities, for example: loves, which have a plurality of independent continuants as their bearers. ‘**Quality\_**of’ is defined in terms of **s-depends**, rather than **inheres**, to take account of the fact that there are relational qualities.

### 2.2.2 Realizable entity

*a* is a realizable entity =Def. *a* is a specifically dependent continuant that inheres in some material entity and is of a type instances of which are **realized** (exhibited, manifested, actualized) in processes of a correlated type.

(examples: the role of being a doctor, the function of the reproductive organs, the disposition of blood to coagulate, the disposition of metal to conduct electricity)

## The realizes relation

Elucidation: if *a* **realizes** *b***at** *t*,then this meansthat, for some material entity *c*, *a* is a process in which *c* **participates at** *t* and *b* is a disposition or role of which *c* is the**bearer***.*

Note: *t* here is an interval, rather than a instant (temporal boundary)

Reciprocal dependent continuants (e.g. husband/wife; blocking dispositions)

Axiom: the bearer of a realized realizable entity participates in the realization

#### Role (Externally-Grounded Realizable Entity)

*a* is a *role* =Def. *a* is a realizable entity which exists because its bearer is in some special physical, social, or institutional set of circumstances in which the bearer does not have to be, and is not such that, if it ceases to exist, then the physical make-up of the bearer is thereby changed.[[1]](#endnote-1)

‘Role’ is another name for what we might call an extrinsic or externally-grounded realizable entity. An entity is a role not because of the way it itself is, but because of something that happens or obtains externally. Examples include:

* the role of an instance of a chemical compound to serve as analyte in an experiment,
* the role of a portion of penicillin to act as a drug,
* the role of bacteria in causing infection, and
* the role of a stone in marking a boundary.

Roles are optional in the sense that the bearer of a role can lose the role without being physically changed. Because a role is not a reflection of the in-built physical make-up of its bearer, there are therapeutic and prophylactic roles, and input and output roles. For example, the primary function—or input role—of mitochondria is to produce adenosine triphosphate (ATP).[[2]](#endnote-2) However, given that they produce high levels of oxidative stress, these same mitochondria play an output role in Alzheimer’s disease. A heart has the function of pumping blood, but in certain circumstances that same heart can play the role of dinner for a lion or of plasticized prop in a museum display. Water does not have any function per se, but it does play many different roles, for example in helping to initiate the growth process of a seed, or in a hydroelectric experiment, or in washing clothes.

Typically roles are also marked by *optionality of realization*. However, there are some realization dependent roles (e.g. pathogen), which are such that entities bear the role in question only if they have already begun to realize it.

There is also a distinction between having a role and playing a role. An entity can play a role, as when a passenger plays the role of a pilot on a commercial plane in an emergency, or a pyramidal neuron plays the role occupied by a damaged stellar neuron in the brain; but neither the person nor the pyramidal neuron have those roles.

The correct form for generating phase sortals referring to roles is as follows:

* John has student role
* John is a student =Def. John bears the student role.

Biological father is not a role; compare it represents a spurious nominalization of some historical fact, analogous to: person who attended the Bills game, person who made the pilgrimate to Mecca.

#### Disposition (Internally-Grounded Realizable Entity)

It is common to find researchers making claims like:

* an atom of element X has the disposition to decay to an atom of element Y,
* the cell wall is disposed to filter chemicals in endocitosis and exocitosis,
* certain people have a disposition to develop colon cancer, and
* children are innately disposed to categorize objects in certain ways.

*a* is a disposition =Def. *a* is a realizable entity which is such that (1) if it ceases to exist, then its bearer is physically changed, and (2) its realization occurs when this bearer is in some special physical circumstances, and (3) this realization occurs in virtue of the bearer’s physical make-up.

Unlike roles, dispositions are not optional. If an entity is a certain way, then it has a certain disposition, and if it ceases to be that way, then it loses that disposition. A disposition is also known as an internally-grounded realizable entity. That is, it is a realizable entity that is a reflection of the in-built or acquired physical make-up of the independent continuant.

Dispositions exist along a strength continuum. Weaker forms of disposition are realized in only a fraction of triggering cases. These forms occur in a significant number of entities of a similar type such that there exists a statistical, concomitant correlation present between two entities, if they are in certain circumstances. Examples of weaker forms of disposition include:

* a hemophiliac’s disposition to bleed an abnormally large amount of blood,
* a person who smokes two packs of cigarettes a day throughout adulthood has the disposition to die of a disease earlier than average, and
* crime has the disposition to rise in heavily populated cities during the summer months.

Diseases, according to the Ontology for General Medical Science, are dispositions. We are referring to disposition also when we consider genetic and other risk factors for specific diseases.

#### Capability (Should we include capability? If so, how define it?)

1. A capability is a disposition that exists in virtue of the bearer’s physical make-up, and enables the entity in which it inheres to participate in events of a certain kind.

Examples include:

Define in terms of relation: **capable\_of** ?

*a* capable\_of *B* =Def. *a* is of a type instances of which engage in processes of type *B*

Capabilities are what the thing can do, sometimes as side effects.

#### Function

A function is a disposition that exists in virtue of the bearer’s physical make-up,[[3]](#endnote-3), [[4]](#endnote-4) and this physical make-up is something the bearer possesses because it came into being, either through evolution (in the case of natural biological entities) or through intentional design (in the case of artifacts), in order to realize processes of a certain sort. Examples include:

* the function of amylase in saliva to break down starch into sugar,
* the function of a hammer to drive in nails, and
* the function of a heart pacemaker to regulate the beating of a heart through electricity.

Functions are realized in processes called functionings. Each function has a bearer with a specific type of physical make-up. This is something which, in the biological case, the bearer has naturally evolved to have (as in a hypothalamus secreting hormones) and, in the artifact case, something which the bearer has been constructed to have (as in an Erlenmeyer flask designed to hold liquid).

It is not accidental or arbitrary that a given eye has the function to see or that a given screwdriver has been designed and constructed with the function of fastening screws. Rather, these functions are integral to these entities in virtue of the fact that the latter have evolved, or been constructed, to have a corresponding physical make-up. Thus, for example, because of its physical make-up the heart’s function is to pump blood and not merely to thump or produce sounds, which are by-products of the heart’s proper functioning.[[5]](#endnote-5)

Like dispositions of other sorts, a function is an internally-grounded realizable entity: it is such that if it ceases to exist, then its bearer is physically changed. A non-functioning lung or attic fan would indicate that the physical make-up of these things had changed—in the case of the lung, possibly a cancerous lesion; in the case of the attic fan, possibly a screw missing. These entities would still have their function, but they would not be capable of functioning until the physical change is rectified. The entities would lose their function if they were changed drastically, for example by being permanentaly removed from the body, in the case of the lung, or by being irreparably crushed in the case of the attic fan Thus, if a continuant has a function, then it is built to exercise this function reliably on the basis of its physical make-up. But again, a function need not in every case be exercised or manifested: its bearer may be broken, or it may never be in the right kind of context, or provided with the right kind of input.

We can distinguish two varieties of function, artifactual function and biological function. However, these are not subtypes, since the same function – for example: to pump – can exist both in artifacts and in biological entities.

Defined relations:

*a* **role\_of** *b* **at** *t =* Def. *a* is a role and *a* **inheres\_in** *b* **at** *t*

*a* **disposition\_of** *b* **at** *t =*Def. *a* is a disposition and *a* **inheres\_in** *b* **at** *t*

*a* **function\_of** *b* **at** *t =*Def. *a* is a function and *a* **inheres\_in** *b* **at** *t*

These relations are defined in terms of **inheres** because there are no relational roles and dispositions (?).

### 2.3 Generically Dependent Continuant

*a* **g-depends on** *b* **at** *t*1=Def. *a* exists **at** *t*1and *b* exists **at** *t*1and for some *B* it holds that (*Bb* **at** *t*1)and necessarily, for all *t* (if *a* exists **at *t*** then some *B* exists **at** *t*)

Axiom: if *a* **g-depends on** *b* **at** *t*1at some time, then *a* **g-depends** on something at all times at which it exists.

*a* is a *generically dependent continuant* =Def. *a* is a continuant that **generically depends** on one or more other entities.

(example: the pdf file on your laptop, the pdf file that is a copy thereof in my laptop; the sequence of this protein molecule; the sequence that is a copy thereof in that protein molecule)

Question: are all cases of generical dependence cases of generic dependence on material entities such as hard drives and molecules?

Where BFO’s specifically dependent continuants are subject to what we might call the axiom of non-migration – they cannot migrate from one bearer to another, generically dependent continuants are capable of such migration through a process of exact copying. The *very same pdf file* can be saved to multiple storage devices, and thus it – the numerically identical information artifact – can exist in multiple copies.

We can think of generically dependent continuants, intuitively, as complex continuant patterns of the sort created by authors or designers, or (in the case of DNA sequences) through the processes of evolution. Further examples of generically dependent continuants thus include the chessboard pattern, the Coca Cola trademark, the pattern that is your signature. Each such pattern exists only if it is concretized in some counterpart specifically dependent continuant – the pattern of black and white squares on this actual chessboard; the pattern of red and white swirls on the label of this Coca Cola bottle; the pattern of ink marks on this contract.

Such patterns can be highly complex. The pattern of letters of the alphabet and associated spacing which is the novel *Robinson Crusoe* is concretized in the patterns of ink marks in this and that particular *copy* of the novel. When you create a novel you create a particular instance of the generically dependent continuant type *novel*. When you print further copies in book form, then you create multiple particular instances of the independent continuant type *book.* The common particular patterns of ink marks (complex qualities)

Generically dependent continuants can be **concretized** in multiple ways; you may concretize a novel in your head. You may concretize a piece of software by installing it in your computer. You may concretize a recipe which you find in a cookbook by turning it into a plan which exists in your head as a realizable dependent continuant.

Generically dependent continuants are created entities. The data in your database, for examples, are patterns in some medium – for instance in your hard drive – with a certain kind of provenance. The database itself is an aggregate of such patterns. When you create the database you create a particular instance of the generically dependent continuant type *database*. Similarly each entry in the database is an instance of the generically dependent continuant type datum.

Data, databases, pdf files, novels, and other information artifacts are thus analogous to other created artifacts such as paintings or sculptures. They differ from the latter in that, once having created, they can exist in many copies that are all of equal value.

In the case of a work of music such as Beethoven’s *9th Symphony*, there is again a certain abstract pattern, a generically dependent continuant instance of the type *symphony*, which is itself a subtype of the type *musical work*, which is **concretized** in certain specifically dependent patterns of ink marks that we find in a printed copy of the *score*, or in certain specifically dependent patterns of grooves in a vinyl disk. This score is an instance of the generically dependent continuant type *plan specification*, which is concretized as a network of plans in the minds of the conductor and the members of the orchestra – a plan to create the corresponding *musical performance*. This network of plans is a complex realizable dependent continuant which is **realized** when conductor and orchestra work together to create the already mentioned pattern of air vibrations.

And analogously, when a research term decides to perform an experiment following a published protocol, the protocol itself is a generically dependent continuant instance of the type plan specification. The leader of the research team concretizes this protocol in her mind to create that specifically dependent realizable continuant which is her plan for carrying out this experiment. At the same time she creates a series of sub-protocols, plan specifications for her various team members, which are concretized by them as plans for carrying out their corresponding parts of the experiment. The experiment itself is a realization of these plans.

## Relation of concretization

*a* **concretizes** *b* **at** *t =*Def. *a* is a specifically dependent continuant & *b* is a generically dependent continuant & for some independent continuant *c, a* **s-depends** on*c* and *b* **g-depends** on *c* , and if the *b* migrates to another bearer *d* than an exact copy of *a* will be created in *d.*

# 3. Occurrent

Elucidation: an occurrent is an entity that has **temporal parts** or is a temporal boundary of such an entity. Thus processes, spatiotemporal and temporal regions are occurrents, and so also are the beginnings and endings of processes, as well as the boundaries of spatiotemporal and temporal regions.

Processes, in contrast to material entities, do not standardly come in natural units or grains which are separated from other units of the same sort. Where natural units are identifiable, for example cycles in a cyclical process such as a beating heart, they form a continuous sequence. Lives of organisms are process units, but they too form a continuous series with other pre- and post-life processes such as fertilization or post-mortem decay. Clear examples of boundaries of processes are almost always of the fiat sort (the beginning or end of a race, midnight.

**Projection relations**

spatiotemporal region **projects\_onto** temporal region

spatiotemporal region **projects onto** spatial region **at** *t*

## Occupies relation

Elucidation: a**occupies** r. This is a primitive relation between an occurrent and a temporal or spatiotemporal region which it occupies.

The **occupies** relation is the counterpart, on the occurrent side, of the relation **located\_at.**

Trivially, every spatiotemporal or temporal region occupies itself.

## Relation of temporal parthood

Elucidation:

To say that *a* is a **temporal\_part\_of** *b* is to say that *a* **proper\_part\_of** *b* & *a* and *b* are occurrents & for some spatiotemporal or temporal region *r*, *a* **occupies** *r*& *b* **occupies** *r*

Need to define life / course /

## Relation of boundary-dependence for occurrents

*a* is **boundary\_dependent\_on** *b =*Def. *a* is an *object boundary* & *b* is a *material entity* & *a* **part\_of** *b* **at** *t* & *a* is necessarily such that it cannot exist unless either (*b* exists or there exists some **part** of *b* which includes *a* as **part)**

*a* **temporal\_boundary**\_of *b =*Def. *a* is a temporal region and

*Occurrent*

*a* is an occurrent =Def. *a* is an entity that has **temporal parts** or a temporal boundary of such an entity.

(examples: the life of an organism, a surgical, the spatiotemporal setting occupied by a process of cellular meiosis, the most interesting part of Van Gogh’s life, the spatiotemporal region occupied by the development of a cancer tumor)

*a* **has\_participant** *b* =Def. *a* is an occurrent & *b* is a material entity & *b* **s-depends on** *b*

**How to capture features of processes**

The underlying idea, from the very beginning, is that there are no qualities of processes analogous to the qualities we find on the occurrent side. However, there are clearly many ways in which we make assertions about processes, in which such qualities seem to be ascribed. We offer an account of major families of such assertions by means of a theory of process profiles. Process profiles are themselves processes, which are structural parts of the typically larger and more complex processes in which they are contained. An example of a process profile on which we will concentrate is the beat profile, illustrated by heart beat processes, by drumming processes, and so forth. Every beating process is a beating process in virtue of its including some beat profile as a part.

Other examples of process profile types, with subtypes, include:

* auditory profile (for example that part of the process of a heart’s beating which is audible).
* motion shape profile (trajectory)
* velocity profile

constant velocity profile

2 mph constant velocity profile

3 mph constant velocity profile

increasing velocity profile

* acceleration profile

constant velocity profile

0 ft/s2 acceleration profile

32 ft/s2 acceleration profile

33 ft/s2 acceleration profile

increasing acceleration profile

As applied to a body moving with a constant speed, the view we reject is as follows:

There are three distinct particular entities:  
(1) the process of moving; (2) the determinable speed (process quality); (3) the determinate speed magnitude referred to by the expression '1 m/s' (information artifact).  
  
We accept (1) and (3) but not (2). Why?: because there is no extra entity which could be added or taken away while the process itself would remain the same. Rather, to predicate speed of a process of motion is to assert that that process is of a certain determinate type. But now a process of moving at a given speed might be at the same time a process of getting warmer, and this seems to threaten multiple inheritance. To avoid this problem, we propose an account which accepts the following three entities:

* the (whole) process of moving;
* the process profile (a certain structural part of the whole process) which instantiates the determinable speed universal and which
* at that specific time also instantiates the determinate 1 m/s speed universal

In what follows we use the beat profile example to provide a preliminary account of predications of rates to processes (to those processes which are regular enough to have rates). We can easily extend this account to cases where changes of rate are involved. Thus in addition to the regular beat profile (where a rate can be assigned), there is also an increasing beat profile, a decreasing beat profile, an accelerating beat profile, as well as many many different types of irregular beat profile, some of which, when they are detected in measurements of heart beat processes, are clinically significant.

|  |
| --- |
| Introducing process profiles  There are certain structural dimensions of objects – e.g. shape, mass, temperature, volume – which involve qualities that objects have to have essentially. These qualities can vary, but they must have some value. (Compare the anatomist’s idea of a *Bauplan*.)  There are, I want to claim, analogous structural dimensions of processes, which we call 'profiles'. The idea is that processes of a given sort – e.g. the functioning of a heart – might have a motion profile, an auditory profile, a blood output profile, and so on. Quantitative values, and units of measure, are associated *directly* with process profiles, but with the process as a whole only in a secondary sense. (Compare de Bono et al. on the variables encoded in physiology models used in the study of physiological processes.)  Process profiles are parts of processes, but they are parts not in the sense of ‘pieces’ (separable parts), but rather in the sense of inseparable moments (compare, again, shape) – entities which cannot exist exist in the content of a surrounding whole of this given sort. They are inseparable in the sense that, for example, the motion and blood output and auditory profiles would necessarily have *some* values for any functioning of the heart as a pump.  Basic Assumptions:  1. There are four kinds of occurrents:   * processes (connected and scattered), which are always extended in time * process boundaries (of instantaneous extent), both internal (when a threshold is crossed) and external (beginnings and endings) * temporal regions (points and intervals) * spatiotemporal regions   2. Processes are changes; they have participants, which are the independent continuants which change. Whenever a quality of an independent continuant changes then (trivially) this independent continuant changes also.  3. Continuant entities are located at spatial regions; occurrent entities occupy temporal or spatiotemporal regions.  4. For continuants, predications may need to be time-indexed in order to be true. For example, if x *instantiates* larva at t, then it does not follow that x *instantiates* larva. Instantiation relations for occurrents are never time indexed except in the trivial sense. This is because, while continuants can change their type from one type to the next (e.g. fetus becomes an embryo becomes an infant …), occurrents can never change their type from one time to the next, because occurrents can never change, because occurrents *are* changes. Certainly an occurrent can for example involve parts which are of different sorts in different times. A process of movement can have speed v1 and then have speed v2. But there is nothing here which changes; rather, there is a process with two somewhat different parts.  5. Processes can be arbitrarily summed and divided. In particular, we can identify sub-processes which are fiat segments projecting onto temporal intervals – for example your heart-beating from 4pm to 5pm today; the 4th year of your life.  **Towards a definition of ‘rate’**  Question: How, on the basis of the above, and of the BFO framework, do we do justice to rates of change, which seem intuitively to be attributes of processes in some ways analogous to BFO:qualities?  To answer this question we consider the specific case of beating processes, as for example of a heart.  How do we do justice to the fact that, intuitively, a process of heart beating can change its rate from one time to the next.  Answer: There are two sub-processes (by 5.), one spanning the first time, the other spanning the second time, and the rate of one is different from the rate of the other.  What follows is an attempt to make this work, given that there are beating processes which change continuously (so that we have to make sense of a beating process boundary having a certain rate *at an instant*)  p instanceOf beating-at-n-bpm =def.  **Case 1** (see Figure 1): p is regular, and extends across at least one cycle  there is some decomposition of p into similar process parts p = sum of p1, …, pn, for n ≥ 1, which is such that each of the pi projects onto a time interval of time 1/n  Figure 1  **Case 2** (see figure 2): the rate of beating of a process is varying, but for a certain interval t1 (from 1.5 to 2 seconds), which is less than the extent of the relevant cycle, it is beating at a rate of n bpm.  Here it is as if at the relevant time the process could be extended to Case 1. We need to say something like:  during this interval the beating process is similar to a 0.5 second long segment of a process that is otherwise similar and is beating at n bpm according to our definition. Perhaps like this:  p instance of partial\_interval\_beating-at-n bpm =def. there is some time interval t, p projects onto t, there is some process q such that q instance\_of beating-at-n bpm and p is similar to a segment of q that is of length equal to that of t  Figure 2  **Case 3** (see Figure 3) Constant acceleration (in every minute the rate rises by a certain amount): there might be an instantaneous process (process boundary) p1 to which we can assign a rate of n bpm. To this end we need to use the idea of limits; however small an interval around n we choose, we can find an interval around t1 in which the beating process is arbitrarily closely similar to a process that is an instance of partial\_interval\_beating-at-n bpm.  Thus suppose that the heart is beating as in Figure 3 and that its rate of beating is decreasing continuously between t1 and t2. We want to say that at the mid-point the heart is beating at 64 bpm. Yet by our definitions above at no time in the given interval do we have an instance of beating-at-64-bpm in either Case 1 or Case 2. Remember that we cannot *make* time-indexed instantiation assertions concerning processes at all.  We first define  two beating processes are δ-similar (meaning: have δ-similar beat rates) =def. the difference between their rates (defined under either case 2 or case 3) is less than or equal to δ bpm.  We then define  p instance of instantaneous\_beating-at-n bpm =def. p is a process boundary (instantaneous process part) in the interior of some process p1 and given any δ we can find some process p2 such that p2 interior part of p and p2 part of p1 & p1 δ-similar to some process that is an instance of partial\_interval\_beating-at-n bpm  Figure 4  Case 4: Beating at a rate increasing by a fixed amount (see Figure 4) (this applies also to Figure 5)  **p instance of beating\_at\_a\_rate\_increasing\_by n bpm2**  (i.e. in every minute the rate rises by an increasing amount)  =def. for any instantaneous process boundary p1 in the interior of p and for any m1, if p1 instance of instantaneous\_beating-at-m1 bpm & p1 projects onto t1, then for any δ there is some instantaneous process boundary p2 and some m2 such that p2 instance of instaneous\_beating-at-m2 & p2 projects onto t2 and p1 δ-similar to some process that is an instance of partial\_interval\_beating-at-n bpm & the difference between nand  is less than δ  Figure 4  **The master argument for profiles now reads as follows:**  ‘Similar’ in all of the above has to mean: have a similar beating-motion profile  For suppose that each of the pi involves e.g. the making of a noise of a quite different sort, or the flashing of a color of a quite different sort, or any other kind of change.  Footnote:  The idea, illustrated by Figures 1-3, is to compute the rate of change as the [limiting value](http://en.wikipedia.org/wiki/Limit_of_a_function) of the [ratio of the differences](http://en.wikipedia.org/wiki/Difference_quotient) Δ*y* / Δ*x* as Δ*x* becomes infinitely small.  In [Leibniz's notation](http://en.wikipedia.org/wiki/Leibniz%27s_notation), such an [infinitesimal](http://en.wikipedia.org/wiki/Infinitesimal) change in *x* is denoted by *dx*, and the derivative of *y* with respect to *x* is written  \frac{dy}{dx} \,\!  We will need static process profiles in each category. Thus for example a 0 beat profile (a beat profile in which there are zero beats per interval of time; a velocity profile in which velocity is zero an acceleration profile in which acceleration is zero, etc.  This will form the basis of our treatment of ‘states’ (e.g. of the state of rest), as special sorts of processes (in which nothing happens). Compare the case in which two dispositions of equal and opposite attraction and repulsion can counterbalance each other – the dispositions are realized but there is no movement |

Spatiotemporal Regions

process

process boundary

temporal region

1-dimensional temporal region (temporal interval)

0-dimensional temporal region (temporal boundary)

spatiotemporal region

3+1-dimensional spatiotemporal region

3+0-dimensional spatiotemporal region

*Spatiotemporal region*

Def. An occurrent entity at or in which processual entities can be located.

(examples: the spatiotemporal region occupied by a human life, the spatiotemporal region occupied by the development of a cancer tumor, the spatiotemporal setting occupied by a process of cellular meiosis)

*Processual entity*

Def. An occurrent entity that exists in time by occurring or happening, has temporal parts, and always inheres in some independent continuant entity or entities.

(comment: to contrast with temporal and spatiotemporal regions)

(examples: the life of an organism, the process of meiosis, the course of a disease, the flight of a bird, the process of cell division)

*Temporal region*

Def. An occurrent entity that is part of time.

An occurrent entity upon which a process can be projected.

(Need projects\_onto in relation ontology)

(examples: the time it takes to run a marathon, the duration of a surgical procedure, the moment of death)

*Process*

Def. a processual entity that is extended in time.

(examples: the life of an organism, the process of sleeping, the process of cell-division, a beating of the heart)

*Temporal boundary of process (event)*

Def. a processual entity that is an instantaneous temporal boundary of a process.

(examples: the detaching of a finger in an industrial accident, birth, death, the final separation of two cells at the end of cell-division, the incision at the beginning of a surgery, the beginning of a race)

*Temporal region* (recommend: use dependent on specifying coordinate frame)

1-dimensional temporal region (temporal interval)

0-dimensional temporal region (temporal boundary)

*Temporal instant*

Def. a boundary of a temporal interval

(thus zero-dimensional

(examples: right now, the moment at which a finger is detached in an industrial accident, the moment at which a child is born, the moment of death)

*Temporal interval*

Def. a one-dimensional temporal region.

(examples: the temporal region during which a process occurs)

|  |
| --- |
| continuant  independent continuant  material entity  object  fiat object part  object aggregate  immaterial entity  object boundary  zero-dimensional object boundary  one-dimensional object boundary  two-dimensional object boundary  site  spatial region  zero-dimensional region  one-dimensional region  two-dimensional region  three-dimensional region  specifically dependent continuant  quality  relational quality  realizable entity  role  disposition  function  generically dependent continuant  occurrent  process  process boundary  temporal region  1-dimensional temporal region (temporal interval)  0-dimensional temporal region (temporal boundary)  spatiotemporal region  3+1-dimensional spatiotemporal region  3+0-dimensional spatiotemporal region |

BFO Relations

Check that these are dealt with:

BFO\_0000050 part of  
BFO\_0000051 has part  
BFO\_0000056 participates in  
BFO\_0000057 has participant  
BFO\_0000062 preceded by  
BFO\_0000063 precedes  
BFO\_0000060 immediately preceded by  
BFO\_0000061 immediately precedes

BFO\_0000052 inheres in  
BFO\_0000053 bearer of  
BFO\_0000054 realized by  
BFO\_0000055 realizes

The idea is that BFO includes the minimal set of relations required to    
define BFO classes.

A draft is available here:  
<http://code.google.com/p/bfo/source/browse/#svn/trunk/src/ontology>

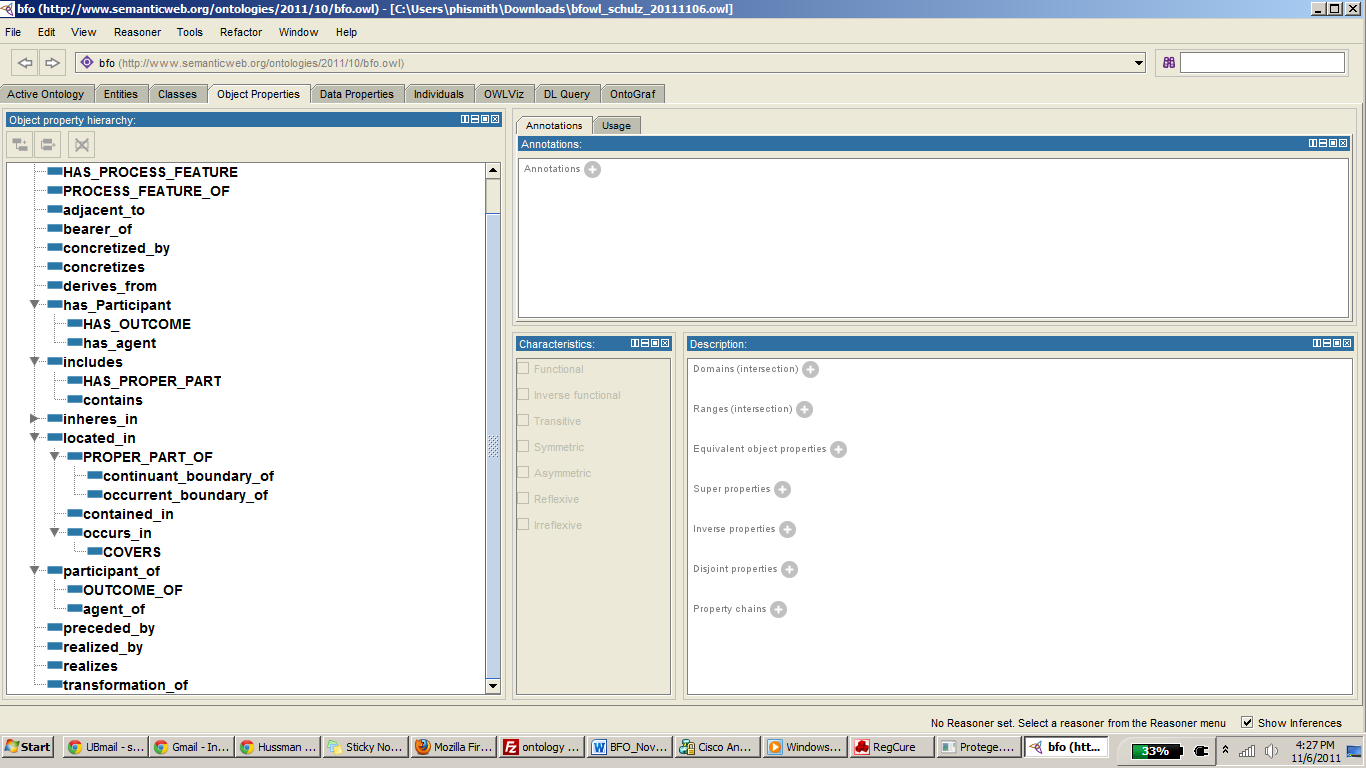
Many of these relations can be treated as "macros", and expanded into    
more complex expressions. For example:

RO\_0002100 has soma part of  
=> has\_part some (GO:cell\_body and part\_of some ?Y)  
RO\_0002104  
=> has plasma membrane part : has\_part some (GO:plasma\_membrane and    
has\_part some ?Y)

An early draft is available here:  
<http://code.google.com/p/obo-relations/source/browse/#svn/trunk/src/>   
ontology

Check relations list here: <http://code.google.com/p/obo-relations/>

Check all these relations have been added:



1. http://www.ifomis.org/bfo. [↑](#endnote-ref-1)
2. Evans, T., Zhu, X., Lee, H., Previll, L., Webber, K., Casadesus, G., Perry, G., and Smith, M. (2006) Alzheimer’s disease: A deregulated cell cycle disease. In M. Sun, ed., Research Progress in Alzheimer’s Disease and Dementia (pp. 109–122). Nova Publishers, New York. [↑](#endnote-ref-2)
3. Johansson, I., Smith, B., Munn, K., Tsikolia, N., Elsner, K., Ernst, D., and Siebert, D. (2005) Functional anatomy: A taxonomic proposal. Acta Biotheoretica, 53, 53–66. [↑](#endnote-ref-3)
4. Mizoguchi, R. and Kitamura, Y. (Forthcoming) A functional ontology of artifacts. *The Monist*. [↑](#endnote-ref-4)
5. Millikan, R. (1984) Language, Thought, and Other Biological Categories. MIT Press, Cambridge, MA. Chapters 1 and 2. [↑](#endnote-ref-5)