BFO 2.0 Reference
Draft

11/9/2011

BFO is a formal ontology, which means: it is neutral with regard to the material domains to which it is applied. The application of a formal ontology such as BFO brings benefits of reuse, cumulation of data, and reasoning, and provides common formal theories (for example of mereology and qualitative spatial reasoning) which do not need to be redeveloped for each successive domain. For such benefits to be possible, however, BFO must be capable of being applied to material domains.

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. This document is thus 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; a parallel effort is underway using OWL.

1. Entity [SECTIONS IN SMALL TYPE ARE FOR BACKGROUND PURPOSES]

Elucidation: An entity is anything that exists.

(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.)

Entities may be either particular (on the narrower reading) or also universal (on a broader reading). In this document we concentrate primarily on entities which are particulars and on relations between particulars, otherwise called 'instance-level relations'. (Two exceptions are our treatment of generic dependence and of the determinable/determinate distinction.) That is, the categories discussed below are in every case categories of particulars (their extensions are sets of particulars in reality). When BFO is supplemented by the Information Artifact Ontology the wider reading is needed, because universals are included among the targets of the **about** relation.

How does BFO:Entity differ from owl:Thing?

The latter is defined as an extensional class so that, for each ontology, all particulars recognized in that ontology fall under this class. Since it is defined in the OWL language itself, that means that any particular in any OWL ontology is an owl:Thing. So if there is an ontology of fairies written in OWL, describing, say, the difference between red fairies and blue fairies, then fairies will be included as members of the class owl:Thing. BFO:*entity*, by contrast, is intended to be restricted to what exists. Thus the direction of fit between ontology and reality is reversed with regard to owl:Thing and BFO:*entity*. Something is an owl:Thing just because it is defined as a particular in an OWL ontology; something is BFO:*entity* only if we have good reasons to believe that it is part of the furniture of reality. Best efforts to achieve veracity is a condition of conformance.

Attributive classes

Often, language is used need to refer to subgroups of entities which instantiate a given universal but are not themselves defined in terms of any corresponding subuniversal – for example: *animal owned by the emporer*, *tuberculosis diagnosed on a Wednesday*. In some cases, terms of this sort need to be included in domain ontologies created by downward population from BFO as top level. The terms in question should be created as children of the corresponding genus (here: *animal* and *tuberculosis*, respectively), but not treated as part of the asserted hierarchy of the ontology in question.

Important examples of such attributive classes involve roles: *professor* (defined as: a *human being* who has the *professor role*). *Entity* should not be used as a genus in creating definitions of this sort.

Relations of parthood

Primitive relations

a **part_of** *b* – where relata are *continuants*

a **part_of** *b* **at** *t* – where relata are *occurrent*s

Relations 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 that persists, endures, or continues to exist through time while maintaining its identity.

Note: *Continuants* may persist for very short periods of time (as for example in the case of a highly unstable isotope).

Axiom: if *a* is a *continuant* and *b* is **part_of** *a* then *b* is a *continuant*
(*Continuants* have no temporal parts.)

Axiom: if *a* is a *continuant* at some time, then there is some *temporal region* during which *a* exists.

Relation of specific dependence

Elucidation: To say that *a* **s-depends on** *b* **is to say that**

a exists
& *a* is necessarily such that, if for some *t*, *a* exists **at** *t* then *b* exists **at** *t* also
& *a* and *b* share no common parts.

In particular, an entity does not **s-depend** on any of its parts.
If *a* **s-depends on** *b* then we can also say that *a* necessitates the existence of *b*; is tied of its nature to *b*. If *a* **s-depends**, then it **s-depends** at every time at which it exists. If *b* is such that some *a* **s-depends on** it, then if *b* ceases to exist, so also does that something. The entities which **s-depend** include *dependent continuants*, which **s-depend** either on their bearers or on each other (for example in the case of the reciprocally dependent roles of husband and wife), and occurrents, which **s-depend** on the *independent continuants* which participate in them.

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 bronze statue, a symphony orchestra, a chair, the bottom right portion of a human torso, a leg; the interior of your mouth; a spatial region.

Axiom: Every *independent continuant* is such that there are *entities* which **inhere** in it.
Subtypes of *independent 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

2.1.1 Material entity

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

Examples: persons, undetached arms of persons, aggregates of persons.

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

'Matter' here is intended in the sense of physics, as something which includes elementary particles among its **proper or improper 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.

Material *entities* may have non-material parts – including the *entities* 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 from particle physics to cosmology. It is the division of reality into natural units, and the fact that these units form aggregates, which is the basis of the phenomenon of *counting*, of the division of the natural units into *groups, organizations, populations, ethnicities, breeds, species*, and so on. It is the division of certain portions of reality into engineered units which is the basis of modern industrial technology, which rests on the distributed mass production of pre-engineered parts through division of labor and on their reassembly into larger, compound units. Material entities which cannot be counted, in contrast, are clouds, mountains, geological layers, habitats, portions of liquid concrete being poured into a hole, and so forth.

BFO rejects Kantian views, which see reality as an undifferentiated mass (or as an undifferentiated process flux), the true structure of which lies behind a veil that is either impenetrable to humans or penetrable only by the practitioners of some future perfected microphysics.

Examples of such units of special importance for the purposes of natural science include: 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 if an entity is properly categorized as BFO:*object*, then it instantiates this universal independently of any granularity considerations.

Elucidation of BFO:*object*

The following elucidation is provided not as part of a formal theory (of qualitative mereotopology), but rather 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.

We first characterize what it means for a material entity to be causally unified, as follows:

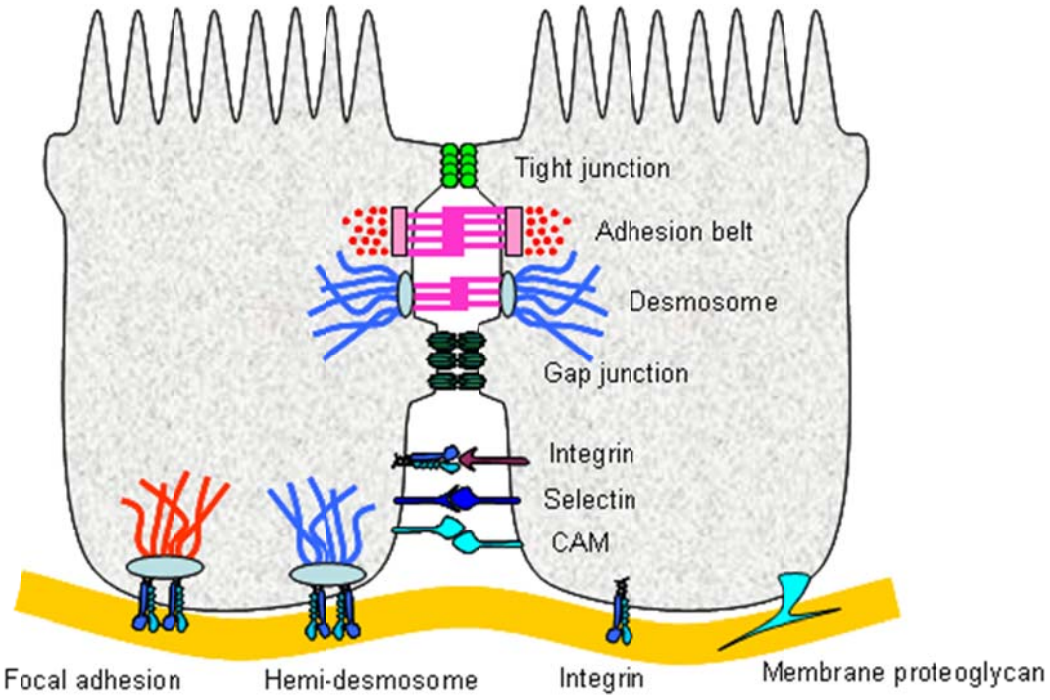
> Elucidation: *a* is *causally unified* means: *a* is a material entity which *either* has no material subparts *or* is such that its material parts are tied together in such a way that, in environments typical for *entities* of the type in question,
>
> a. if a part in the interior of *a* is moved in space 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)
>
> b. 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*

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

(1) Each *object* is a *material entity*. (Hence, like *material entities* in general, each *object* is spatially extended in three dimensions.)

(2) Some *objects* have immaterial parts (the lumen of your gut, the hull of your ship, the filled hole created by an insect trapped in a portion of amber).

(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. (See Figure)



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

(4) Each instance of an *object* universal is causally unified (see above).

(5) This causal unity holds for one or more of the following reasons:

a. The parts of the object 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)

b. The parts are combined together causally through a common membrane or physical covering pointing outwards toward and serving as a boundary in relation to what lies on the exterior of the *object*. (See "16 Days", especially the passages referring to Ingarden's theory of relatively isolated units.)

- The 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.)

- The membrane may be connected to other material *entities* in its environment by means of conduits allowing movement of gases or liquids (as a laptop, for example, may be connected to a charging device by means of wires).

c. 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 (5), 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*.

(8) Objects may contain other objects as parts. They may do this either

- by containing object aggregates as parts, for instance the collection of blood cells in your body is an object aggregate
- by containing objects which are bonded to other objects in such a way that they cannot move separately, as in the case of a lump of iron

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 muscle on a rock, a slimemold, a slice of cake, a pencil, a laptop, a railway carriage, a space ship, a pizza, a 100-mile long tree in Wisconsin, a popypeptide chain.

In virtue of (3), atoms which become part of a molecule through bivalent bonds to still be objects in their own right rather than fiat object parts.

Note that not everything that is causally unified in the sense explained above is an object. Intuitively, objecthood requires causal unity plus a topology which allows an interior and an exterior to be defined, whereby the exterior has special properties (as in the case of biological membranes) which prevent absorption of or fusion with other objects of like type. Clouds and galaxies are subject to the phenomenon of arbitrary fusion (just as clouds can join together arbitrarily to form larger clouds, so also galaxies grow by attracting smaller galaxies as they pass by).

Recommendation: classify clouds as object aggregates and galaxies as obect aggregates.

Axiom: Objects retain their objecthood for as long as they exist. A human body continues to exist even after being buried in a pile of cement. A watch taken apart for repair ceases to exist until it is reassembled.

A conjoined twin in the passage from before to after separation may be used to test this axiom. The following seems to be a consistent set of assertions:

- Twin1 & Twin2 exist both before and after separation.
- Twin1 & Twin2 are both organisms.
- Every organism is an object.
- Successful surgery in cases of conjoined twins is possible only where twins do not share vital organs.

Object artifacts

Objecthood is easily assigned in the case of portions of solid, rigid matter (a chair carved out of a single block of wood or stone). A chunk of iron retains its objecthood for as long as it exists.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. 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

Elucidation: *a* is an *object aggregate* =Def. *a* is a *material entity* consisting exactly of a plurality of *objects* as **parts** which may move independently in space and which are not causally unified.

a is an object aggregate → if *a* exists at *t*, then there are objects o_1, …, o_n at *t* such that:

for all *x* (*x* **part of** *a* **at** *t* iff *x* overlaps some o_i **at** *t*)

An object aggregate is a collection of separate objects. Thus not every collection of objects is an object aggregate. (The collection of atoms in a lump of iron is not an object aggregate.) An object aggregate may be defined by fiat – for example in the case of the aggregate of members of an organization. Object aggregates in such cases may gain and lose object parts while remaining identical.

Some objects may contain object aggregates as parts – for example you contain what is, at any given time, the aggregate of your blood cells. But an object is, by the above, never identical to an object aggregate.

Examples: a cloud in the sky, a symphony orchestra, the aggregate of bearings in a crank shaft, your collection of Meissen ceramic plates.

2.1.1.3 Fiat object part

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

Examples: upper and lower lobes of the left lung, the dorsal and ventral surfaces of the body, the Western hemisphere of the Earth, your head. (Compare FMA: regional part)

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

Do we need to recognize a subuniversal to deal with (polypeptide) chains?

Portions of matter are not extra *entities*

BFO (in contrast to DOLCE) 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 bronze during the period when it plays the statue role. (The portion of bronze may have immaterial parts. Such parts are then, trivially, parts of the statue also.)

If an entity is in one of the three categories – object, fiat object part, object aggregate – at any given time in its existence, then it is so at all times. A leaf (plant organ) falls from a tree. A uterus is explanted. An atom becomes bound up with other atoms in a molecule. A cell becomes bound with another cell in an organism (both cells preserve their existence). A cell divides into two cells (the first cell ceases to exist).

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. Immaterial entities under the former headings are in some cases **parts** of their hosts; in some cases they are external thereto.

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)

2.1.2.1 Object boundary

a is an *object boundary* =Def. *a* is an *immaterial entity* that is **boundary-dependent** on some material entity.

Axiom: Every *object boundary* is a lower-dimensional **part_of** some *material entity*.

On defining 'dimension' see here.

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.

Are there any bona fide examples of object points?

2.1.2.1.2 One-dimensional object boundary (object line)

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

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

2.1.2.1.3 Two-dimensional object boundary (object plane)

See Table 1.

Table 1. Fragment of Foundational Model of Anatomy
▬ Anatomical boundary entity ▬ Anatomical surface

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 interior of the trunk of your car, the interior of your refrigerator, the interior of your office, Manhattan Canyon)

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. As the ship moves through space, its hull moves also. As you pinch and unpinch your nose, your nostril dilates and expands.

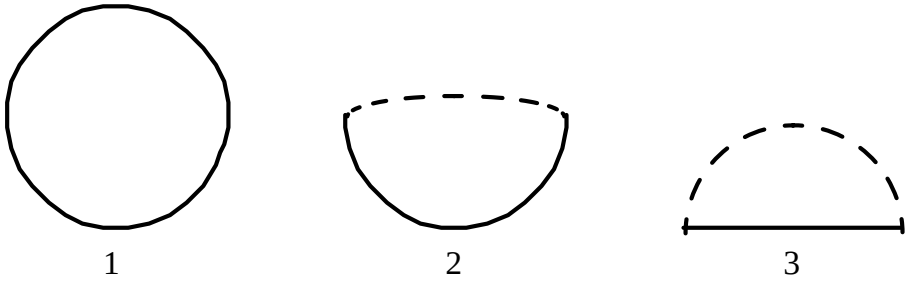


Figure 1: Examples of Types of Site

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

We recommend that users of BFO:*spatial region* specify the coordinate frame which they are employing, for example, when dealing with spatial regions on the surface of the Earth, the coordinate frame of latitude and longitude. Such coordinate frames 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: A spatial region is, intuitively, a 0-, 1-, 2- or 3-dimensional part of space. This elucidation will fall short, however, unless it is understood in a way that conforms with what we know from the theory of relativity. One step in this direction is to add: a spatial region is the sort of entity that can be specified by means of a coordinate frame, and is always at rest relative to this coordinate frame.

Example: The Tropic of Capricorn (with the coordinate frame defined by the lines of latitude and longitude)
Spatial regions have no qualities except shape, size and relative location.

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.

2.1.2.3.1 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_at** 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.*

Examples: your heart **located_in** your body; stem cell **located_in** bone marrow; portion of cocaine **located_in** portion of blood

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_at** r_1 **at** *t* and *b* **located_at** 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*.)

Relation of specific dependence

a **s-depends on** *b* **at** *t* =Def. *a* exists **at** *t* & *a* **s-depends on** *b*

2.2 Specifically *dependent continuant*

Sub-types of *specifically dependent continuant* recognized by BFO are:

quality

relational quality

realizable entity

role

disposition

function

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 this heart: to pump blood, John's love for Mary.

a **inheres in** *b* =Def. *a* is a *dependent continuant* & *b* is an *independent continuant* & *a* **s-depends on** *b* & for all *c* (if *a* **s-depends on** *c* **at** t_1 then overlap(*b*, *c*))

Inherence is a subrelation of specific dependence which holds between a dependent continuant and an independent continuant. It is also required to be (weakly) functional. Thus relational qualities such as love or taller_than do not inhere in their bearers.

a **bearer_of** *b* **at** *t* =Def. *b* **s-depends on** *a* **at** *t* or *b* **g-depends_on** *a* **at** *t*

'Bearer' is a shorthand term of convenience.

2.2.1 Quality

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

Thus, solubility requires a process to be manifested in some solid piece of salt or sugar, while their crystalline quality does not.

Examples: the color of a tomato, the ambient temperature of a portion of air, the length of the circumference of your waist, the shape of a nose, the mass of a piece of gold, the weight of a chimpanzee.

Axiom: If an *entity* is a *quality* at any time that it exists, then it is a quality at every time that it exists. For some qualities, e.g. color, **s-dependence** is not on material bearer but on surface of material bearer. (See discussion of boundary dependence above.)

Qualities of spatial regions are restricted to qualities of size, shape and position.

2.2.1.1 Relational quality

There are relation qualities, for example: loves, taller_than, 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.

a **quality_of** *b* **at** *t* =Def. *a* is a quality & *b* is a material entity & *a* **s-depends_on** *b* **at** *t*

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** in *processes* of a correlated type.

Examples: the role of being a doctor, the function of your reproductive organs, the disposition of your blood to coagulate, the disposition of this piece of metal to conduct electricity.

Relation of realization

Elucidation: if *a* **realizes** *b* **at** *t*, then this means that there is some *material entity c* & *a* is a *process* in which *c* **participates at** *t* & *b* is a *disposition* or *role* of which *c* is **bearer**.

Note that *t* here ranges over *temporal intervals*, rather than over instants of time (*temporal boundaries*).

There are also reciprocal *realizable dependent continuants* (e.g. husband/wife; blocking dispositions).

Axiom: if a realizable entity entity is realized, then its bearer participates in this realization.

2.2.2.1 Role (Externally-Grounded Realizable entity)

Elucidation: *a* is a *role* means: *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.

'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 an infection
- the role of a stone in marking a boundary

Optionality of Roles

Because a role is not a consequence of the in-built physical make-up of its bearer, roles are optional in the sense that the bearer of a role can lose the role without being thereby physically changed. Most of the roles we here distinguish involve some form of social ascription or imputation. Candidate non-social roles however include therapeutic and prophylactic roles, input and output roles, and positional roles (for example a given protein plays the role of peripheral membrane protein). For example, the primary function—or input role—of mitochondria is to produce adenosine triphosphate (ATP). 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.

It is sometimes claimed that there are obligatory symbionts which constitute a counter-example to the thesis of optionality of roles. In fact, however, because even if organisms require complementary organisms in order to survive, the absence of such complementary organisms will not lead immediately to the death of the organism in question. Thus the latter will survive, even if only for a short period of time.

Having a role vs. playing a role.
There is 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.

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

Attribute role classes

The correct form for generating phase sortal expressions involving reference to roles is as follows:

- student(*a*, *t*) =Def. *a* **has_role** student role **at** *t*

Here ‘student(John, *t*)’ means: John is a **member_of** the attributive class *student* **at** *t.*

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. Here the correct form of attribution definition is roughly as follows:

biological_father(*a*) =Def. male(*a*)
& some zygote #1
& some child #2

& some process of fertilization #3
& #1 **output_of** #3
& *a* **agent_of #3**
& #2 **transformation_of** #1.

2.2.2.2 Disposition (Internally-Grounded Realizable entity)

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.

Examples:

- 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.

Unlike roles, dispositions are not optional. If an entity is a certain way, then it has a certain disposition, and if its physical makeup is changed then it may lose that disposition. A disposition can for this reason also be referred to 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* in which it inheres.

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 between two *entities*, if they are in certain circumstances.

Each disposition type is associated with one or more characteristic realization process types – instantiated by those processes in which it is realized. Dispositions may also be associated with

characteristic trigger process types – instantiated by processes (for example of being dropped on a hard surface) in which they are realized. (See A. Bird's theory of causality based on dispositions and triggers.)

Diseases are dispositions according to the Ontology for General Medical Science (OGMS). We are referring to disposition also when we consider genetic and other risk factors for specific diseases. These are predispositions to disease – in other words they are dispositions to acquire certain further dispositions. The realization of such a predisposition consists in processes which change the physical makeup of their bearer in such a way that parts of this bearer serve as the physical basis for a disease. This physical basis is referred to be OGMS as a *disorder*.

2.2.2.3 Capability (Should we include? 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

Hypothesis: *a* is a capability means that *a* is the sort of thing that can be a function in some appropriately designed bearer. If *a* has capability *b*, then very likely something is built do have *b* as its function. E.g. a mouth has the capability to emit a whistling sound.

2.2.2.4 Function

A *function* is a disposition that exists in virtue of the bearer's physical make-up 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
- 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 the heart's function is to pump blood, and not merely to make thumping produce sounds. The latter are by-products of the heart's proper functioning.

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. In some cases an entity may preserve its function even while it is physically changed in ways which make it incapable of functioning. 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 for example through clinical intervention or mechanical repair. 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.

To exercise its function the bearer needs to be in the right kind of context, or provided with the right kind of input. (See triggers, above.)

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_1 and *b* exists **at** t_1 and for some *B* it holds that (*b* **instantiates** *B* **at** t_1) and necessarily, for all *t* (if *a* exists **at** ***t*** then some instance of *B* exists **at** *t*)

Axiom: if *a* **g-depends on** *b* **at** t_1 at 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.

Axiom: all cases of generical dependence are 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 (complex qualities) 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 logo, the pattern of a traffic sign. 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 paint on the traffic signboard, your social security number , your recipe for spaghetti carbonara.

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.*

Generically *dependent continuants* can be **concretized** in multiple ways; you may concretize a poem in your head by reading it to yourself and creating an instance of like pattern. 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 example, are patterns, qualities instantiated 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*. 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, however, in that, once they have been created, they can exist in many copies that are all of equal value.

Music

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. The score is an instance of the generically *dependent continuant* type *plan specification*, which is **concretized** as a network of plans – distributed across the minds of the conductor and the members of the orchestra – to create a corresponding *musical performance*. This

network of plans is a complex *realizable dependent continuant* which is **realized** when conductor and orchestra work together to realize the plan by creating a performance of the symphony by creation a process which involves a pattern of air vibrations conforming to the score and audible to an audience.

Research protocols

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* **at** *t* and *b* **g-depends** on *c* **at** *t*, and if *b* migrates from bearer *c* to another bearer *d* than an exact copy of *a* will be created in *d.*

3. *Occurrent*

Occurrents, in contrast to continuants, provide little in the way of natural units and few opportunities for counting. Those opportunities which do arise are typically either parasitic on the existence of natural units on the continuant side or they are fiat in nature. Thus for example we can count *lives*; we can count football games.

Elucidation: an *occurrent* is an *entity* that has **temporal parts**.

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.

Since *temporal regions* are **temporal parts** of themselves this means that *0-dimensional temporal regions* are also *occurrents*.

Subtypes of *occurrent* are:

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

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 exactly **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* **part_of** *b* & *a* and *b* are *occurrents* & for some *spatiotemporal* or *temporal region r*, *a* **occupies** *r* & *b* **occupies** a region including *r* as **part.**

Life / course / trajectory / history

The life (?) of a *material entity* is the totality of processes taking place in the spatiotemporal region **occupied** by that *material entity*.

Problem: neutrinos passing through.

Need to appeal to **agent_of**?

Relation of boundary-dependence for *occurrents*

a is **boundary_dependent_on** *b* =Def. *a* and *b* are *occurrents* & *a* **temporal_part** of *b* **at** *t* & *a* is necessarily such that it cannot exist unless either (*b* exists or there exists some **temporal_part** of *b* which includes *a* as **temporal_part)**

The missing **'at** *t*' here signifies that this is a relation between occurrents

a **temporal_boundary_of** *b* =Def. either *a* is an *occurrent* & *a* is **boundary-dependent** on *b* or *a* **instantiates** *0-dimensional temporal region*

Process

p is a process =Def. *a* is an *occurrent* that has **temporal proper parts** and **s-depends** on some material entity.

Examples: the life of an organism, the process of sleeping, the process of cell-division, a beating of the heart, the process of meiosis, the course of a disease, the flight of a bird, the process of aging.

Process boundary

A temporal boundary of a process (event)

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.

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 unfold in a continuous series from other pre-life processes such as fertilization and they unfold in turn in continuous series of post-life processes such as post-mortem decay. Clear examples of boundaries of processes are almost always of the fiat sort (the beginning or end of a race, midnight.

Process boundary
p is a *process boundary* =Def. *p* is an *occurrent* entity which **boundary-depends** on a *process*.

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

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, the millennium

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 one or other determinate quality subtype must in every case be instantiated. These structural dimensions of an organism are captured in the anatomist's idea of a *Bauplan*.

There are analogous structural dimensions of processes, which we call 'profiles'. The idea is that for processes of a given sort, for example processes in which cells or organs participate, there is a repertoire of such profiles. (Compare de Bono et al. on the variables encoded in physiology models used in the study of physiological processes.

These process profiles are essential to the processes in question in the sense that shape, for example, is essential to a continuant entity. Johansson talks in this connection of *4-dimensional process shapes*. Just as you must have some determinable three-dimensional spatial shape at any given time, so also any given instance of your walking must have some determinable four-dimensional process shape. But which *determinate* shape, under either handing, can of course vary from occasion to occasion.

You are not a shape. That is, you are not an instance of the universal shape. Rather, your shape (this particular instance or shape trope, the specifically dependent shape quality that is yours and yours alone) is an instance of the universal shape, and it instantiates different determinable shape qualities at different times.

Similarly, your process of walking is not a process shape. That is, this process is not an instance of the universal process shape. Rather its process shape (this particular instance, the four-dimensional shape profile that belongs to it, and to it alone, as structural part) is an instance of the universal four-dimensional process shape profile, and it instantiates different determinable four-dimensional process shape profiles on different occasions of walking.

The repertoire of process profiles included, for example, in those processes which are the functioning of your heart will include, in addition to the process shape profile also 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.

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 structural parts (compare, again, shape, or the mass of a material entity) – *entities* which cannot exist except 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 instantiate *some* determine profile subtype for any given functioning of your heart as a pump.

In the draft Towards a Definition of Rate, we use the beat profile example to provide a preliminary account of predications of rates to processes, including processes whose rates are changing discontinuously or continuously. The beat profile is illustrated by heart beat processes, by drumming processes, and by simple cyclical processes (birthdays, …) in general. 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.

While there are no qualities of processes analogous to the qualities we find on the *occurrent* side, there are clearly many ways in which we make assertions about processes, in which attributes or features seem to be ascribed to processes in a way analogous to the way *qualities* are ascribed to *material entities*. We now offer an account of major families of such assertions by means of the theory of process profiles. An example of a process profile on which we will concentrate is the beat profile. Every beating process is a beating process in virtue of its including some beat profile as a structural, organizing process part.

Further examples of process profile types, with subtypes provide for illustrative purposes, include:

- auditory profile (for example that part of the process of a heart's beating which is audible).
- four-dimensional process 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/s^2 acceleration profile
        - 32 ft/s^2 acceleration profile
        - 33 ft/s^2 acceleration profile
    - increasing acceleration profile

The types and subtypes herer are analogous to the types and subtypes of qualities recognized by BFO-conformant ontologies, for example:

- length

6 cm length

7 cm length

The user must however bear in mind, in both sets of cases, the subtypes in question, while they need to be formulated using a specific unit of measure, are in fact unit-specification independent.

In the case of a body moving with a constant speed, we need to distinguish, in addition to (1) the process of moving also (2) its determinable speed and (3) the determinate speed (a real-number magnitude), referred to by means of (4) an expression (information artifact) such as '7 m/s'.

We accept (1) and (4) but not (2) and (3) as instances of BFO categories. Why is this so? Compare the parallel case on the side of qualities of *continuants*. There we can imagine an *independent continuant* object, John, who, on a certain day, either does or does not go on a diet. In the former case his weight quality will decrease, it will go darker, in the latter case this quality will remain constant. In either case John will remain the same individual as he was before the day in question.

In the case of a process, in contrast, no parallel scenario is imaginable. This is because there is no extra entity which could be imagined to vary from one time to the next while the process itself would remain the same individual process. If something varied, then the process itself would be a *different* process.

To predicate speed, for instance '7 m/s', to a process of motion is in fact to assert – roughly – that that the process in question *is of a certain determinate type*. More precisely, it is to assert that the process in question contains as one of its structural parts a corresponding motion profile which instantiates the determinable universal: *speed* and also the determinate universal: *7 m/s speed.*

Why processes do not change

Processes do not change, because processes *are* changes. They are changes in those *independent continuants* which are their participants.

For *continuants*, predications may need to be time-indexed in order to be true. For example, if *a instantiates* larva at *t*, then it does not follow that *a instantiates* larva *simpliciter*. For ocurrents, in contrast, instantiation relations always hold *simpliciter*. This is because, while *continuants* can change their type from one type to the next (e.g. a fetus becomes an embryo becomes an infant …), *occurrents* can never change their type from one time to the next. Certainly an *occurrent* can for example involve

parts which are of different sorts in different times. A process of movement can, for example, have speed v_1 at one time and then have a different speed v_2 at a later time. But there is then nothing in the realm of *occurrents* which *changes*; rather, there is (*simpliciter*, un-time-indexedly) a process with two different parts.

Processes can be arbitrarily summed and divided. In particular, we can identify sub-processes which are fiat segments occupying constituent temporal intervals of the temporal interval occupied by the process as a whole – for example your heart-beating from 4pm to 5pm today; the 4th year of your life.

How to deal with predications of processes

To assert, now, that a beating process *has rate 4 bpm*, is to assert that there is some beat profile which is a **part of** this process and which **occupies** the same temporal interval as this process and which **instantiates** the determinate universal: *4bpm beat profile*.

More generally:

'*p* has F of value *n* and unit *u*' is an abbreviation of convenience for: there is some process profile p_o which is **part of** *p* and which **occupies** the same temporal interval as *p* and which is an **instance** of the determinable F-process profile type and which is an **instance** of the *n u*s F-process profile determinate type.

States as Static process profiles

For many (all?) process profiles we can distinguish static (or 'null') process profiles. Thus for example a null beat profile is a beat profile in which there are zero beats per interval of time; a null velocity profile is one in which velocity is zero, a null acceleration profile is one in which acceleration is zero, and so on.

Processes with null process profiles are often called 'states' (state of rest, state of uniform motion, …). 'States' are special sorts of processes (they are processes in which, along the relevant dimension, nothing happens). Such states can be highly complex: consider 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.

Comparing Qualities

Let Q be a quality universal , DSU(Q) = all determinate sub-universals of Q.
For example Q = length, DSU(Q) = 1 cm-length, 1.5 cm-length, 2 cm-length, etc. (again, each DSU is structured independently of choice of units of measure).
Here DSU(Q) is ordered linearly, so that there is an isomorphism from DSU(length) to the real numbers, and in virtue of this isomorphism we can define 'shorter-in-length than' accordingly in terms of 'less than' for real numbers.
Here, the structure of DSU(Q) explains how length qualities relate to each other.

DOLCE reifies a 'quality space' as a mathematical entity not only for each quality, but also for space and time. Thus it is a certain mathematical entity which serves, in DOLCE, as the representation of what it means to say that two people are standing next to each other. Each person is mapped to a certain region in a certain quality space, and these two regions are adjacent.

Comparing Process (Profile) Types

Let P be a process profile universal (e.g.), DSU(P) = all determinate sub-universals of P.
For example P = regular-beat-process-profile, DSU(P) = 60 bpm beat process profile, 61 bpm beat process profile, 62 bpm beat process profile, etc. (again independently of choice of units of measure)
Here DSU(P) is ordered linearly, so that there is an isomorphism from DSU(P) to the real numbers, and we can define 'beats faster than' accordingly in terms of 'greater than' for real numbers.
The structure of DSU(P) explains how beat processes relate to each other in terms of faster and shorter.

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.

3+1-dimensional spatiotemporal region

3+0-dimensional spatiotemporal region

Temporal region

Def. An *occurrent* entity that is part of time.

An *occurrent* entity upon which a process can be projected.

1-dimensional temporal region (temporal interval)

Example: the temporal region during which a process occurs.

0-dimensional temporal region (temporal boundary)

A temporal boundary of a temporal region.

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

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

Lacks?
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
http://code.google.com/p/obo-relations/