Chapter 6

Introduction to Basic Formal Ontology

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Introduction to Basic Formal Ontology: Occurrents

Having presented the *continuant* categories of BFO, we will now focus on the *occurrent* categories starting, again, with the most general, and then working downward through their respective subtypes. The occurrent portion of BFO represents entities that occur, happen, unfold, or develop in time. In commonsensical terms, these entities are occurrences or happenings or the processes of change; they are the ontological counterparts of present participles (runnings, swimmings, dividings, orbitings).

A BFO *occurrent* is, more precisely, either an entity that unfolds itself in time, or it is the instantaneous boundary of such an entity (for example, a beginning or an ending) along what we can think of as the time axis, or it is a temporal or spatiotemporal region that such an entity occupies. *Occurrent*, correspondingly, has four subtypes:

• BFO: *process*

• BFO: *process boundary*

• BFO: *temporal region*

•  BFO: *spatiotemporal region*

BFO: Process

A BFO: *process* is an *occurrent* entity that exists in time by occurring or happening, has temporal parts, and always depends on some (at least one) *material entity*. The dependence here is analogous to that which we find in the relation between a specifically dependent continuant and its independent continuant bearer(s). Examples of BFO: *process* include the life of this organism, that process of meiosis, the course of this disease, that flight of that bird, this process of cell division, this fall of water down this waterfall. My headache (experience of pain in my head) is dependent on me. It cannot also be *your* headache. I can feel your pain, but only in the sense that you and I may experience qualitatively identical pains. But the pain experiences themselves will be numerically distinct; they will be two distinct instances of the same type of pain experience.

The first key feature of processes is that they have temporal parts. Whereas John, considered as a substance, exists along with all of his parts at every instant in which he exists at all, there is no instant of time at which the process we call “John’s life” would exist as a whole. Rather, this process unfolds along (and is divided out among) a series of temporal parts, such as for instance John’s childhood, his adolescence, his adulthood, his old age; the first year of his life; the seven-thousandth minute of his life, and so forth. These are all temporal parts of John’s life, and reflect the fact that John’s life can be partitioned into temporal parts in different ways and at different levels of granularity.

Processes such as John’s life thus have many other processes as parts. Some are temporal proper parts of John’s life (for example, the process that is the sum total of what happens to John during his childhood); some are temporally coextensive with John’s life (for example, the process of change in John’s temperature from the beginning to the end of John’s existence).1 Each of these processes also has its own existence extended in time, and hence its own temporal parts.

Just as there are relational qualities, so also there are relational processes, which depend on multiple material entities as their relata. For example, John courting Mary, a moving body’s crashing into a wall, a game of snooker, the videotaping of an explosion, a war.

Objects, as we have seen, can gain and lose parts while maintaining their identity. In the case of processes, in contrast, the gain and loss of parts is ruled out as a matter of necessity. This is because, if two processes should differ with regard to even the smallest part, then these two processes are nonidentical. John is still John (still numerically the same John) even if he suffers the loss of his arm in an industrial accident; but the process that is John’s life and in which he loses his arm is *not the same life as* the process that is John’s life (in what we might think of as some alternative possible world) in which he does not lose his arm. John can survive as the same individual (continuant) across many different changes to his parts and qualities, but there is only one life that is his, and this is so independently of whether he can choose how to live this life as it unfolds.

BFO: History

BFO: *histories* are one important subtype of *process*. Each material entity and each site has from the BFO point of view a unique *as(history)[history*, which is defined as follows:

history = def. the sum of all processes taking place in the *spatiotemporal region* occupied by the material entity or site in question

A history (occurrent) is thus always a history of something (continuant). What is interesting about histories is that they are, in an important sense, complete. For example, the history of John is the sum of all processes that have occurred within John throughout the course of his entire life, at all granularities. Thus the history of an object such as John is more than just the totality of events that might be described in John’s biography. It *]It* will include also, for example, all the movements of neutrinos within his interior as they pass through, the movements of his blood cells, as well as the movements of his heart and lungs and of all other constituent organs of his body, and so forth.

The relation between a material entity and its history is one-to-one. Histories are thus very special kinds of processes, since not only is it the case that, for any material entity or site, there is exactly one process which is its history; it is also the case that (by definition of BFO: *history*) there is for every history exactly one material entity or site that it is the history of.

BFO: Process Boundary

A BFO: *process boundary* is an occurrent entity that is the instantaneous temporal boundary of a process. Process boundaries are the beginnings and endings of the processes they bound. More precisely: a process boundary is a temporal part that itself has no temporal parts (where the relation of temporal parthood is as defined in chapter 7). It is the limiting or smallest temporal process part. Examples include the forming of a synapse, the onset of REM sleep, the detachment of a finger in an industrial accident, the final separation of two cells at the end of cell-division, the incision at the beginning of a surgery, where all these terms (“forming,” “incision,” etc.) are understood as referring to instantaneous changes rather than to the results of such changes. (We leave open the question whether process boundaries—like object boundaries—are always fiat in nature, and also whether they manifest something like the granularity dependence that we identified in the realm of continuants.)

BFO: Spatiotemporal Region

A *spatiotemporal region* is an occurrent entity at or in which occurrent entities can be located. A spatiotemporal region is part of spacetime (that is: it is a part of the whole of spacetime) and each spatiotemporal region is defined relative to some frame of reference involving a four-dimensional system of coordinates. Just as BFO, in its continuant representation of entities, views space as a container within which objects and their qualities exist, so the accompanying occurrent representation of processes views spacetime as an analogous container, within which processes unfold and in which spatiotemporal regions can be identified as parts. Examples of such spatiotemporal regions include the region occupied by a human life, the region occupied by the development of a cancer tumor, the region occupied by a process of cellular meiosis, or the region occupied by a war.

BFO’s occurrent ontology, in its current version, thus views spacetime, as a whole, existing in its entirety in its four (three plus time) dimensions. Processes, in this spacetime, have a duration, a beginning, and an end. One can think of each process as a temporally extended continuum, a spacetime *worm*, stretched out in and through the single unified container that is the entirety of spacetime. We note that this view of spacetime worms is distinct from popular four-dimensionalist views according to which objects (such as molecules or people or planets) would themselves be extended in time and would have temporal parts. BFO does indeed embrace a four-dimensionalist perspective; but it combines this with a three-dimensionalist perspective for continuants, and does not attempt to reduce the one to the other.

BFO: Temporal Region

A *temporal region* is an occurrent entity that is a part of time (of the whole of time). Temporal regions differ from spatiotemporal regions in that they are extended or serve as boundaries only along the temporal dimension. A temporal region is the result of projecting a spatiotemporal region onto this temporal dimension.

Temporal regions are introduced in BFO to provide a basis for consistent representation of temporal data. Since there is no absolute time, temporal regions—like spatial regions—require for their representation some selected frame of reference. Users of BFO 2.0 are thus encouraged to specify the temporal coordinate system they are using, but this will—in all the applications known to us currently—be either identical to or trivially intertranslatable with the coordinate systems employed by other users (thus with the clock and calendar systems used for keeping track of terrestrial time).

Since temporal regions have temporal parts (are extended in time) in just the way that processes have temporal parts, they belong to BFO’s occurrent perspective. Reference to temporal regions is however employed also when referring to BFO’s continuant entities, for example, when we use them as a means for indexing relations between continuant entities such as parthood that hold only at certain times.

BFO: Zero-Dimensional Temporal Region

A *zero-dimensional temporal region*—also called a *temporal instant*—is a temporal region that is without extent. For all intents and purposes a zero-dimensional temporal region is a smallest instant of time just as a process boundary is a smallest temporal part of a process. Zero-dimensional temporal regions are the temporal regions that process boundaries are located in. Examples include 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 someone’s death, and the turn of the nineteenth century.

BFO: One-Dimensional Temporal Region

A *one-dimensional temporal region*—also called a *temporal interval*—is a temporal region that is extended in time. It has further temporal regions as parts, including its zero-dimensional temporal region boundaries. One-dimensional temporal regions are the temporal regions in which processes occur or unfold. For example, the temporal region that is the first hour of the day, or the nineteenth century, or the temporal region in which John’s life is located, or the temporal region occupied by World War II.

An Example of Occurrent Classification

Having outlined the occurrent perspective of BFO, we can now give a simple illustration of BFO’s classificatory power by considering how it classifies the entities that will be involved when a woman undergoes an electrocardiogram (EKG/ECG) at a cardiology clinic:

• the EKG test itself is an instance of *process,*

• the start and end of the test are instances of *process boundary,*

• the specific electrical activity measured by the test is an instance of *process,*

•  the points in time at which the EKG test starts and ends are instances of *temporal instant,*

• the time taken by the test as a whole is an instance of *temporal interval*

• any slice of spacetime during the EKG test, for example as represented on the output graph, is an instance of *spatiotemporal instant*

Classifying Universals with BFO

As we noted at the beginning of chapter 5, the categories and relations recognized by the BFO continuant and occurrent perspectives can be used to talk about both universals and particulars. An ontology is by our definition a representational artifact whose representational units are intended to represent universals and relationships among universals on the side of reality, but we come to know what universals and relationships exist only by examining particular instances that we observe in reality, for example, in the context of a scientific experiment. And it is not only domain ontologies that are representations of universals (and, by extension, of their particular instances), but also formal ontologies such as BFO. Hence *temporal region*, like other BFO categories, has instances in reality, such as this five-minute interval starting now, and that five-year interval ending last midnight. You yourself are an instance of BFO: *object.* From the BFO perspective, if we are given a universal that current science tells us exists—has instances—on the side of reality, the first question we need to ask is whether these instances are *continuant* or *occurrent* entities. If the universal in question has *continuant* instances, then the next question is whether these are *independent continuant* instances or *dependent continuant* instances, and so on, until the appropriate formal ontological category has been located within one or other of the two BFO hierarchies presented in chapters 5 and 6. It should be noted that the formal-ontological relationships that obtain between different ontological categories will imply also relationships among the instances of these categories. For example, if BFO: *quality* is dependent upon BFO: *material entity*, then every instance of the quality *red* is dependent upon some instance of *material entity* to serve as its bearer.

Exhaustiveness of BFO Categories

BFO is an ontology that is designed to support information-driven scientific research, and itself shares some of the features of an empirical scientific theory. Thus BFO changes (albeit very slowly) in reflection of lessons learned through use, and it will continue to change in the future. Thus it is possible that there are domain-neutral universals (types of entities) in reality that are needed to perform an adequate job of annotating the results of scientific experiments that BFO has thus far failed to incorporate.

Consistent with BFO’s principle of fallibilism, we acknowledge that it is possible that future research in ontology and in the natural sciences, as well as continued attempts at specific domain implementations, will reveal the need not only for an expansion of the top-level categories of BFO but also for corrections of its treatment of the universals already recognized. Such corrections have been made already in the development of earlier versions.2 Clearly, changes in an ontology such as BFO that is used by a large number of independent groups must be managed on the basis of a careful scientific review process involving collaboration between end users and ontology developers and providing documentation of the principled reasons for any proposed changes.

BFO’s Perspectivalism

We have now reached the point where the perspectivalism underlying BFO can be more clearly stated. The *continuant* perspective of BFO represents some portion of space and its *continuant* occupants—including qualities of these objects—as they exist at given instants of time. But it does this in such a way that the identity over time of regions of space, and of material entities occupying such regions, and of qualities and other dependent continuants, can be asserted. In this way BFO avoids any reductionist view of continuants as mere sums of object slices or object stages. Time is in a sense external to the continuant perspective, and an assertion to the effect that a given material entity has a given quality at a given time, or that a given material entity is a part of another material entity at a given time, is represented not by referring to the temporal regions involved as extra entities, but rather by using temporal indexing of the pertinent relational verb.

BFO’s *occurrent* perspective, by contrast, represents regions of time, and of spacetime, and the processes that occupy them, as if they were being viewed from the perspective of an idealized observer who is assumed to be outside of time. Time is thus internal to the occurrent perspective—the observer discovers that processes can be ordered along the temporal dimension and that they occupy successive temporal regions, the latter being represented explicitly as extra entities. On this view both times and the changes that occur in these times are represented. The occurrent perspective thereby captures the continuous flow of processes each blending into the next, with process parts being distinguishable within larger process wholes on successively finer levels of granularity. The transformation of Jill’s hair from blond to brown can be represented as an occurrent process, involving various part processes (changes in color of individual hairs, chemical processes in each hair shaft, processes of cuticle penetration, and so forth).

But it is also possible to represent the passage of time and the occurrence of change from the continuant perspective. This is done by lining up a series of representations of a given portion of reality as it exists at a corresponding series of different times, and then observing the differences and similarities between the objects represented. Such representations can take account also of changes in qualities. Thus we might have a continuant ontology including a representation of Jill (*object*) from last year when she had blond hair (*quality*), and another *continuant* ontology including a representation of Jill as she is this year, when her hair is brown. One could then point to the difference in hair color as a change in quality, but nevertheless identify the object in which this hair color inheres, namely Jill (or Jill’s hair), as numerically identical in the two cases.

Using anatomy and physiology as exemplars, we can say that the continuant perspective corresponds to anatomy, the study of the three-dimensional kinds of structures inside the body, while the occurrent perspective corresponds to physiology, the study of the kinds of processes in which these structures participate. And if we can imagine that there is a single representation of physiology for a given organism extending across the entire set of processes constituting the organism’s life, then we must contrast this with the need for a series of distinct anatomical representations as the continuant structures making up the organism change from one life stage to the next—for example, from embryo to fetus to child to adult, and so forth.

Thus the BFO ontology is perspectival along two major dimensions, as illustrated in figure 6.1, which represents the distinction between BFO’s continuant perspectives (in the left-hand quadrants) and its occurrent perspective (in the right-hand quadrants). This figure also illustrates (along the vertical dimension) how BFO distinguishes between different granular perspectives, with coarser and finer grains in the top and bottom quadrants respectively. As we saw already, one and the same material entity can reappear in different BFO granular perspectives, as when, for example, a symphony orchestra appears as aggregate of players and conductor, as a collection of cells and extracellular material, as a collection of molecules, and so forth.

[Insert figure 6.1]

BFO’s Perspectivalism in Practice

The Open Biological and Biomedical Ontologies (OBO) Foundry (formerly the Open Biomedical Ontologies Foundry3) is a collaborative experiment in which some dozen ontologies are thus far involved, including the Gene Ontology (GO) at its core. The OBO Foundry is based on the voluntary acceptance of an evolving set of principles of good practice in ontology development by its participants. These include the requirement that ontologies:

• serve as controlled vocabularies to ensure the accumulation and comparability of scientific research,

• demonstrate usefulness in the annotation and integration of data resources, and

• be semantically interoperable.

The ontologies in the OBO Foundry suite are designed also to bring the benefits of modular development, with collaborating groups of experts taking responsibility for the representations of the entities and relations in their respective domains of expertise.

BFO provides the common upper-level ontology architecture for all the OBO Foundry ontologies, and it thereby also provides the framework within which we can understand the relations between these ontologies as they are developed by separate teams working in tandem. Here GO’s three constituent ontologies of Cellular Components (independent continuants), Molecular Functions (dependent continuants), and Biological Processes (occurrents) are mapped within a framework defined in terms of BFO’s categories along the horizontal dimension and in terms of levels of granularity along the vertical as in figure 6.2.

[Insert figure 6.2]

Further Reading on Processes and Events

<jrn>Dretske, Fred. Can Events Move? *Mind* 76 (1967): 479–492.</jrn>

<bok>Galton, Anthony. Qualitative Spatial Change. Oxford: Oxford University Press, 2001</bok>

<jrn>Grenon, Pierre, and Barry Smith. “SNAP and SPAN: Towards Dynamic Spatial Ontology.” *Spatial Cognition and Computation* 4 (1) (2004): 1–10.</jrn>

<bok>Sider, Ted. Four-Dimensionalism: An Ontology of Persistence and Time. Oxford: Oxford University Press, 2005.</bok>

<jrn>Simons, Peter. “Continuants and Occurrents.” *Proceedings of the Aristotelian Society* 74 (2000): 59–75.</jrn>

<jrn>Smith, Barry. “Classifying Processes: An Essay in Applied Ontology.” *Ratio* 25 (4) (2012): 463–488.</jrn>

<jrn>Zemach, Eddy. “Four Ontologies.” *Journal of Philosophy* 23 (1970): 231–247.</jrn>

Figure 6.1

The continuant and occurrent perspectives of BFO

Figure 6.2

Organization of the OBO Foundry ontologies (with the three branches of the Gene Ontology shaded)

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1. On this, see Barry Smith, “Classifying Processes: An Essay in Applied Ontology,” *Ratio* 25, no. 4 (2012): 463–488.

2. See Selja Seppälä, Barry Smith, and Werner Ceusters, “Applying the Realism-Based Ontology Versioning Method for Tracking Changes in the Basic Formal Ontology,” in *Formal Ontology in Information Systems: Proceedings of FOIS 2014* (Amsterdam: IOS Press, 2014), 227–240.

3. See <http://obofoundry.org/>, accessed December 17, 2014.

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