Roles and Their Siblings in Basic Formal Ontology

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Abstract

Roles are entities that pervade our everyday life as well as biologists' and medical specialists' actual practice. Their nature nonetheless remains nebulous in spite of a large amount of recent research on it in various disciplines. This paper aims to provide an in-depth study of the term 'role' in alignment with an upper ontology Basic Formal Ontology (BFO). Closer examination reveals that the meanings of the term 'role' can be well disambiguated in terms of five BFO categories: a generically dependent continuant, a site, a role, a disposition, and a function. We also discuss the BFO characterization of role and its practical utility in the biomedical field with a focus on its relation with the BFO methodological principle of ontological realism and other BFO realizable entities: dispositions and functions.

Keywords:

role, Basic Formal Ontology (BFO), ontological realism

I. Introduction

Talk of roles is ubiquitous in our ordinary life and in a number of different academic fields, ranging from knowledge representation [1] and conceptual modeling [2] to cognitive science and linguistics. Several examples of expressions comprising the term 'role' are listed below:

1. A passenger plays the role of a pilot on a commercial plane in an emergency. [3, p. 58]

2. Jane's being the seventh person to fill the role of director of this institute [4, p. 100]

3. Joe's being the third person to play a particular role in a play [4, p. 101]

4. A pyramidal neuron plays the role occupied by a damaged stellar neuron in the brain. [3, p. 58]

5. Jim has the role of a nurse. [4, p. 100]

6. the role of a stone in marking a boundary [4, p. 100]

7. the role of a magnet to attract iron objects

8. the role of the heart to pump blood

Roles are vital to biomedical ontologies at least in two respects. First, the term 'role' is frequently used in the biomedical literature: e.g., "the specific role of calcium in preventing disease." Second, healthcare systems would not be completely accounted for unless their organizational structure is well-specified in terms of roles, or especially so-called 'social roles' [5,6]. Examples of those medical roles include healthcare providers (e.g., doctors and pharmacists), receivers (e.g., patients), and policy makers (e.g., members of the World Health Organization). Therefore, a deeper understanding of roles will contribute to a robust construction and an effective utilization of biomedical ontologies.

Roles nevertheless remain nebulous entities, although they have been extensively researched in foundational ontology research for the last few decades [7]. For instance, it is a long-standing issue whether there is any single definition of role, some prior attempts [2,8] to offer it notwithstanding. Moreover, it is still a worthwhile challenge to provide a generic characterization of multiple meanings of role within a single theoretical framework. Despite some endeavors to meet it [9,10], little careful consideration has been given to a general ontology of roles *vis-à-vis* the biomedical domain.

In this paper we provide a close ontological investigation into the meanings of the term 'role' with an emphasis its usage of the term 'role'. To do so, we exploit Basic Formal Ontology (BFO) [3,4] as an upper ontology (aka foundational ontology), namely an ontology to furnish the most general categories (e.g., space and time) and relations (e.g., identity and parthood) to serve as a useful guideline for building domain ontologies of high semantic interoperability. The BFO-based exploration of the term 'role' would be of great value for biomedical ontologies because the practical utility of BFO to them is shown by the achievement of the Open Biomedical Ontologies (OBO) Foundry [11]: a collaborative project to coordinate ontologies to support biomedical data integration such that BFO can provide a common semantic basis for all the OBO ontologies.

In the most basic BFO framework, entities fall into two kinds: universals (aka types, classes) and particulars (aka tokens, instances). Particulars (e.g., Mary) bear the instance-of relation to universals (e.g., Human). Particulars, on which we place a primary focus in this paper, fall into two categories: continuants and occurrents. Characteristically, continuants can persist, that is to say, they can exist at one time and also exist at another different time; whereas occurrents (including processes) extend through time. Continuants can be further divided into independent continuants (including objects) and dependent continuants (intuitively: properties). Independent continuants, or especially objects (e.g., stones) can be bearers of dependent

continuants (e.g., hardness) and they can also participate in occurrents (e.g., a fall of the stone).

For this purpose, we draw upon Toyoshima's [12] thesis that, based on a detailed analysis of upper ontologies, there are (at least) three closely intertwined notions of role at a foundational level: a *role specification*, a *role position*, and a *role potential*. It is found on closer examination that those three facets of roles (and other meanings of the term 'role') can be well-defined in terms of some existing BFO categories. This would also testify to the explanatory force of BFO (with regard to roles) as compared to its relative smallness among upper ontologies.

The paper is structured as follows. Section II presents Toyoshima's [12] argument for three roles. Section III analyzes from the BFO viewpoint those three aspects of role and other possible meanings of the term 'role'. Section IV discusses the BFO notion of role, its connections with the BFO principle of ontological realism as well as the BFO categories of disposition and function, and its practical utility in the biomedical domain. Section V concludes the paper with some brief remarks on future possible directions of research.

II. Three Facets of Roles

Toyoshima [12] examines some preceding accounts of role, being motivated to know which ontological conception of role is suitable for which type of conceptual modeling. He then hypothesizes that different theories of role might depend on different 'role choices' made by the theories: choices as to which is most fundamental among 'three facets' of role (which he calls the 'role triad'), or its three main ontological interpretations: namely, a role specification, a role position, and a role potential. On his view, the role triad would defy explicit analysis, but it can be elucidated by analogy and illustrated with the question of what it is supposed to mean to say, e.g., that Mary is a student of University at Buffalo (UB), given the fact that a student is taken to be a paradigmatic example of role and Mary bears a student role, or simply Mary is a role-bearer.

A) Role Specification

One approach to Mary's studentness focuses on the deontic or normative dimension of her student role. Mary *must* gain admission to UB in order to become a UB student. To enjoy a full-time student status, she *needs* to register for a certain number of credit hours per semester. She is also *required* to defend her dissertation to obtain a doctoral degree from UB. Mary's studentness is thus explicable in terms of the satisfaction of the constraints or conditions that are, so to speak, 'embedded' in her student role.

This observation would lead to an analogy between a role and a specification. The ontological nature of a specification remains obscure, but Turner [13] maintains insightfully that a specification is something that has "correctness jurisdiction over an artefact" [13, p. 147]. By 'correctness jurisdiction' he means that the specification places "empirical demands on the physical device" [13, p. 144]. If an artifact is not built to a certain specification, the artifact is defective with respect to that specification. Duncan [14] illustrates this point as follows: "For example, if I build a physical implementation of a stack and the device does not allow me to add and remove items from the top

of the device, my device is defective relative to the specification of a stack" [14, pp. 16-17]. Quite importantly, Turner considers specifications as intentional: "Our intentional stance determines what we take to be the specification: something is a specification if we give it normal force over the construction of an artefact" [13, p. 147].

A role specification refers to a role that is understood by analogy with a specification and role-bearing is interpreted as *meeting a role specification*. On this specification view of role, a role-bearer is to its role what an artifact is to its specification. In this respect, roles and artifacts are closely linked from a modeling perspective [15]. In the U.S., for instance, an aircraft has to meet the strict specification laid down by the Federal Aviation Administration (FAA). This means that an aircraft-like aggregate of mechanical parts is not an aircraft unless it is constructed exactly to the FAA specification. Likewise, UB has drawn up intentionally its 'student role specification' (e.g., admission requirements), and Mary fails to be a student (in other words: to bear a student role) unless she satisfies the UB-student role specification.

Despite their striking similarity, a role specification and a specification (resp. a role-bearer and an artifact) differ greatly from each other at least in two points. First, they are temporally different: a role specification and a role-bearer are temporary (time-relative) but a specification and an artifact are permanent (time-insensitive). For instance, an American aircraft emerges when it is built to the FAA specification and it continues to exist until it is physically destroyed; whereas, Mary is a UB student as long as she meets a UB-student role specification and she can survive even after ceasing to be a student. Second and connectedly, they are modally contrary: the former are contingent (accidental) but the latter are necessary (essential). (Note that, *pace* Fine [16], we lightly assume throughout this paper a conceptual overlap between modality and essentiality merely for a practical purpose.) While artifactness (e.g., FAA-aircraftness) constitutes the essence of an American aircraft, for example, roleness (e.g., UB-studentness) is inessential to Mary. It must be emphasized that temporality and contingency/accidentality are key characteristics of a general notion of role irrespective of which role choice is taken.

B) Role Position

Another possibility for understanding Mary's studentness is based on the kind of situation in which Mary bears a student role. As a UB student, Mary can use various facilities and enjoy educational opportunities (e.g., taking classes). Mary's studentness may then consist in the fact that she locates herself in a specific 'sphere' or 'position' where she can do something role-related.

A role as conceptualized this way is analogous with a relative place [17]. Given the Newtonian conception of absolute space, both *absolute places* and *relative places* persist and may be occupied by various (material) objects at various times. Unlike absolute places (which are parts of absolute space that are independent of objects), relative places stand in fixed spatial relations with one or more objects (*reference objects* [17]). Examples include places in and around a ship whose reference object is the ship.

A role position means a role that is figured out by analogy to a relative place and role-bearing is construed as *occupying a role*

position. Seen from this positional perspective, roles stand in fixed 'conceptual' relations towards one or more entities, which may be sometimes called 'context' in the relevant literature [10,18]. (Note that, despite Smith's [19] warning against concepts in ontology research, we are using the term 'conceptual' in its broad sense as a kind of placeholder. Its precise meaning should be further clarified in the future investigation.) In bearing a UB-student role, for example, Mary occupies the student role position that exists relative to UB.

The analogy between role positions and relative places would shed light on the alleged relational nature of roles [7,8,20]. One salient feature of relative places is that they may move relative to one another when their reference objects move relative to one another. Using Donnelly's [17] example, when a ship moves relative to the earth, places with the ship as their reference object (e.g. the ship's hold) move relative to places with the earth as their reference object. In a similar vein, role positions may 'conceptually move' relative to one another when their contexts 'conceptually move' relative to one another. For instance, when a human resource department changes its importance with respect to its company, personnel director role positions (whose context is the human resource department) change their relationship with executive role positions (whose context is the company).

C)   Role Potential

Yet another interpretation of Mary's studentness builds upon the ability of Mary to do something role-associated (which is sometimes informally called 'circumstantial possibility'). Since she is a UB student, Mary *can* do many things (e.g., getting a student discount). She is *able* to acquire a degree from UB, whereas non-UB students are not. Mary's studentness would be explainable in terms of the potential that she can have in bearing a student role.

A role potential designates a role that is thought of as a sort of circumstantial ability and role-bearing is translated as *having a role potential*. It is important to remark that a role-bearer has only to possess the role-related ability instead of demonstrating it actually. To remain a UB student (i.e., to bear a UB-student role), Mary does not need to use any student discount; it is only necessary that she be able to do it.

A role potential may be easiest to understand in the role triad because it is intuitively grasped as a special kind of ability and avoids complications added by analogies with the complex notions such as a specification (in the case of a role specification) and a relative place (in the case of a role position). In contrast, a role potential should be treated with the utmost caution because it could be otherwise conflated with other apparently similar but different entities, viz. dispositions and functions (see Section IV for details on this point).

III. Roles and Their Siblings in BFO

In this section we delineate into which BFO category falls each of the role triad (a role specification, a role position, and a role performance) and other ontological accounts of the term 'role'. We also illustrate them with the examples (1)-(8) listed in Section I. Note that this section draws partially upon Toyoshima [12] (especially its Section 4.3).

We introduce a fine-grained classification of dependent continuants for the sake of future argument. In BFO, there are two kinds of dependent continuants. One is a specifically dependent continuant: "A continuant entity that depends on precisely one independent continuant for its existence. The former is dependent on the latter in the sense that, if the latter ceases to exist, then the former will as a matter of necessity cease to exist also" [4, p. 185]. Examples include the mass of a kidney and the shape of a hand.

The other is a generically dependent continuant: "A continuant that is dependent on one or other independent continuants and can migrate from one bearer to another through a process of copying. We can think of generically dependent continuants as complex continuant patterns either of the sort created by authors or designers or (in the case of DNA sequences) brought into being through the processes of evolution" [4, p. 179]. Examples include the pdf file on Mary's laptop and the pdf file that is a copy thereof on John's laptop. Characteristically, a generically dependent continuants exists only if it is *concretized* in some counterpart specifically dependent continuant. To take one example, a paragraph of a novel in concretized in each pattern (quality) of ink on the pages of the printed novel.

One subtype of specifically dependent continuant is a realizable entity (subtypes of which are to be discussed in detail below): "A specifically dependent continuant entity that has at least one independent continuant as its bearer, and whose instances can be realized (manifested, actualized, executed) in associated processes of specific correlated types in which the bearer participates" [4, p. 183]. Examples include the role of being a doctor, the disposition of a fragile glass to break, and the function of a hammer to hit nails.

A)   Role Specification as a BFO-generically Dependent Continuant

A role specification would be most reasonably classified as a generically dependent continuant. For one thing, a specification is plausibly taken to be a generically dependent continuant. Duncan [14] analyzes Turner's [13] conception of specification on the basis of BFO and contends that it is a kind of information. To our eyes, information is naturally seen as a generically dependent continuant because it obeys the 'rule of migration'.

For another, an ontological theory of role that endorses explicitly a role specification can be construed in the BFO fashion as a commitment to the view that a role is a generically dependent continuant. Masolo et al. [8] propose a general framework for social roles in compliance with an upper ontology the Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE) [21]. At the nub of their argument is that social roles are fundamentally characterized by the DOLCE entity of *description*. As Toyoshima [12] argues, they take a specification approach to role and a DOLCE-description could be well conceived as a generically dependent continuant that is connected to agents' intentionality.

Examples (1)-(3) are explicable in terms of a role specification as a generically dependent continuant (see [5, p. 101] concerning Examples (2)-(3)). In Example (1), a pilot role of a passenger means a generically dependent continuant whose bearers are passengers, or especially those who know well about the operation of the plane. In Example (2), the role of director of the institute depends generically on people (including Jane) with

some qualifications (e.g., age and career). In Example (3), the particular role in the play can migrate among actors (such as Joe), e.g., with a certain level of acting proficiency.

B)   Role Position as a BFO-site

The BFO categorization of a role position would be more controversial than that of a role specification owing to the still unclear character of the former. A role position is however arguably most persuasively regarded as a site. A site is "a three-dimensional *immaterial entity* that either (1) is (partially or wholly) bounded by a *material entity* or (2) is a three-dimensional immaterial part of an entity satisfying (1)" [4, p. 112], where a material entity is an "independent continuant that has some portion of matter as part, is spatially extended in three dimensions, and that continues to exist through some interval of time, however short" [4, p. 180] and an immaterial entity is an "independent continuant that contains no material entities as parts" [ibid.]. Examples of sites include a rabbit hole, Mary's nasal cavity, and a kangaroo pouch.

A site-based perspective on a role position has its advantages and disadvantages. A site obviously represents the BFO way of incorporating a relative place (see e.g., [22,23]), and it would be straightforward to label a role position as a site. On the other hand, a role position would be considerably different from a site in the sense of not being explicitly bound or demarcated in relation to material entities. In the Mary-student example, it might be possible to think that Mary's role position is the kind of site that is formed with respect to physical buildings possessed by UB, but only with a worry over a somewhat arbitrary reification of role positions. It is nonetheless equally true that there is no other promising BFO-categorical candidate for a role position. Finally, Example (4) can be well explained from the viewpoint of a role position as a site: the role of the damaged stellar neuron refers to a site that is identified relative to the brain (context) and it is now 'occupied' by the pyramidal neuron.

C)   Role Potential as a BFO-role

It is not hard to see that a role potential accords well with the BFO category of role: "A realizable entity that (1) exists because the bearer is in some special physical, social, or institutional set of circumstances in which the bearer does not have to be, and (2) is not such that, if this realizable entity ceases to exist, then the physical make-up of the bearer is thereby changed. A role is thus always optional" [4, p. 184]. Given the BFO conception of role, for instance, Mary is a UB student in virtue of her student role that can be realized in, e.g., a process of her using a student discount. This would mean that a BFO-role is closely akin to a circumstantial ability, which underlies the idea of a role potential.

As said above, the potential view of role would require elucidation of roles and other comparable entities such as dispositions and functions. This issue is to be addressed in Section IV. In addition, it will be also discussed there the question of why BFO takes a potential-centered approach to role. Examples (5)-(6) are interpretable in terms of a role performance as a role. In Example (5), Jim's nurse role is a role that can be realized in processes of his taking care of sick or injured people. In Example (6), the stone in question bears a role that can be realized in a process of boundary demarcation.

D)   'Role' as a BFO-disposition

We have above pondered three facets of role and their BFO categories, but the term 'role' may be too polysemous to be understood in terms of the ontological notion of role alone. Consider Example (7): 'the role of a magnet to attract iron objects'. None of the role triad captures the meaning of the term 'role' of this example. In particular, a magnet attracts iron objects permanently and essentially rather than temporally and accidentally. We submit that, contrary to its linguistic surface, the term 'role' thereof refers to the BFO entity of disposition. A disposition is: "A realizable entity (a power, potential, or tendency) that exists because of certain features of the physical makeup [*material basis*] of the independent continuant that is its bearer" [4, p. 178, with our supplementary explanation]. A classical example of a disposition is fragility: the disposition to break when pressed with a certain force. More specifically, fragility of a glass is the disposition of the glass (bearer) to break (realization) that depends on a particular physical molecule structure (material basis) of the glass.

In BFO, dispositions sharply contrast with roles in terms of 'groundedness'. Dispositions are internally grounded: if a disposition ceases to exist, then its bearer is physically changed. Roles are externally grounded in the sense that this is not the case; see the item (2) of the BFO definition of role. The BFO grounding differentiation between dispositions and roles would mesh with our temporal and modal one between artifactness and role. When a bearer (whether natural or artifactual) of a disposition fails to have the disposition, the bearer may sometimes (if not always) lose its essence. An aircraft would be no longer an aircraft when it loses a disposition to fly, for example. In that case, the disposition of a bearer determines the essence of the bearer (or at least serves to do so). In Example (7), a magnet has a disposition to attract iron objects and this disposition embodies the essence of the magnet. However, a bearer of a role is always the same physically even when the bearer loses that role, and a role is a mere accidental feature of its bearer. Mary remains physically unchanged when she is admitted to UB, and her studentness is (ontologically) irrelevant to her essential nature (which may be extremely difficult to define explicitly, though).

E)   'Role' as a BFO-function

The dispositional clarification of the term 'role' extends to the BFO category of function because BFO, or precisely the latest version of BFO (BFO 2.0) conceives function dispositionally [24] (see [25,26] for criticism): "A *function* is a special kind of disposition. It is a realizable entity whose realization is an end-directed activity of its bearer that occurs because this bearer is (a) of a specific kind and (b) in the kind or kinds of contexts that it is made or selected for. Thus 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 of how it came into being --- either through natural selection (in the case of biological entities) or through intentional design (in the case of artifacts)" [4, pp. 102-103].

To illustrate this, consider Example (8): 'the role of the heart to pump blood'. First of all, the heart has a disposition to pump blood: it depends on a certain organic structure of the heart and the heart would undergo physical change when it loses this disposition. Analyzed more meticulously, the disposition of the

heart to pump blood is a function of the heart because it has emerged through evolutionary processes of the organism. To take another example, consider the phrase 'the role of an aircraft to carry goods or passengers'. In ontological parlance, an aircraft has a function (but not a role) to carry good or passengers because the aircraft has been designed and produced to do so. A relationship between role and function is however further complicated by the issue of 'use function' to be addressed in Section IV.

IV. Discussion

A) The Role Triad in BFO and Ontological Realism

Although we have identified the five BFO meanings of the term 'role', questions remain about a detailed description of the BFO conception of the role triad. Here three of them will be brought up for discussion. First, why does BFO put a premium on a role potential, as is supported by the finding that it is classified as a role in BFO? Toyoshima [12] holds that there is a strong correlation between role choices of upper ontologies and their meta-ontological choices [27]: roughly, choices that are fundamental enough to determine ontological choices [21], namely choices as to whether and how a certain ontological category or relation is adopted. The DOLCE theory of role focuses on a role specification, for instance, because DOLCE aims to represent categories with a clear cognitive bias that are associated with e.g., human cognition and socio-cultural artifacts (which is a DOLCE meta-ontological choice), and a role specification is arguably the most cognitive and/or linguistic way of understanding roles in the sense of emphasizing their intentional aspect.

Toyoshima [12] attributes the BFO role choice of a role potential to the BFO meta-ontological adoption of ontological realism [28] (see [29,30] for criticism): "The realist methodology is based on the idea that the most effective way to ensure mutual consistency of ontologies over time and to ensure that ontologies are maintained in such a way as to keep pace with advances in empirical research is to view ontologies as representations of the reality that is described by science. This is the *fundamental principle* of ontological realism" [28, p. 139]. It is a rather complicated matter to assess exactly what ontological realism entails (see e.g., [31]), but one plausible corollary of this policy would be that BFO-based ontologies should maximize symbiosis with empirically scientific inquiry, which would imply in turn that the BFO notion of role should be consistent with scientific activities. This results reasonably in the BFO choice of a role potential because scientists typically focus on the structure and *behavior* of the natural world. To investigate the human mind, for instance, contemporary cognitive scientists and psychologists tend to highlight the importance of people's behaviors such as their facial expressions and actions. Taken with a scientific attitude, roles (e.g., Mary's student role) would be preferably ontologized in terms of externally observable performances of role-bearers (e.g., Mary's using a student discount).

Second, how can a role specification and a role position be described or defined given the BFO performance-oriented view of role? This amounts to the problem of what kind of generically dependent continuant (resp. site) is a role specification (resp. a role position), assuming the ontology-design method of the

Aristotelian definition [32] where a term can be defined by dint of a genus (as a species with a differentia). The identity of a generically dependent continuant is a highly debatable topic (see e.g., [6,33,34]); and so is a site (but see [17] for some thoughts). We can safely say however that both of the definitions of a role specification and a role position should comprise the BFO term 'role' since it is so paramount as to ground all other role-related notions in BFO; and that a role specification needs to be constrained at least by its bearer and its concretization, and a role position at least by which material entity bounds or demarcates it.

Taking all this into consideration, first of all, it is reasonable to think that a role specification has as its bearer a bearer of a role and it is also concretized in the role of the bearer. Suppose for instance that, in Example (2), Bob was the sixth director of the institute. In this scenario, Jane's director role differs from Bob's, but they both concretize the same role specification to the effect that, e.g., a director of the institute is in charge of activities of the members of the institute. Next, informally speaking, a role position would be plausibly relativized to the context in which a certain independent continuant can have some role. It could be further added that a role position can be occupied by the role-bearer under discussion. In Example (4), a role position exists in relation with the brain and it was at first occupied by a healthy stellar neuron, but later it is by the pyramidal neuron. Finally, preliminary definitions of a role specification and a role position are provided as follows:

- BFO-role specification =def. a generically dependent continuant (i) whose bearer has a role and (ii) that is concretized in the role of the bearer.

- BFO-role position =def. a site that (i) exists relative to the special physical, social, or institutional set of circumstances in virtue of which an independent continuant can have a role and (ii) can be occupied by the role-bearer.

It should be noted that the item (i) of the definition of a role position depends on part of the BFO existing definition of a role; and that a role position does not always need to be occupied by some role-bearer and it can be occupied by different role-bearers at different times. We intend to leave room for the flexibility of role positions so that they could help to solve some existing problems with a BFO-role (see below for details).

Third and lastly, why does BFO specify only the role-having relation (**has_role**) but not the role-playing one [3, p. 58]? As is indicated by Examples (1), (3), and (4), talk of role-playing is quite commonplace in our everyday life. It is however contentious whether and how the phrase 'plays a role' should be taken with ontological seriousness (see e.g., [35]). One tenable idea would be that role-playing conveys the level of achievement of role-related goals. Mary's behavior is evaluable by a criterion (e.g., obtained credits) for being a student, for instance. Different role choices would yield different understandings of role-playing, namely as meeting a role specification, as occupying a role position, or as having a role potential. Characteristic of the BFO construal of role is to reduce the alleged role-playing to realization. Mary's student actions are explicable in terms of realizations of her student role. Accordingly, BFO only needs the standard property-having relation (one subtype of which is the **has_role** relation), instead of a new primitive role-playing one.

B) Roles, Dispositions, and Functions

There is a broad consensus on the high utility for ontologizing a wide array of entities that is possessed by realizable entities, ranging from the BFO subtypes of realizables [36] (i.e., dispositions, functions, and roles) to other kinds of realizables (e.g., tendencies [37]). It is nevertheless a highly controversial subject how BFO-realizables are to be individuated. It would be indeed valuable to elaborate on a comparatively revisionary classification of BFO-realizables (see e.g., [25]). To simplify the matter, however, we will confine ourselves to two topics regarding the interrelationships between roles and other two realizable entities while retaining the present, BFO 2.0 characterization of them.

First, a cloud of suspicion may hang over the 'grounding distinction' between roles and dispositions. Guarino [38, p. 17] asserts, for example: "I think that, especially for social roles, the corresponding attitudes/commitments/dispositions are not independent from the physical make-up of their bearer. For instance, the commitment to realize a student role of course requires some changes in the brain's "make-up" of its bearer. I would say that, in general, *active* role-properties (*being the lover of Mary*) presuppose some (non-essential) change in the physical make-up of their role bearers, while this is not required for passive roles (*being loved by John*)." Paraphrased using the Mary-student example, the core of his argument is that Mary's student role should not be a BFO-role (an *externally grounded* realizable entity) because there must be some physical change involved in Mary's entering UB.

Although it may be a misinterpretation of a BFO-role, Guarino's criticism would help to elucidate the difference between roles and dispositions. Quite important is the observation that the change (including emergence and disappearance) of roles are frequently concurrent with that of dispositions. To see this point, let us stipulate that Mary became more diligent after graduation from UB. It would appear that Mary's assiduity was caused by her neural transformation, which was in turn by her student role. Actually, however, Mary's diligence should be ascribed to the fact that Mary's disposition to work hard was strengthened by realizations (e.g., taking classes at UB) of her student role which she no longer bears after graduation. On the other hand, Mary's disposition to go to UB may have been greatly weakened when she lost her UB-student role.

Second, we have seen the cases in which the term 'role' refers to a disposition or a function. One may wonder about their opposite: the term 'disposition' or 'function' means a role when coming under scrutiny. To the best of our knowledge, the term 'disposition' rarely, if ever, refers to a role; whereas greater care may be needed to ensure that the term 'function' does not designate a role. To illustrate the latter, consider the issue of 'use function': roughly, the kind of functions that agents attribute to objects in actually using them for their use purpose (see e.g., [39] for more details). If Mary uses a screw driver to open her paint cans, for instance, it has the use function to open paint cans [25]. In spite of an ongoing discussion about BFO-functions, the disputants generally acknowledge that use functions should be categorized as roles because they are 'accidental functions': they have nothing to do with the essence of their bearers [24,25].

C) Roles in Biomedical Ontologies

As was alluded to in Section I, roles are crucial for biomedical ontologies, partly because of the widespread usage of the term 'role' in the biomedical literature, partly because of a growing importance of social roles in ontologies of healthcare systems. As for the former, we have explicated the term 'role' by leveraging some existing BFO categories. This will help biologists and medical specialists to understand correctly the term 'role' and represent accurately its meaning on a case-by-case basis when they build and/or ameliorate OBO ontologies.

We have also shown that the BFO potential-centered conception of role is well-suitable for scientific ontologies in general. This is all the more the case with biomedical ontologies for several reasons. First, ontological realism is currently one of the most prevailing approaches to biomedical ontologies [40]. Second, BFO-roles are relatively understandable for biomedical experts because they are closely akin to dispositions, which are central to biomedicine [37] and serve as a useful conceptual tool for an ontological analysis of the explanatory practice in biomedicine from both theoretical [41] and practical [42,43,44] points of view. Third, it has been pointed out that "many so-called functions in biomedical ontologies are, strictly speaking, roles" [25, p. 11].

As for the latter, our work will have implications for the construction of social ontologies in the biomedical domain. For one thing, there is general agreement among researchers in social ontologies aligned with BFO that deontic entities (e.g., claims, obligations, and rights) are most appropriately classified as generically dependent continuants that are concretized in (social) roles, regardless of whether they are, more concretely, socio-legal generically dependent continuants [45] or directive information entities [46] or others. Deontic entities as construed this way can be viewed as a subtype of role specifications; and in this regard, we might have discussed in some way a theoretical foundation for deontic entities in social ontology.

For another, it is nowadays fairly popular to model organizations (totally or partially) upon interrelations among roles in various disciplines, including multiagent systems [47,48] and foundational ontology research [49,50,51]. It is sometimes claimed however that the BFO conception of role fits badly with this approach because it faces what may be called the 'problem of non-transferability' [46] or especially the 'problem of vacant (empty) role'. Being postulated to be represented by a configuration of roles, an organization should remain the same even when there exists a 'vacant role': a role to be beard by nobody. Recall an extensive story of Example (2) in Section IV-A: the structure of the institute has not changed itself since Bob resigned as the sixth director until Jane is newly elected as the seventh director. BFO-roles would nonetheless seem to embrace the discrepancy between the real structure of an organization and its 'role structure' because they have to depend specifically on individual agents (such as Bob and Jane) and they are thus non-transferable. The issue of vacant role is still unresolved, but one possible answer to this question may be to ground an organizational structure upon a constellation of role positions (rather than roles) of the organization because role positions thereof, by definition, exist even in the case of vacant roles, insofar as does the organization. Our complete solution to the general problem of non-transferability will require not only clearer delineation of the idea of a role position but also careful

ontological consideration of the identity of organizations (see e.g., [52]).

V. Conclusion

To summarize, we examined within the BFO framework the meanings of the term 'role'. We also discussed the BFO potential-oriented conception of role as an externally grounded realizable entity with a focus on its connections with ontological realism, dispositions, and functions as well as its usefulness for an ontological modeling in the biomedical field. We ended up with the following BFO-based disambiguation of the term 'role' in the aforementioned examples (1)-(8):

1. A passenger plays the role of a pilot on a commercial plane in an emergency.

- **Generically dependent continuant** (role specification)

2. Jane's being the seventh person to fill the role of director of this institute

- **Generically dependent continuant** (role specification)

3. Joe's being the third person to play a particular role in a play

- **Generically dependent continuant** (role specification)

4. A pyramidal neuron plays the role occupied by a damaged stellar neuron in the brain. **Site** (role position)

- **Site** (role position)

5. Jim has the role of a nurse.

- **Site** (role position)

6. the role of a stone in marking a boundary

- **Role** (role potential; an externally grounded realizable entity)

7. the role of a magnet to attract iron objects

- **Disposition** (an internally grounded realizable entity)

8. the role of the heart to pump blood

- **Function** (a subtype of disposition)

In the future we will be able to proceed along two main directions of research. On the theoretical side, further development is warranted of the BFO characterization of a role specification and a role position, which will require in turn a deeper understanding of a generically dependent continuant and a site. Besides, further clarification should be given to complex relationships between roles, dispositions, and function. On the practical side, the utility of the BFO specification hitherto of the term 'role' needs to be verified through its application to the building and enhancement of biomedical ontologies, e.g., of healthcare systems [5,6]. In addition, since ontological realism prescribes that ontologies should represent, above all, universals [28], this necessitates the extension of our work on the role triad to the sphere of universals and their formal representation specified in e.g., Web Ontology Language (OWL) [53]. Finally, among BFO-realizables, roles have been less carefully investigated than dispositions and functions. This may raise doubts about the BFO characterization of role. For instance,

Guarino [38, p. 14] states that it "reflects a very peculiar understanding of the role notion which, although useful, would require a broader framework". We hope that our argument over BFO-roles and their sibling entities will dispel this kind of worry.

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