

Formal Ontology applied to Philosophy of Science: the Species Problem

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In recent years, applications of formal ontology have formed a research front at the intersection of biological, biomedical research and information science/technology. Its possible applications to and import for more traditional theoretical problems in biology, however, have been rarely addressed. The goal of the present paper is to utilize the toolkit of formal ontology in the analysis of one of the most controversial issues of supra-individual biology and biophilosophy, *viz.* the Species Problem. Reconstructing the relevant features of the state-of-the-art discourse within an ontological framework may heavily contribute to the clarification of the nature of this debate.

The problem

The species problem is generally described as the permanent failure to construct a sufficient theoretical definition of species as such that meets the empirical, methodological and philosophical criteria for that concept cumulated throughout the history of the problem. Among those criteria are for the concept to account for the ontological status of species taxa (the latter being consensually individuals rather than classes), and, in most cases, to denote a category that counts as being a natural kind. Further potential is attributed to the definition as making a claim with respect to species realism and pluralism. Indeed, the theoretical discourse shows heavy interdependence between arguments on the ontology of species taxa/category and the methodological issues of defining the concept, the abundant reference to the so-called individuality thesis (SAI) in the context of biological systematics being a salient example.

The agenda

My aim is to construct a comprehensive formal model of the modern species problem (SP), explicating the conceptual linkages between the methodological and the philosophical issues. Formal ontology is applied in modelling the general argument, according to which the semantic act of defining the species concept (SC) has many-faceted ontological import.

The formal framework

To this end I utilize two approaches of formal ontology, combining the formal concept of *ontological commitment* (OC) developed by Guarino et al. (cf. 1994), with the *logic of natural kinds* (LNK) as invented by Cocchiarella (cf. Cocchiarella 1986).

According to the former, an OC, technically speaking, is a set of models M relative to a first-order language L , by the members of which it is allowed to interpret the elements (predicates) of L . A specific OC is characterized by a formal theory T in an extension of L , containing modal and mereological symbols as well. An OC, so conceptualized, is to express the intended meaning of the concepts in L by constraining their semantic behaviour via T , the latter being capable of formulated in the meta-language also by (meta-level) predicates applied to the object level ones (e.g. *Rigid* (F), F being a predicate symbol in L). Such an approach is conceivable as characterizing the *a priori* nature of the domain throughout M .

LNK is a calculus in second order modal and sortal logic (with the appropriate set of models). The motivation behind is to capture the rules of predication derivable from the ontological stance that there exist traditional (Aristotelian) natural kinds a set of our common words stand for. The corresponding models, therefore, include a sort for special predicate intensions bearing the logically expressible properties of natural kinds, including modal stability, reidentifiability etc. The schema for these models also demonstrates a specific ontology, the commitment to which (i.e. constraining the set of possible interpretations for the appropriate type of theory) may impose a certain behaviour on the concept symbols evaluated within this system.

The model

The basic idea of the model is that any appropriate definition of the species category is compatible with a certain set of ontological commitments, thereby determining the ontological dimensions of the concept. To map the linkages between definitional and ontological issues within the discourse of the species problem, I attempt to incorporate the LNK into the formal concept of OC. The resulting frame is a second-order theory T' with rich expressive potential capable of (1) mapping taxa either as real compound individuals, comprised of organisms as parts or as classes with organisms as elements; (2) mapping the species category as either being or not being a natural kind comprised of taxa. The definition of the species category S within the theory is constructed so that it is sensitive to the ontological part of T' .

The solution is based on the procedure of constraining the behavior of the primitives in the language of T' . Below is the outline of the formalization of the idea that the definitive relation used by the species concept determines whether or not taxa are individuals.

An application of the model: Reconstructing relational species concepts as denoting individuals

According to many arguments, a particular SC has important implications on the ontological status of species taxa. A mainstream view is that referring to a relation between organisms that is (or that could be reduced to) a spatiotemporal relation (e.g. interbreeding), an SC denotes taxa as individuals, while utilizing an abstract (e.g. some similarity) relation, the concept reconstructs taxa as classes. This line of reasoning draws on an ontological distinction concerning the capacities of different types of relations. To formally express this feature of various SCs, we introduce the concept of *spatiotemporal relation*, as a meta-level predicate capable of distinguishing certain relations in L' :

$$ST(R) \leftrightarrow_{def} \overline{NEC} \forall x \forall y (xRy \rightarrow [\exists^c z [x \leq z \wedge y \leq z] \wedge \neg \exists^c q [x = q \vee y = q]])$$

where \exists^c ranges over the sort of compound individuals, and \leq is the part-of relation. That is, if organisms (and only organisms) are interrelated by a material relation, they are part of the same (compound) individual. In this way, if a predicate S standing for the species category is introduced to L' via reference to such a relation, it is capable of denoting individuals, otherwise it is not guaranteed by definition:

$$S_R(x) \leftrightarrow_{def} \forall y \forall z (y, z \leq x \rightarrow yRz) \wedge \varphi$$

where φ is some ranking criterion.

Similar considerations hold with respect to the relation of the formal sort for an extended concept of natural kinds and the species category. In the paper, most aspects of the ontological capacities of SCs are elaborated, including category/taxon realism and versions of pluralism as well.

References

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- N.B. Cocchiarella. Philosophical perspectives on formal theories of predication. *Handbook of Philosophical Logic*, 4, 1986.