Species as units of generalization in biological science: a philosophical analysis
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1 General introduction

1.1. The species problem

Charles Darwin concluded the *Origin of Species* on an optimistic note:

> "When the views entertained in this volume on the origin of species (…) are generally admitted, we can dimly foresee that there will be a considerable revolution in natural history. Systematists (…) will not be incessantly haunted by the shadowy doubt whether this or that form be in essence a species. (…) The endless disputes whether or not some fifty species of British brambles are true species will cease." (Darwin, 1859: 484).

In the time that has passed since the publication of the *Origin of Species*, Darwin's optimism has however proved unjustified: Darwinian evolution has become generally accepted, but the disputes in biological science regarding the correct partitioning of organismal diversity into species continue as before.

That these disputes have not subsided, is primarily due to a persistent lack of clarity regarding one of the central terms in biological science: 'species'. Notwithstanding the large amount of work that has been done in attempts to clarify the nature of those things or classes that biologists call 'species', as well as the criteria by means of which species can be delimited in nature and organisms can be allocated to species, the lack of clarity still persists. What has come to be known as 'the species problem' essentially consists of two distinct, but intricately interwoven, issues, one ontological and the other epistemological. In the present dissertation, emphasis lies first on the ontological side of the species problem, before turning to epistemological issues.

For a variety of reasons it is important to address the species problem in the context of the present state of affairs in biological science. One reason pertains to the foundations of biological science. Without a clear perspective on what the term 'species' refers to, how and in how many ways the units called 'species' function in biological research and how these units can be delimited in practice, biological science itself is lacking an essential part of its foundations. Contributing to resolve the conceptual side of the species problem is one of the principal tasks of investigators in the foundations of biological science.

Another fundamental reason pertains to the advancement of philosophy of science. Philosophy of biology, as I perceive it, stands with one leg in biological science and with the other leg in general philosophy of science, in that the issues that are addressed in the field of philosophy of biology have direct consequences for both these fields of investigation. This is also the case with respect to the species problem. Issues from general philosophy of science, such as the nature of scientific explanation and of scientific kinds, epistemological and ontological issues regarding natural kinds, the nature of individuality and the question what sorts of things there are in the world, all can be tackled using the species problem as a case study, entailing new insights into these issues (as the following chapters show).

The work on the species problem presented here is also relevant for the current biodiversity crisis. Faced with the rapid extinction of biodiversity on Earth, much effort is put into evaluating how diverse life on Earth actually is, how rapidly extinction actually proceeds and how extinctions can be countered. Usually, these efforts hinge on a notion of species: biodiversity is measured in terms of the number of species and species are understood as the units that become extinct and are worthy of conservation. A better understanding of the nature of 'species' directly affects our assessment of the state of biodiversity on Earth and thus can direct human actions in relation to the biodiversity crisis.

The present dissertation aims to contribute to resolving the species problem in its contemporary form by addressing two aspects of the problem. First, the nature of the species problem is examined and it is shown that the species problem is deeper than is commonly thought: when considering the ontological reference of the term 'species', it is found that multiple independent scientific concepts – rather than one single concept – are at stake. Second, one of the epistemic roles of 'species' in biological science is elaborated in detail: the role of 'species' as referring to units of generalization, that is, as denoting kinds of organisms over which explanatory and predictive generalizations hold. The following section gives an outline of the steps taken in addressing these issues.

1.2. Outline and summary of the present dissertation

In ***Chapter 2***, a first exploration of the nature of the species problem is undertaken. The species problem has attracted the interest of biologists and philosophers from times well before Darwin's lifetime up to the present day. By now, the volume of literature that has been published on the issue has grown to immense proportions. Then, one may legitimately wonder, why has the problem not been solved long ago? Why is it that every year still new papers and books (including the present dissertation) that address this issue see the light?

Several authors who have considered the species problem have suggested various reasons for the persistence of the problem. Some have argued that the resolution of the problem has been hampered by an undue emphasis on the philosophical aspects of the matter and that the best approach to take is to gather more empirical data regarding the organismal world. Others have countered that deeper philosophical analysis, rather than more empirical investigation, is the adequate approach. In contrast to these suggestions, I take the view that neither the empirical aspects of the species problem nor the philosophical issues that it encompasses constitute the principal reason for the problem's persistence. Rather, they are the symptoms of what I believe is the underlying reason why the species problem has to the present day resisted a resolution: the failure to recognize that the term 'species' does not refer to one single scientific concept, but has during the development of biological science become a placeholder for a number of *independent* concepts. In sum: in present-day biology, 'species' is a homonymic term.

While in Chapter 2 this perspective on the species problem is only suggested and is compared to the suggestion that was recently advanced in the literature, that 'species' is a family resemblance concept (in that all actually existing species resemble each other in various ways, while there is no property common to them all), in ***Chapter 3*** it is argued and elaborated in detail. In this chapter, an epistemological and an ontological analysis of the term 'species' are conducted.

When considering the epistemic roles in which the term 'species' features in contemporary biological science, three distinct roles are identified: species function as units of taxonomic classification (i.e., units in the general reference system that biologists use to order the specimens they study), units of generalization (i.e., kinds of organisms over which explanatory and predictive scientific generalizations can be made) and units of evolution (i.e., the entities that participate in evolutionary processes and undergo evolutionary change). Contrary to what is widely (usually implicitly) assumed, there is no a priori reason why these three roles should all be performed by a single scientific concept. In fact, as is argued in this chapter, the requirements that these roles impose on the concept that is to play them are not always compatible, implying that more than one concept is needed to play these roles.

The examination of the ontology of the term 'species' that is conducted in Chapter 3 reveals that as it is used in present-day biology this term indeed denotes multiple distinct concepts. During the development of biological science, 'species' has come to denote four distinct sorts of referents: cohesive systems of synchronously living organisms that participate as wholes in evolutionary processes; segments of the phylogenetic tree of life that consist of both past and present organisms that are connected by means of ancestor-descendant relations; classes of evolutionary units (that is, classes that have systems of synchronous organisms as their members); and classes of organisms that share particular structural or behavioral properties. These four sorts of referents are ontologically very different, implying that they cannot be subsumed under a single scientific concept and that four distinct concepts are at stake in the species problem. In short, 'species' as currently used is a homonymic term that functions as the placeholder for four independent scientific concepts, each referring to a particular ontological category.

It should be emphasized that I do not propose that all four concepts *should* be incorporated in the conceptual framework of biological science. Rather, I present the diagnosis that the four concepts identified in Chapter 3 *are* in fact incorporated in the present-day conceptual framework of biology. Whether their placement in this conceptual framework will in the end prove necessary is an empirical matter, rather than an issue to be addressed by conceptual analysis.

After having established this state of affairs, its consequences are drawn for two ideas that determine much of contemporary thought on the species question: species individualism and species pluralism (also in Chapter 3). It is shown that both these positions rest on the (usually implicit) assumption that the term 'species' stands for one single scientific concept (be it in the case of pluralism an overarching concept that can be refined into a number of distinct but interconnected subconcepts). As such, neither species individualism nor species pluralism match the actual state of affairs in biological science, in which 'species' is used to denote four independent concepts. My conclusion is therefore that the adoption of species individualism and/or species pluralism stands in the way, rather than helps, when addressing the species problem.

Species individualism in particular is widely adopted by both biologists and philosophers of biology. It is again addressed in the ***Appendix***, where I show that a recently published defense of species individualism fails on several counts.

The last two chapters of this dissertation focus on one of the three roles of species identified in Chapter 3: the role of species as units of generalization. In ***Chapter 4***, which contains the spin-off for general philosophy of science of the work presented in this dissertation, the nature of scientific generalizations and kinds is considered. On the traditional view in philosophy of science, scientific explanation and prediction essentially consist in the making of well-founded generalizations. Observed similarities in the properties of different entities, for instance, are explained by identifying these entities as belonging to the same natural kind and thereby subsuming them under a generalization of the type 'All (or most) entities of kind *K* exhibit property *p*.' In a similar fashion, unobserved properties of present and future entities of a particular kind are predicted by means of a generalization stating that if a particular entity would be a member of kind *K*, it would (with a high probability) exhibit a particular property or set of properties. In this chapter, it is shown that two sorts of generalizations are required to explain and predict the similarities that organisms exhibit in their structural and behavioral properties.

It is widely assumed that all of scientific explanation and prediction takes place in terms of universal laws of nature. In contrast, the considerations in Chapter 4 show that two fundamentally different sorts of generalizations play a role in scientific explanation and prediction: law-generalizations and kind-generalizations. Law-generalizations pertain to changes in states of affairs and do not directly invoke scientific kinds; kind-generalizations pertain to the properties that material entities exhibit and hold over the members of kinds of entities.

An examination of kind-generalizations shows that two sorts of scientific kinds exist, over which explanatory and predictive generalizations hold that rest on different types of underlying factors: spatiotemporally unlimited causal kinds, over which generalizations hold that rest on causal mechanisms to which their member entities are subject, and spatiotemporally limited historical kinds, over which generalizations hold that rest on the shared history of their member entities. The nature of the factors that underlie generalizations over the members of causal kinds is such that these generalizations may be exceptionless, but may also exhibit exceptions. Similarly, the nature of the factors that underlie generalizations over the members of historical kinds is such that historical generalizations may exhibit exceptions, but may also be exceptionless.

From these findings it follows that the common use of the criterion of universality to evaluate the scientific validity of all proposed explanations and to assess the scientific status of scientific disciplines, is incorrect. Whereas the criterion of universality is appropriate for explanations in terms of law-generalizations, it is misplaced for explanations in terms of kind-generalizations. Explanations and predictions of similarities in the properties of material entities rest on kind-generalizations that should not be assessed in terms of universality. This means that the widespread view that valid scientific explanations and predictions can only rest on exceptionless, spatiotemporally unlimited generalizations, is incorrect.

A consequence is that the scientific status of biology should be seen in a novel perspective. Generally, biology is contrasted with the physical sciences with respect to explanatory and predictive content. Whereas the physical sciences deal in universal generalizations (that is, laws of nature) that serve as the basis of valid scientific explanations and predictions, so the argument goes, the generalizations of biology are non-universal and therefore cannot by themselves support scientific explanations and predictions. Biology, it is then concluded, cannot produce explanations of its own but uses explanations and predictions that rest on the laws of the physical sciences. This argumentation is now found wanting: biology does possess explanatory and predictive generalizations of its own, which however should not be assessed in terms of universality (as is the case with all kind-generalizations).

Chapter 4 constitutes a forerunner of ***Chapter 5***, in which the role of species as units of generalization in biological science is considered. Paul Griffiths and Ruth Millikan have recently argued that species, on the adoption of the ontology of species as segments of the phylogenetic tree of life, can and should be conceptualized as scientific kinds over which explanatory and predictive generalizations hold. Contrary to Griffiths' suggestion, I argue that the ontology of species as phylogenetic tree-segments intrinsically conflicts with any possible conceptualization of species as natural kinds (which, from the perspective taken in the present dissertation, are contained in the category of causal kinds). Furthermore, in this chapter it is found that not all sorts of species-level tree-segments can be conceptualized as historical kinds of organisms. This is possible only under one particular definition of species as segments of the tree of life, i.e., the *Composite Species Concept*.

1.3. Concluding remark

The chapters in the present dissertation have been written in different stages of investigation. As a consequence, they reflect changes that my understanding of the present-day species question has undergone. One example is the following. While in Chapter 3 I assume that the role of species as units of generalization presupposes that species possess a class ontology, in Chapter 5 I show that this role of species is well compatible with an ontology of species as spatiotemporally limited historical entities: under the *Composite Species Concept*, phylogenetic tree-segments can be conceptualized as historical kinds – that is, units of historical generalization. This finding, in turn, entails another result that is unforeseen in Chapter 3. In that chapter, it is argued that more than one concept is needed to perform the three epistemic roles of 'species'. The *Composite Species Concept* was initially devised to provide a definition of species as units of classification but as it now turns out, the *Composite Species Concept* defines entities that can simultaneously perform two of the epistemic roles of 'species' in contemporary biology: that of units of historical generalization and of units of classification.

Reference

Darwin, C. R. (1859). *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*. London: John Murray.