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Chapter 1

The Species Problem, Why Again?

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Additional information is available at the end of the chapter

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1. Introduction

Every scientific discipline, in the semantic terms, is a set of theoretical constructs, i.e theories, concepts, ideas, etc., of different levels of generality. One of paradoxes of development of the science lies in the fact that the more general and fundamental are constructs of such kind, the less clearly can they be delineated at the level of common understanding and defined by means of formal language of the given discipline. As a result, the latter may be likened to a building with a very shaky foundation (basic concepts), with pretty loosely aligned walls (derived concepts), and with a roof just looking quite solidly (the facilities of solving technical problems).

The idea of *the* species belongs to such basic conceptions in the biological sciences, this idea has being been acknowledged repeatedly over the centuries. Accordingly, in the light of the above paradox, the species notion was and remains to be among the most disputed and controversial in biology, with a compass of viewpoints ranging from acknowledging the unconditional and self-evident objective reality of the species to denying it as an objective (natural) phenomenon. Despite the efforts of generations of theoreticians, it appeared impossible to reach a universal and all-suiting understanding and definition of what is *the* species of living organisms, i.e. the "biological species" in its most general (not particular Mayrian) sense.

The fundamental nature of the species notion in biology has led to an attempt to establish a particular biological discipline about it proposed to be called "eidology" or "eidonomy" (after the Greece term "eidos", see 2.2; not in sense of Husserl) [1-6]. Its focal point was declared to be development of some general theory of *the* species of living beings, which would explain both the existence and most general properties of the species as a natural phenomenon, along with variety of its manifestations in different groups of organisms reflected by particular species concepts.

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Disputability and ambiguity of the basic notion of *the* species has generated the well-known "species problem", which appears to be of the same fundamental character to biology as that notion. It was explicitly highlighted in the early 20th century [7-8], but it is clearly much older; as a matter of fact, it had emerged, though without an official nomination, at the time when both natural philosophers and subsequently natural scientists had began to use the term "species" ("eidos") to describe the diversity of both organisms and other things. Current attitude toward this problem varies from its ignoring by practicing biologists to its explicit fixation in theoretical studies as a particular theoretical construct built upon the species notion. Not a once biologists and philosophers participating in the discussion of this problem tried to offer their understanding of the species as more or less radical and more or less general solutions of the species problem. But each of them appeared eventually proved to be more or less particular and not deciding but just supplementing the problem and thus making it far more "problematic". So the species problem in biology seems to be doomed to remain eternal as a consequence of fundamentally irremovable disputability and ambiguity of the very notion of *the* species.

In this chapter, I draw attention to some key issues of the species problem as it is seemed to me now. First, I shall try to delineate somehow what precisely might be called the "species problem" and to identify its origins, both historical and cognitive. Second, I shall present possible scientific and philosophical contexts of its analysis, with emphasis on the non-classical philosophy of science. Third, I shall consider, within the latter philosophy, a possible natural science context of the consideration of the species problem represented in the form of a "conceptual pyramid", a part of which is the species notion as a theoretical construct. At last, it will be shown that another "radical solution" of the species problem may be just to acknowledge objective multiplicity of the "kinds of species" of living beings, corresponding to which is subjective multiplicity of the species concepts.

2. Whence the species problem

Any cognitive problem is systemic by its nature, and the species problem provides no exception. It is structured, multifaceted, multi-component, with the issues of different levels of generality and significance interacting within it. These issues appear and disappear with the development of the problem, which, in its turn, is caused by development of the scientific discipline in which it has been subsisting. In particular, taxonomic aspect of consideration of the species problem was dominating previously, while its "detaxonomization" is noticeable at the present time, according to which the "species in classification" becomes separated from the "species in nature" and it is the latter that is now being considered as a focal point of the species problem [9-11]. Respectively, discussion of this problem should begin with consideration of the following key issues: *What* is the species problem? Why is it about just the *species*? Why is it just the *problem*? [10, 12-13].

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2.1. What is the species problem

Generally speaking, any problem is generated by a cognitive issue that has no clear-cut single answer, and this is true for the species problem. The latter is a consequence of the above-stressed irremovable ambiguity of the species notion (in its general biological sense), which means impossibility to give an exhaustive comprehensive theoretical definition of the species as a biological phenomenon. This is referred to as the "species uncertainty" [14-15].

I think, however, that ambiguity of the species concept in itself is not the whole problem. Its important (maybe the core) part seems to be a contradiction between polysemy of the species notion and unsuccessful striving of discussants to reduce it to a single most general (or at least most appropriate) definition common to the entire biology.

An aspiration for a unified comprehension and definition of the species is quite understandable; every science must have some unified thesaurus, through which the subject area of that science is uniformly described. From such a perspective, usage of some common term for a certain natural phenomenon—in our particular case, for a manifestation of diversity of organisms—implies that the phenomenon in question is endowed with a unique property, which allows to recognize it among other phenomena of the "same kind". Therefore, the history of the species problem appeared to be largely a story of searches for such a fundamental overall property of *the* species ("specieshood", see 5), which could be adequately reflected in a single definition.

The species problem, in such a general meaning, emerged simultaneously with the very notion of species (= eidos) in the Ancient times, where it initially had quite different interpretations (see 2.2). In the scholastic period, this ambiguity has been reduced to a logical interpretation of the species. In modern times, however, dominated became biological understanding of *the* species as a group of organisms, which diverse interpretations are currently being tried to reduce to its evolutionary or genetic (reproductive) or operational meanings. Another contemporary attempt, if not to reduce but at least to put diverse treatments in some order, is to build a kind of "conceptual pyramid" of different levels of generality of these treatments (see 4.1).

One of the key issues that shapes contemporary understanding of the species problems concerns explanation of emergence of both *the* species (in the general sense) as a natural phenomenon and actual diversity of its manifestations. I think that there cannot be any properly developed theory of the species (whatever might it be) without putting and answering these fundamental questions.

2.2. Why the species

Fundamental status of the species concept has deep historical roots, without reference to which one can hardly understand the reasons for such a great attention paid both to the species proper and to the species problem under consideration.

In a very rough approximation (for details, see [2, 16-17], the history of the term "species" dominating nowadays in biology goes back to the Aristotelian notion of "eidos" de-

noting certain "form" through which the formless "matter" assumes its actual existence. So, the "species" (= "eidos" = "form") such treated was "external" with respect to the "matter", which is evident, for instance, from Theophrastos' concept of plants changing their "species" due to changes of conditions of their growth [18]. Under this naturphilosophical doctrine, the actual existence of any natural body is impossible without respective "eidos" making the thing what it is. This ontology had been supplemented by a cognitive construct called later "genus-species scheme" by neo-Platonists and scholastics, in which the "eidos"="species" got rather logical status of one of the universal categories of knowledge. According to this integrated onto-epistemological construct, the "eidos"="species" is universal and fundamental in both to the Nature itself and to the knowledge about the Nature. Therefore, nothing can exist without the species, be it a body in the objective world or its image inferred within the logical generic-species subjective scheme. This led to a strong belief of earlier Aristotle interpreters formulated explicitly by Boethius that "[*if*] *we do not know what is the species, nothing would secure us from misunderstandings*" (translated from the Russian edition [19]).

Strictly speaking, it is this Ancient historical and cognitive landmark from which it is reasonable to trace the above "eidology" with its presumption of universality and fundamentality of the species, whatever its particular interpretation may be, and all that is associated with it. Searching for a "final answer" to the question "What is *the* species?" gave birth to some "Boethian tradition". It was brought to biology by Aristotelian A. Cesalpino having first applied explicitly generic-species scheme to classification of botanical objects. Subsequently, it was filled in part with the biological content by J. Ray, and then fixed by Linnaeus, for whom it was the species that was the basic unit of the Natural System. So, past and present theoreticians, having tried and still trying to answer somehow the above question, were and still are "Boethians", as they were and still are believing this issue is one of the most fundamental in biology.

Possible answers to that "Boethian question" have been being traditionally sought most often in the framework of the dichotomy preset by neo-Platonists and early scholastics in the form of opposition of realism *vs.* nominalism [13, 20-22]. Commitment to the realism requires acknowledge of the species objectively and undoubtedly existing as a kind of fundamental and universal "unit of Nature". Nominalists deny objectivity (reality) of the species in the sense just indicated, or at least do not recognize its particular fundamental status in the hierarchy of the Nature (bionominalism, see [11]), though acknowledge necessity and universality of the species as a useful "unit of classification".

Discussants, even belonging to opposite research schools, can quite agree with each other in recognition of fundamental status of the above "Boethian question", whatever its particular answer might be. For instance, both "methodist" Linnaeus and "naturalist" Buffon (in his later years) believed in objective (real) status of the species as a universal and fundamental "unit of the Nature". On the other hand, evolutionist Darwin, rejecting alongside with logician J. Bentham distinctiveness of the species as a fundamental taxonomic and eventually natural category, called however his famous book just "*The Origin of Species*...", and not of races or of something like that.

One of peculiar manifestations of the "Boethian tradition", I think, is an exaggerated attention to the species category displayed by many biologists who use to pay too much attention to it. Due to this, other aspects of the biological diversity, both "vertical" (e.g. supraspecific groups) and "horizontal" (e.g. ecomorphs), are usually treated as of secondary importance. This standpoint seems to be obsolete with regard to modern understanding of biodiversity, but it nevertheless still persists in contemporary biology thus impoverishing the overall picture of the biodiversity [23].

2.3. Why the problem

A brief answer to this question was given above (see 2.1); the problem is that the notion of species, which has become fundamental for biology due to, among others, its "historical burden", cannot be filled with a single content [12, 17, 22]. It has many meanings, which cannot be reduced to a single, albeit rather complicated, formula such as " The species is...".

An ambiguity of the species notion has as deep historical roots as this notion itself. It has been originally used to refer to essentially different phenomena, some of which belonged to the actual diversity of organisms, while others to the ways this diversity was described. And this is one of the main sources of the species problem.

Thus, Aristotle understood the "eidos" as both the groups of organisms (e.g. "tetrapods") and the essential properties characterizing them (e.g. "tetrapodness"). Such "dual" (from the modern standpoint) usage of the same term "eidos" was quite natural to the Ancient understanding of the Nature as the "Physis" and understanding of the species (eidos) as the "form" shaping the matter [24] (see 2.2). This standpoint was partially preserved in the natural history at least until the 16th century (occurred in J. Ray's writings, see [25]. However, these two aspects of the Ancient understanding of *the* species (eidos), as a taxon or as a meron, are recognized in the modern biology as fundamentally different, so their joining under the same term became removed by separation of two aspects, taxonomic and meronomic, of the organismal diversity [26]. Accordingly, taxonomically treated "eidos" became fixed as *the* species, while its meronomic treatment provides the notion of homologue.

Further, although Aristotle distinguished terminologically between "natural" and "logical" groups and seemed to use the term "eidos" only to designate the second ones [16], scholasticism united them under the single Latin term "species". It has not probably been without influence of Thomism, as one of its key ideas related to the topic under discussion was assertion of the unity of three "hypostases" of the essences—before things (*ante res*), within things (*in rebus*), and after things (*post res*)—as different aspects of the same universal organizing principle of the world of both things and ideas. Modern natural science recognizes a necessity of handling the "natural species" separately from the "logical species" [10, 11, 12, 13, 27], but this is not yet reflected properly in the existing thesaurus of "eidology". And this also contributes to the problematic situation; obviously, any discussion of ontological status of the species becomes meaningless if it is not indicated explicitly what kind of "species", natural or logical, is referred to (see also 3.4).

An important source of the species problem, in its general sense, is the multidimensional nature of the "species in nature" understood also in its general sense. It means that the species a) is a member of different natural processes, and b) it possess its own internal structure of different kind. Every aspect of the species natural history (e.g. genealogical, ecological, reproductive, etc.) can be fixed in the form of its key (essential) property to be used for elaborating certain species concept, which is advocated by its authors and proponents as a "principal" one. An aspiration for ascribing a universal meaning of the species to such particular concepts and, accordingly, the belittling of other concepts leads to competition between them, which however can be inconsistent under certain circumstance (see 5.2).

A particular aspect of the species multidimensionality and thus of the species problem became apparent relatively recently; it is the necessity for separate consideration of "the species taxon problem" and "the species category problem" [16, 28-29]. In the terms adopted here, the species category is defined by the specieshood, while the species taxon is (quite roughly) defined by particular manifestation of the specieshood in particular groups of organisms.

One of the sources of the species problem is that biologists (and occasionally philosophers) put quite different questions analyzing the species concepts and their applications; this was noticed repeatedly by many authors [9, 10, 12, 13, 16, 22, 30-34]. Some of these questions are about essential properties of the species (i.e. about the above mentioned "specieshood"), others deal with the mechanisms of emergence and sustainable subsistence of the species, and more others consider how to recognize particular species in the empirical studies. In this regard, the species problem is quite comparable to the homology problem or to the gene problem; in each of them, respective unit, though uniformly called (the species, the homologue, the gene, respectively), are recognized and treated much differently in particular research programs.

Pretty curious seems to be a kind of "psychological" source of the species problem, i.e. conviction of the debate participants that this problem does actually exist [35]. Due to this, the species problem takes certain kind of independence and self-sufficiency as a particular conceptual construct interested mainly to some theoreticians.

It is important to bear in one's mind that the species problem is a dynamic construct. It has been developing in parallel with development of both the natural science and the philosophy of science, responding one or another way to the new ideas elaborated by them. Accordingly, the content of the problem has been changing with time; some of its aspects fallen away, some came as new ones to gain particular attention. One of the most important recent changes was due to completing the above rigid dichotomy between "realism *vs*. nominalism" to a trichotomy by adding a modern version of the conceptualism to them [10, 27, 36]. The latter brings its own focus to the general species problem, which allows to take a fresh look at the multidimensional nature of the species proper and to legitimizes the "species pluralism" (see 3.1).

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3. Understanding species: Cognitive situation

One of the most important in the contemporary cognitive science is the notion of cognitive situation, within which object, subject, purpose, and means of knowledge are determined. Understanding of its content and structure was changing considerably with the evolution of philosophy of science. The most significant shift occurred in the second half of the 20th century in connection with transition from the classical to the non-classical scientific paradigm [37]. The latter evidently, albeit it is not fully acknowledged yet, affects understanding of the entire species problem [10].

3.1. Classical *vs*. non-classical views of the species

Classical science is based on the following key assumptions. The Universe is organized (structured) by a single principle; the structure of the Universe is therefore linear and admits a reduction of its diversity to a minimum ("atomic") level; the unity of the Universe as a global natural phenomenon is reflected in the unity of a "final theory" describing it; it is comprehended by means of a unified general method (in its broadest sense, i.e. *Organon*). This general idea, in its natural philosophy version, is rooted in the Biblical worldview, according to which the Universe arose as a result of realization of the unified plan of Divine creation, and none other that Linnaeus wrote that *"Natura est lex Dei"* (see [38]). In the positivist version of the classical science, emphasis is made not on the unity of the Universe origin, but just on the method of its cognition; it is acknowledged that "the world is simple and allows as a simple description" following some unified protocol (R. Carnap). This general position is known as the onto-epistemological monism.

With respect to the species issues, monistic position, in its extreme form, is expressed in the recognition of the species as a universal unit of organization of the living matter, which existence does not require any proof [2]. Accordingly, there can be only one "true" species concept (or theory) describing (and eventually explaining) this universal phenomenon by means of some universal theory. In a more moderate version, which recognizes validity of different concepts, it means a possibility to elaborate finally an "ideal" [39], or a "primary" [40-42], or a "universal" [43] species concept, in relation to which other concepts, though locally true, have a subordinate (secondary, derivative) status. But it turns out that different philosophical backgrounds leads to different understanding of which exactly species concept (theory) should be considered as "primary". An emphasis on ontology leads to aspiration for as broad as possible biologically meaningful definition of *the* species. An emphasis on epistemology presumes search of as wide as possible operational theory-neutral concept. So, in some broadest perspective, any such candidates for a "universal" species concept provide just some partial decisions of the overall species problem.

The non-classical scientific paradigm is based on acknowledging complexity of both the Universe and of any of its components (fragments, aspects, levels, etc.), which are endowed with some emergent properties and are ontologically irreducible to each other. This means a fundamental impossibility of any kind of "universal theory of everything"; instead, different components (fragments, aspects, etc.) of the Universe are described by different partial theo-

ries that do not compete with each other but are complementary [44]. A part of non-classical paradigm is the modern conceptualism, according to which no empirical knowledge can exist out of the context configured by an informal (content-wise) theory of certain level of generality. The same is thought to be true for the method; a unified "Organon" (except for the comparative method in its most general sense) is impossible, various mutually irreducible components (fragments, aspects, etc.) of the Universe are described by particular methods satisfying conditions of the relevant informal theories. Of essential importance is recognition of irremovable presence of an "observer" in the cognitive situation; it is the cognizing subject that chooses somehow what and how exactly should be investigated in the Universe. This means fundamental impossibility of any kind of "absolutely objective" knowledge. From this it follows the onto-epistemological pluralism, with respect to the species issues meaning the following.

It is acknowledged, as an initial condition for analysis of the species problem, that (a) the biota is objectively structured in multi-faceted and multi-level ways, (b) one of manifestations of this structuredness is the subsistence of certain structural units, and (c) one of these units is what is usually called *the* species. Further, it is recognized that, just like the biota itself, the "species in Nature" understood in such a very general sense is by itself a complex and multi-faceted phenomenon. Recognition of this "species unit" in its whatever manifestations at the theoretical level is based on an informal (biologically meaningful) theory, which provides some general criteria of what is *the* species as a natural phenomenon. Therefore, any kind of theorizing about *the* species involves, by necessity, explicit fixation of some biologically meaningful context within which this natural phenomenon with its properties (manifestations) should be considered. Different mutually irreducible manifestations of *the* species are reflected in different species concepts which describe it in various ways and thus are complementary to each other. Together, they constitute a kind of general conceptual space as an "existential domain" of the species problem as a theoretical construct (see 3.2). It is also acknowledged that any empirical species concepts (in particular, those based on the similarity as such) are biologically sound only if they are correlated with certain biologically meaningful (evolutionary, or ecological, or else) theoretical concept. And, at last, no empirical identification of *a* particular "species in Nature" is possible without the above informal concept defining *the* species at theoretical level, as it is just the meaningful theory that indicates to a researcher what and how to "see" (to research) in the Nature (A. Einstein).

3.2. Three-partitioned cognitive situation for the species problem

Cognitive situation [37] is, in general, three-partitioned; it includes objective (ontological), epistemic and subjective components. The first component defines *what* to study, the second defines *how* to study, and the third defines *who* studies. In the framework of classical and non-classical paradigms, interrelations between these components are interpreted in significantly different ways.

In the classical science seeking for an "absolutely objective" knowledge by an "absolutely objective" method, the mutual influence of the above three components is though to be minimized. With this, the learning subject is "excluded" from the cognitive situation in or-

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der to eliminate its influence on the results of the learning, so the entire situation is supposed to be two-partitioned, consisting of non-interrelated ontological and epistemic components.

In the non-classical science, an irremovable presence and interaction of all the above three components of cognitive situation is acknowledged, which means the following. The objective component forming ontological basis of the species problem is construed taking into account certain epistemological conditions (e.g. observability). Epistemic component, as a set of principles and standards of studying the species issues, is formed, on the one hand, by a subject of the cognitive activity and, on the other hand, should be adequate to the ontology of the object (e.g. to its probabilistic nature). Subjective component in its most general sense embraces the entire spectrum of the learning subject ranging from particular scholars to scientific communities formed around particular scientific paradigms (research programs). It is the subject that captures, in some or other way, certain aspect of the biotic structure, in which context it becomes meaningful to consider *the* species (in its general sense) as an element of that structure. This "capturing" is a kind of cognitive act that makes it possible to identify *the* species in the cognitive situation as something liable to a theoretical comprehension and empirical identification. And it is the learning subject that, after all, decides how to define and to study that structure.

Each of these components exists in the cognitive situation by means of various concepts, definitions and occasionally personal ideas fixing them some or other way. This means that each cognitive situation involves a kind of "conceptualizing the world" [45] and therefore is associated with certain "conceptual space" [46], outside of which it does not exist. Such a "space" should be outlined as explicitly as possible; as a matter of fact, if some phenomenon is not reflected in concepts and definitions (or at least does not appear as a part of personal knowledge), then it is absent in the cognitive situation and cannot be reasonably investigated. One of such conceptual spaces is built around the species notion and eventually the species problem. This space can generally be regarded as three-dimensional; its "cognitive axes" correspond to the above three components of the cognitive situation. Such an understanding of the latter allows to consider every partial species concept as a local area (subspace) in that conceptual space, so its content can be properly and fully determined only by its projecting onto all three axes of that space. In particular, the latter means that, say, evolutionary species should be apprehended not in an "absolute" sense as something unconditionally existing in the Nature but as a particular aspect of the biota's structure recognized by a particular research community based on a particular theoretical concept.

With this way of considering particular species concepts, it is to be taken into account that they can be "loaded" with each of the components in a different degree; or, in other words, they can be projected onto corresponding axes of the conceptual space in different ways. In this regard, it is important to emphasize that these axes, although intercorrelated because of interaction of respective components of the cognitive situation, can be considered as "orthogonal" in some utmost sense. Therefore, the species concepts, to the extent that they are "loaded" with (projected onto) basically different axes, may have substantially different cognitive meaning, with some of them being primarily ontological (e.g. phylogenetic) while

others being primarily epistemological (e.g. phenetic). Such way of viewing of the overall conceptual space allows to stress that only the species concepts basically "loaded" with (projected onto) the same "cognitive axis" may be considered as the items of the "same kind", and thus may compete with each other (for instance, evolutionary and phylogenetic concepts). Contrary to this, species concepts basically "loaded" with (projected onto) different "cognitive axes" are not of the "same kind" and cannot compete directly in the given conceptual space; the instances are theory-burden phylogenetic and theory-neutral phenetic concepts. What compete actually under such a circumstance are not particular species concept but respective "cognitive axes" which are given more or less significance within the frameworks of particular natural science philosophies.

Further structuring of the overall conceptual space of the species problem is an important issue involving each of its "cognitive axes". Thus, the object (ontological) axis includes, for instance, ecological and phylogenetic aspects of subsistence of the "species in Nature"; or its phenomenological (e.g. genealogy) and causal (e.g. reproductive mechanisms) aspects. The epistemological axis includes, for instance, logical or mathematical foundations of the researches concerning the species subject. At last, the subject axis includes personal (intuitive) or "collective" (paradigmal) attitude to the "species in Nature". All this has a significant relevance to consideration of certain conditions of comparability and "competibility" of the species concepts considered elsewhere (see 5.2).

3.3. Species concept as an onto-epistemological model

In considering structure of the cognitive situation of the species problem, it is fundamentally important to understand that its objective (ontological) component encompasses not infinite objective reality (the Universe itself), but its finite model (representation) suitable for its handling as a theoretical construct. This model is given in a form of fixed concepts and definitions, it emerges as a result of some reduction operation, which is based on certain ideas of what is essential and what is not for analysis of the species problem. First, the biota is "extracted" from the Universe by breaking off some of its relationship with other components of the Universe irrelevant to representation of the biota in terms of its own structure. Then some structural units of the biota are singled out, one of which is designated as the species. When considering these items, only those characteristics of the biotic structure become evidently included that are deemed relevant to the species problem. This sequential operation of reduction is resulted in an onto-epistemological "species model" as a part of the objective component of cognitive situation of the species problem.

Each such "species model" is a biologically meaningful theoretical construct, which in more conventional terms is usually called the "species concept". It provides an item that could be properly denoted as the "species in theory". As it can be seen from the foregoing, the latter exists in the form of certain verbal definitions, which allow to distinguish the species from other units in the biotic structure (e.g. macro-monophyletic groups, ecomorphs, discrete age and sex groups, etc.). The combination of these definitions, as noted above, outlines the conceptual space of the species problem, and each onto-epistemological species model (concept)

can be regarded as a local area of that space. In the terms adopted here, the less reducing is a species model, the greater part of conceptual space is occupied by the respective area.

In Max Weber's terms (see [47]), such an ontological species model can be interpreted as an "ideal type" that fixes essential properties of what is perceived by a researcher as the "species in Nature" being an objective natural phenomenon. Various properties are regarded as essential or nonessential under some biologically meaningful theory, which defines simultaneously (a) particular consideration aspect of the biotic structure in general and (b) the candidates "species in Nature" in particular. It is such a theory that gives a reduction basis resulted into a particular ontological "species model" (this issue is considered in some detail in one of the following sections, see 4.2). It is clear that the more reducing a model is, i.e. the more supposedly "nonessential" properties are dropped in its design, the more distant it is from the "species in Nature" being modeled, so the poorer and the more partial is it in its content. For instance, the genealogical species model is more reducing and less meaningful than the evolutionary one; there is "less" of the "species in Nature" in the former than in the latter.

It is clear that the ontological models are not the only possible. Epistemological models (concepts) figure along with them, which are construed with a minimum appeal to the objective component of cognitive situation. These include various types of operational concepts aimed at developing methods for identifying and describing some structural units by tradition called the species. But, from the conceptualism standpoint, such models and respective units they allow to recognize are biologically "empty" without reference to any and meaningful theory therefore cannot be related directly to the "species in Nature". It is possible to talk also about "subjective models" as manifestations of personal knowledge, i.e. of scientists' intuitive images about how the biota is structured at the species level.

It should be emphasized that degree of reduction of the ontological species model (concept) depends on degree of "meddling" of a subject (researcher) into the cognitive situation. As it was pointed out above, it is the subject that decides, which of the relations of the "species in Nature" with its "Umgebung" are to be omitted in order to make the "species in theory" meeting certain epistemological criteria, for example, to make it more operational. It is seen from this that the more reducing the ontological species model (concept) is due to its operationalization, the less of objective and more of subjective components is embedded in it. From this viewpoint, for example, definition of the species as a phylogroup is more "subjective" (in the sense just indicated) than its evolutionary definition. At best, such reducing models can be more appropriate, under conditions of operationalism, as "intersubjective" (in the sense of Popper), which does not indispensably implies they are more "objective".

There can be quite a lot of ways of reducing cognitively infinite Universe to particular ontological biota models and of further reducing the latter to some finite ontological species models. The potential number of such reducing models are just as many as informal theories of the biotic structure can be elaborated to infer essential criteria for construing the species models (presumably, they are not infinitely numerous). Any such finite "species in theory", as noted above, is necessarily a reducing partial representation of cognitively inexhaustible multidimensional "species in Nature". This means that certain natural phenomenon denot-

ed by the "species" notion, in its most general understanding, may be represented by a number of partial ontological species models (concepts). This serves as a prerequisite for the "species pluralism" from the very beginning of construing the species problem at the ontological level.

In a more general and a more formal sense, each of the theories serving as reducing base for elaborating particular species models (concepts) can be considered as a "possible world" in sense of Kripke. Each of these worlds is defined by a variable (or a set of variables), which are treated as most significant for understanding and defining *the* species, be they genealogical, ecological, ethological or any other possible consideration. This formalism might be of use from a semantic standpoint in considering definitions and naming different "kinds of species" (see 5.2). Besides, from a more practical viewpoint, it allows to distinguish, in some informal way, "good" and "bad" species, with the former being uniformly recognized in different "possible worlds" defined by different variables [10].

In the analysis of objective component of the cognitive situation within the non-classical scientific paradigm, one of theoretically meaningful issues in the species problem becomes the determination of not competitive relations between the onto-epistemological species models (concepts) but the conditions of their mutual interpretability, i.e. of translation of statements of one concept into those of another with minimal loss of information. Obviously, the greater is overlap of the areas in the general conceptual space corresponding to different species models (concepts), the more they are mutually interpretable. This standpoint makes cognitive situation of the species problem more clearly structured and allows a more accurate solving of practical tasks of comparison of particular species classifications based on different onto-epistemological models (concepts).

3.4. Species as "one of the many"

In the classical tradition, the species is considered *a priori* as a basic unit of the Natural System (see 2.2). This tradition is continued by the modern concept of biodiversity, according to which the species is the latter's basic unit [48]. But if the Natural System had a naturphilosophical status of the universal "law of Nature", in which the species took a unique place (see "Philosophy of Botany" of Linnaeus), the biodiversity is merely an epiphenomenon of some fundamental property of the biota, namely of its structure. I believe that, in modern biology, it is the biotic structure, and not some Natural System of naturphilosophy, that should be represented by certain informal model in the cognitive situation of the species problem. The implications of this substitution is that this structure is not only multi-level, but also multifold, with the species can be seen as just "one of the many" units of this structure [23].

The currently dominating paradigm of biodiversity (or rather, of the biotic structure) implies that the latter is subdivided into two internested hierarchies, phylogenetic and ecological [49]. At the same time it is presumed that they are obviously not completely independent of each other but are, as a matter of fact, just mutually irreducible aspects of the single structured biota.

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Phylogenetic aspects of the biotic structure corresponds to the multi-level phylogenetic pattern in which the species is "one of the many" monophyletic groups of different levels of generality. This viewpoint was anticipated by those biologists of the 19th century who rejected fundamental status of the species as a unit of either classification or evolution (see 2.2), this idea is currently reflected in designation of the species, according to the phylogenetic species concept, as a *phylo*species or *clado*species or just as a phylogroup [50-52].

Ecological aspect of the biotic structure corresponds to the hierarchy of ecosystems, with its own basic structural units (elements). Within this general conception, it is possible to fix *eco*specis at some level of ecological hierarchy defined by its position in the niche structure of local communities [53-55]. However, there is another approach do describing community structure, which basic unit is the ecomorph, i.e. an array of organisms characterized by unity of ecological and morphological characters, irrespective of their phylogenetic history [56-57]. These ecomorphs may, for example, be age stages in organisms with "discrete" ontogeny (like larvae and imagoes in insects with complete metamorphosis), or gender groups performing different functions in the ecosystems (like mosquito's males and females), or occasionally castes in the social insects. In the terms of ecological structure, all these units are equivalent in the sense they take some comparable fixed positions in the hierarchy of ecosystems. In this perspective, the species in its "local" interpretation (as "non-dimensional species" of Mayr) is just "one of the many" of such ecomorphs. Indeed, it presumably does not matter for some waterfowl community, if respective ecological niches are occupied by different species of aquatic and terrestrial predatory insects or by larval and imago stages of the same dragonfly species.

The above consideration allows to emphasize that the species as a unit of the biotic structure is not an *a priori* given "basic" natural phenomenon, which is obligatory "the same" (in a sense) in all hierarchies of the biotic structure. It is just one of several manifestations (aspects) of that structure, so it is not *the* "species" but *a* "species unit", which is fixed somehow by a subject of the cognitive situation based on some ontological model (theory) of the biota. The latter model includes, as its part, indication of certain essential characteristics and parameters (structural, functional, temporal, etc.) that allow to fix certain units of the biotic structure (biodiversity), among which there might be the "species unit" in question. It is evident that various ontological models fitting certain research programs may presume various ways of fixation of the latter unit. In one case, it will be a phylospecies, in another — ecospecies, in the third — biospecies, etc. Taking into account the above ideas of the conceptual space, these units coincide to the extent that the parameters of the "species models" fixing them overlap in that space.

Such a theoretical (cognitive) determination of the ways of fixation of the "species units" of the biotic structure leads to a conclusion that the aforementioned "species pluralism" (see 3.1) is actually unavoidable. Moreover, its inevitable extension (hopefully asymptotic) can be assumed because of supposed progressive complication of the concepts of the biotic structure including causes and principles of its organization, functioning and evolution.

3.5. In what senses are the species "real"?

Within an intersection of the ontological and epistemological components of cognitive situation of the species problem (see 3.2), theoretical issues concerning the species "modes of being" are most important. One of these involves ontology of the "species units", which consideration is based on certain epistemic criteria of the species reality.

Approaches to solve this issue—or rather this problem, because it does not have any unique trivial solution—has being been discussed in a great amount of literature since the neo-Platonists (see 2.2). Previously, it most often was considered in the context of the classical scientific philosophical paradigm, according to which the species are either "real" in the sense that they exist objectively in the Nature (position of realism), or "unreal" being just outputs of some cognitive activity (position of nominalism).

Within the non-classical onto-epistemology, which important part is the contemporary conceptualism (see 3.1), diversity of the very "reality" is acknowledged; by this, I mean not the above S. Kripke's plural "possible worlds", but the "three worlds" in sense of K. Popper [58]. According to the latter, the "first world" corresponds to the objective reality, this is what exists "in fact" outside an observer. The "second world" corresponds to the subjective reality in consciousness (and unconsciousness) of a researcher, which is composed of subjective images reflecting what exists (or occasionally does not) "in fact". The "third world" (or a substantial part of it) corresponds to the theoretical reality, that is to the conceptual space in which the species problem is considered.

It is evident that those "three worlds" of Popper correspond to a degree to the three basic components of cognitive situation or, what is almost the same, to the "axes" of the conceptual space outlined above (see 3.1). From this it follows that the issue of the species reality as a part of the respective problem gains a particular emphasis; the question of whether the species is real or not should be raised with taking into account existence of those different realities. So this question becomes complete if only certain "cognitive axis" is indicated, as well. The "species in Nature" possess a reality which is used to be denoted as an objective. The "species in theory" is also "real", but its reality is different, it is that of a theoretical construct within the overall conceptual space. To a researcher, his/her own ideas of the species are part of his/her mental subjective reality, so it is also "real" in a peculiar manner. Thus, all these "species" existing in different Popperian "worlds", are obviously "real" in their own ways, though their realities are of essentially different ontology—and this is another aspect of the "species pluralism". With this perspective of considering species "realities", one of the key issues is to establish a correspondence between all of them.

In this regard, the "species in classification" deserves close attention. Classification can be considered as a model (representation) of some aspect of the structure of biological diversity, so it can be attributed with some reservations to the "third world" of Popper. But this is not a theoretical reality in its strict sense; rather, the "species in classification" is a judgment (hypothesis) about the "species in Nature" put forward on the basis of some data at hands within the scientific context provided by particular "species in theory". Thus, the "species in

classification" is a kind of connecting link between all three "species realities" allowing to set a required correspondence between them.

3.6. Cognitive styles

The subjective component of cognitive situation is multidimensional and multilevel, like its other basic components. In referring to it in the non-classical theory of science, attention is most often paid to division of overall scientific community into research schools adhered to particular paradigms (research programs). This implies a particular theoretical interpretation of empirical data by members of this community according to a particular theoretical construct underlying respective paradigm (research program). This is, that is to say, an "apparent" non-personal manifestation of the subjective component. Relevance of this "paradigm effect" to the present issue is quite obvious; every sufficiently general species concept (biological, phenetic, phylogenetic, etc.) serves as a core for the formation of a particular paradigm (or is a part of respective research program). Therefore, this level of organization of the subjective component is considered in a lot of publications and so is hardly worth being discussed here any longer.

Much less attention is drawn to a lower level of the subjective component corresponding to the individual cognitive styles underlying researchers' personal (tacit) knowledge [59, 60]. These styles are responsible for forming an array of the Popperian "third worlds". Cognitive (thinking) styles are implied by researchers' way of perception of the world, they are diverse and multifaceted, can be ordered (in the simplest case) in pairs of opposites [61]. Examples include researchers' inclination for holistic or reduction vision of the whole biota and any of its structural elements, for intuitive or rational way of knowledge, etc. A pair of opposites "typological *vs*. population" thinking styles is known to be quite relevant to the species problem [62-63].

In the framework of contrasting classical and non-classical scientific paradigms (see 3.1), of special significance is the pair of "discrete *vs*. fuzzy" thinking, which corresponds evidently to the dichotomy of "discrete *vs*. fuzzy" logic [64]. The principal meaning of fuzzy thinking is that it frees a researcher from having to look for the sharp edges where they cannot in principle be drawn. "Splitting" phyletic lineages into fragments corresponding to the "vertical species" of paleontologists is an example of situations where such a thinking style is more than relevant. Another typical example is the interspecies hybridization; if it is not widespread in nature and not absorptive, it does not preclude recognition of the species status of respective units. In both these cases, the species are treated as "fuzzy" entities, contrary to the provisions of "xenotaxonomy" (in sense of [65]). This "fuzzy" term was suggested for a particular case of prokaryote species [66- 67], but it certainly deserves more wide treatment just outlined [10, 68]. Finally, this style allows to see not so dramatically the entire situation with the "species pluralism"; at least some of the ontological species models (concepts) are not exclusive but overlap and complement each others due to their having certain conceptual constructs in common, so, in a sense, these concepts are not "discrete" but "fuzzy".

4. Defining species: Conceptual pyramid

Any sufficiently advanced theoretical construct (theory, concept, etc.) is organized in a conceptual pyramid, which is caused by certain reason of logical nature.

According to the classical theory of definitions [69], each notion can be sufficiently strictly defined only within the above mentioned logical genus-species scheme (see 2.2). This means that (a) each particular notion must be related as a "logical species" to a more general notion as its "logical genus" and (b) within the latter, several "logical species" should be distinguished as the latter's partial notions, so that any each of them can be properly defined only with reference to its counterparts within the same "logical genus". Therefore, in order to define *the* species as a natural phenomenon, it is necessary to define, first, that natural phenomenon which notion can be considered as a "logical genus" for the biologically meaningful species notion and, second, those natural phenomena, which notions can serve, along with the species notion, as different "logical species" within the given "logical genus" properly defined.

Similar though less formal hierarchical scheme of definitions is implied by well-known Gödel's incompleteness theorem. Elaborated initially as purely mathematical, in its more general epistemological interpretation [70-71] it affirms that any theory (concept) cannot be exhaustively defined in the terms of the language of this theory (concept) itself. For such a definition to be properly construed, a kind of meta-language is required, which belongs to a theory (concept) of higher level of generality ("logical genus"), with respect to which the given notion is its partial interpretation ("logical species").

All the above has a direct bearing on the analysis of logical structure and content of the species problem. First of all, both argumentation schemes imply that species concepts should be arranged in a kind of "conceptual pyramid" of various levels of generality, with the most general concepts belonging to the "tip" of the pyramid and the least general ones being placed at its base. "Pyramidal" shape of the resulting structure is due to the fact that, at each level of generality, partial concepts are evidently more numerous than more general (inclusive) ones. Next, each species concept of lower generality level gains its substantiation only within the context provided by the concept of higher generality level. At last, what is quite important, such a "pyramidal" construction of the entire species problem means that within the species concept(s) proper, even of the highest generality level, the very notion of species cannot be well defined.

4.1. Pyramid(s) of the species concepts

There more than 20 species concepts are currently recognized [16, 17, 41, 72-74]; as it was pointed out (see 2.1), such a multiplicity is one of the core aspects of the species problem. Each of these concepts provides its own species definition (although not quite strict in most cases), based on a particular understanding of what are essential properties constituting the key parameter of the "specieshood".

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Several classifications of the species concepts and definitions of different levels of generality were elaborated for ordering such a multiplicity of concepts. The latter are grouped in each of these classifications according to the parameters that are taken as the most important by respective authors for ordering the concepts. This appeared to be resulted in several hierarchical arrangements of the species concepts, with their amount reflecting number of the bases (ordering parameters), which can be fixed for classifying those concepts. This gives rise to a peculiar aspect of the species problem, now it is not diversity of the concepts proper, but of their classifications.

In one of the earlier versions of such conceptual pyramids, recognition of "primary" and "secondary" species concepts was proposed [40-41]. This implies that the primary concepts include more characteristics of the species than the secondary, so the former are more general and less in number while the latter are their partial interpretation and thus are more numerous. In a sense, this idea is similar to that of Gilmour [75] who suggested to recognize "general purpose" (primary) and "special purpose" (secondary) classifications. In the just mentioned Mayden's [41] classification, evolutionary species concept is referred to as the primary, because it actually is one of the most inclusive in its content. However, a systemic consideration of the species [9, 10, 76], though not explicitly formulated as a concept (see below), provides its even more general treatment, so it is the latter that can claim to be the primary, indeed, for this particular conceptual pyramid.

In another, more general approach to elaborating classifications of such kind, one of the most important grounds giving fundamentally different conceptual pyramids, I believe, might be consideration of the species in accordance to the ways they are considered within the conceptual space.

One such classification presumes distinguishing among concepts corresponding to either ontological or epistemological considerations of the species [77]. As it was mentioned above (see 3.2), they can be considered as different "projections" of the general species concept onto different "axes" of the conceptual space, so they may be considered as equivalent in this respect. The former are theoretically laden and give an idea of *what* is the species as a natural phenomenon (evolutionary, genealogical, reproductive, etc.). The latter are theory-neutral and indicate *how* to distinguish particular species whatever might be their theoretical foundations (operational taxonomic unit, minimal recognizable unit, etc.). However, from the conceptualism standpoint addressed to ontology (see 3.1), such a hierarchy cannot be considered as well established, because, in biology as a natural history science, formal operational concepts cannot function as sound scientific constructs outside the context given by biologically meaningful informal concepts. Attributing them an equal status (rank in the conceptual pyramid) yields a biased view of the entire species problem as it implies substitution of theoretical issues about meaningful species definitions by elaborating facilities for practical species identifications [10, 33, 39, 41, 74, 78]. Within the above hierarchy of the "primary" and "secondary" species concepts, operational ones are nothing more than "tertiary" ones belonging to the lowest level of the conceptual pyramid.

Close to the previous one by its meaning is a division of the species concepts reflecting their belonging to the "first" and the "third" worlds of Popper (see 3.4), which are the "species in

Nature" and the "species in theory" (or maybe the "species in classification"). Proponents of this division offer to use the term "species" to designate a unit of taxonomic classification, while natural units (populations) are to be denoted by some different terms [11, 79-81]; this idea goes back to Aristotle, see 2.3).

Another type of classification of the species concepts by general onto-epistemological criterion is a hotly debated interpretation of the species (in general sense) as a class, or as a cluster, or as a historical group, or as a individual (see 5.2). Such a classification by its content may be, with some reservations, considered as not actually biological but rather philosophical [39].

In the classification of species concepts elaborated on the basis of biologically meaningful criteria, a distinguish is made between diachronic and synchronic or, which is nearly the same, between historical and structural groups of concepts [82]. The former are evolutionary concepts, including the phylogenetic one, while the latter include, for example, typological and reproductive (genetic) concept. Recognition of structural and processual concepts [13] is close to this categorization; to them I would add a functional (ecological) group of concepts.

Some classification can be elaborated on the basis of what is taken as the principal parameter of the "specieshood" to be used for a theoretical species definition; this gives the following principal groups of the species concepts [17].

- the species as a similarity-based commonality unites such concepts as typological, phenetic, genetic, all presuming sharing particular traits by the species; also commonality of ontogenetic processes shared by conspecifics [83] and homeostatic property cluster concept [84] can be mentioned here;
- the species as a reproductive commonality summarizes generational and biological (in the narrow sense, i.e. "reproductive") concepts; fitting this category is also recognition concept [85-86], where emphasis is made not on the isolation, but on the integration, the latter gives the cohesion concept [87];
- the species as a historic commonality, these are phylogenetic, or genealogical concepts in both general and various partial interpretations;
- the species as a evolutionary commonality of both historical origin and peculiar "evolutionary role" of conspecifics;
- the species as a particular ecological commonality according to the ecospecies concept, or to the functional concept of Khlebosolov [88]. It is to be mentioned that biosystematics was the first to have developed a detailed hierarchy and nomenclature of ecologically treated "species units" in parallel to the taxonomic "Linnaean species" [53, 89];
- the species as a systemic unit [76] including its treatment as an element of the biota being a non-equilibrium system [9, 10, 23].

In discussion of the pyramid of the species concepts itself, one of the principal question is, whether it is possible to elaborate something like an "ideal" species concept, which would include in its definition all manifestations of the species units existing in the biological na-

ture [10, 39, 41, 90-91]. The aforementioned evolutionary species was a suggested candidate for such a concept, as it is characterized by combination of evolutionary, genetic and occasionally ecological parameters [41, 92]. A more general definition of the species as a structural unit of the biota considered as evolving non-equilibrium system should also be mentioned in this respect. One of the promising ideas seemingly never discussed before can be an elaboration of a kind of general "framework concept" [93]; it provides a meaningful interpretation of the conceptual space and formulates biologically sound conditions, under which particular species concepts of different levels of generality can be inferred.

4.2. An "ultimate beginner" for the species concepts

Any of the conceptual pyramids of the species problem, in the ways of their construing considered in the previous section, remains closed on itself. However, in the terms of the above genus-species scheme supplemented with epistemologically interpreted incompleteness theorem (see 4), any kind of the "species pyramid" should be built into a concept (theory) of the next higher level of generality. The latter is designed to serve as a "logical genus" for any of "ideal" or "universal" species concepts as its partial "logical species". This provides a possibility to fix such a content-wise consideration context of the entire species problem, in which the most basic questions of the species theory (which is still absent) becomes meaningful; what is the species as a unit of the biotic structure, how it differs from other such units, why and how it emerged, and finally what (if any) is the species level of this organization.

Of the existing theories, which can serve as something like "superstructure" over the conceptual pyramid of the species problem, two have been most often being discussed for decades, evolutionary and ecological ones. In the context of the evolutionary theory, process of evolution is, rather metaphorically, represented in a form of (reduced to) branching phyletic lineages, which fragments are treated as (phylo)species. This theory sets the context for the phylogenetic species concepts. In the context of ecological theory, the (eco)species is treated as an element of the ecosystem structure; this serves as a justification for the ecological species concepts. As noted above (see 4.1), within the conceptual pyramid of the species problem proper, these two groups of concepts are thought to be generalized by the evolutionary species concept. But the latter itself remains without a more general justification. For such a justification, some higher-level ontological model (meta-model) is requested, which would treat the biota on a unified basis of both evolutionary and ecological standpoints.

Such a model would imply that the biota is a global evolving ecosystem. Within biology, a rather general theory of phylocenogenesis presumes such consideration, according to which phylogenetic development of the species units occurs within the ecosystems providing them with the diversity of ecomorphological units [94]. However, there is a more general ontological model (concept) treating the biota as a non-equilibrium system described in the terms of synergetics mentioned already in the previous section. From this perspective, any system of such kind is "doomed" to develop, and its development leads to its hierarchical structuring [95]. In the case of biota, its historical development, commonly referred to as the biological evolution, entails its structuring due to causal relationships that regulate flows of matter, energy, and information [96]. Thus, the biotic structure, with all its constituent elements

(units), is an inevitable (axiomatic) consequence of historical development of the biota as a non-equilibrium system.

Meanwhile, according to this model, though presuming evolution of the biota as a whole, different categories of causes (proximate, initial, material, etc.), to the extent that they are independent and are not reducible to each other or to a single more general cause, act in a complementary manner and give rise to mutually irreducible and mutually complementary aspects (manifestations) of the overall biotic structure. Two such general aspects are being usually considered, the above mentioned ecological and phylogenetic, each with its own specific hierarchy; there are might be more of them, but these two are enough for the present issue. In each of them, their own structural elements (units) of different levels of generality are being patterned, which not only are not obliged to, but even cannot coincide, as they are generated by the discordant causes.

An important part of the structuring of the evolving biota is appearance of (quasi)discrete elements (units) of certain (not exactly fixed) levels of generality. One of these are of higher levels (such as local ecosystems or monophyla), others are of lower levels (such as ecomorphs or species). In the latter case, following the established tradition, at least some of these elements (units) can be uniformly designated as the species, though with explicit indication of the hierarchy they belong to (phylo-, eco-, etc.). At the same time, it is to be kept in one's mind that, in some approaches to describe these hierarchies, it is possible to do without the notion of species at all (see 3.3).

In this regard, again and inevitably, a fundamental question arises about what, if any, is exactly the "species in general" in its traditional meaning inherited from the classical science. To answer it within the above general causal model of the evolving biota, of primary importance becomes a task to elaborate a concept of some universal element (unit) of the biotic structure, with which it could be possible to associate actually "primary", or "ideal" species concept. The latter should probably include a reference to an area of intersection (or interaction) of general categories of causes, under which effect certain structural unit equally relevant to both (and other conceivable) hierarchies is emerged. Evolutionary species concept, not a once mentioned above, seems to fit this condition more than any other biologically meaningful concept. However, attempts to elaborate something more extensive in its content used to be resulted in so called "combinatorial" type of concept (in sense of [97]), with not definition proper, but with just a more or less long list of properties thought to be essential for the species (such as in [2]).

Such a "combinatorial" status of the general species concept seems to be due an effect of the so called "Hull principle" [10, 98-99], which means theoretical impossibility for the multidimensional "species in Nature" to be defied by a single exhaustive "formula". This principle, in its turn, is a consequence of (a) inverse relationship between strictness and richness of any natural science concept and/or notion and (b) the uncertainty relation between mutually irreducible species characteristics presumed by the principle of subsidiarity. With the "Hull principle" in effect, the above mentioned framework concept (see 4.1), and not a definition, might be a candidate for such a desired theoretical construct. It would allow to fix and to

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investigate certain pattern of structural organization of the biota at the level of generality attributed traditionally to the species.

In the cognitive situation given by the biota's ontological model just outlined above, any general definition of the species, whatever might it be, should be a final link in a downward cascade of definitions of higher levels of generality, forming their own conceptual meta-pyramid. At the latter's tip, there appears such (or any other appropriate) biotic model as an "ultimate beginner" for the species concepts in general. At some lower level of this meta-pyramid, definitions of the causes of the biotic structure are fixed, then definitions of elements (units) of that structure go, and finally a definition of the species as one of these elements (units) of the biotic structure is formulated. Such a cascade of the inclusive definitions corresponds clearly to the sequential reduction of the initial basic ontological model to some particular species model (concept) (see 3.3).

It follows from the foregoing that, in a general biological theory relevant to the species issues, one of the principal notions should be not that of the species, but of a discrete element (unit) of the biotic structure. So, the "species problem" turns out to be the "biotic unit problem". As it was indicated above, such a unit (element) may be conventional species, phylogroup, ecomorph, age phase, etc., and the species in its current common understanding is just "one the many" of these elements. Accordingly, the tip of the conceptual pyramid of the species problem proper should be not any "ideal" species concept proper, but rather the general concept of the unit (element) of the biotic structure, a particular case of which is the species concept being sought.

It is evident that such a biotic model, whatever general might it be, should have its own meaningful foundation, which means that it itself should be built into a higher-level pyramid, in which the model in question becomes a "logical species" of some "logical genus". So the point is that an "ultimate beginner" at far higher level of generality is needed for substantiation of the very biotic model. This obviously extends the cognitive situation of the entire species problem beyond the biological issues.

Remaining within the framework of the above synergetic model, it might be reasonable, in order to substantiate a possibility to treat the biota as a particular kind of the non-equilibrium system, to look at some other versions of the latter to analyze how they are being structured and if there is something in common to all them that might somehow correspond to the species in its general biological understanding. System of scientific knowledge may serve as another instance of such kind of non-equilibrium systems, which development, according to evolutionary epistemology, can be liken to the biological evolution [100]. From this perspective, particular scientific ideas and concepts can be considered as particular "species" or some "species-like entities" that are born, live and extinct just like the biological species [101-102]. One cannot exclude that such an expanded way to consider the species problem would allow to formulate it more correctly for the biological science. In this context, of certain meaning could be an idea of the "ontological species" [11, 103] as a manifestation of the same type of organization of such systems, regardless of their particular natural, cognitive, or any other status.

5. Evolving specieshood

It was noted above that, within a given cognitive situation, designation of any natural phenomenon by a single notion implies that it is endowed with certain fundamental property that is preserved in all its appearances and thus distinguishes it from other natural phenomena of the same kind. In the classical terminology, such a property is routinely designated as the essence; as to the species in its most general sense, its essence was suggested to denote as the "specieshood" [9, 10, 99, 104]. By an initial assumption, it is the latter that makes the species what it is by its "nature", distinguishes it from other units of the biota's structure, and marks eventually the species level of organization of the living matter, i.e. defines the "species as a rank".

From this, it is evident that one of the key issues in the species problem is that about the "specieshood", namely, about that possible specific quality, which makes any species *the* species and distinguishes the latter from other units of the structured biota. The main part of this issue is, whether a fixed level can be found in the hierarchical structure of the biota that would correlate quite strongly with the "specieshood".

Addressing to the essence (essential characteristics) of the species as a natural phenomenon obviously involves the species problem in what is called the "modern essentialism". I do not intend to discuss here this very sophisticated matter; I would rather note only that, if the "species is Nature" is not supposed to be just an arithmetic sum of its constituent organisms, but is indeed a natural phenomenon endowed with some emergent properties, then it is quite normal to speak of its essence [105-106].

The main objections against essentialist interpretation of the species, within the biological consideration of the species problem (i.e. leaving aside philosophical arguments for and against essentialism), are as following: the species (a) evolve and (b) are organized in different ways. This contradicts an initial assumption of the classical essentialism, according to which essences should be permanent and universal for particular commonalities (such as "natural kinds"). The latter point corresponds evidently to the stationary world picture originated from the classical (Platonic) natural philosophy. However, within the contemporary global evolutionism, a fundamentally different interpretation of essentialism is rather admissible, allowing for a possibility of evolutionary changes of the essences themselves [107].

5.1. Evolution of *the* species

The above (see 4.2) synergetic model of the biota as an evolutionary non-equilibrium system may be taken as a background of a concept of the evolving specieshood. According to this model, life on Earth had historically originated and then was gradually developing; this is a kind of the "central dogma" of the whole modern evolutionism. This development implied gradual structuring of the biota, including before all formation of ecosystems and their complication by means of structuring the flows of matter, energy and information.

A part of this gradual structuring was as gradual formation and perfection of units of the biotic structure involved in the regulation of these main flows. Partly repeating (see 4.2), it

should be emphasized that these flows are patterned by different categories of causality, and to the extent that the latter generate and arrange these flows more or less independently, structural units of the ecosystems are formed within each flow more or less independently from each other, as well. Using the current terminology, one can assume that structuring of the ecological component includes formation and specialization of ecomorphological units (ecomorphs), while structuring of the phylogenetic components includes formation and specialization (differentiation) of the phylogenetic units (let they be termed species).

This idealized model presumes that the "ecomorph way" of organizing the biota was being formed along the formation of ecosystems as a mode of structuring the flows of matter and energy. Respectively, the "species way" of organizing the biota was being formed with the formation of phylogeny as a mode of structuring the information flows. The both was being formed simultaneously but due to different causes. It follows from this consideration that such a dissociation of ecological (ecomorphs) and phylogenetic (species) ways of structuring the evolving biota lead to a well known discrepancy between units of ecological and phylogenetic patterns. On the one hand, this made it principally possible for the species units to become ecomorphologically differentiated, with emergence of ecologically different "morphs" (such as age phases) within them. On the other hand, different species evolved similar ecomorphological features to fit similar ecological niches. The above mentioned phylocenogenetic theory (see 4.2) allows to connect these ways of the biota structuring in a general model; this provides a meaningful theoretical background for a metaphorical interpretation of the species as "genealogical actors" playing particular roles in the "ecological theater" accordingly to certain environmentally and historically written "scripts" [39].

As it was noted above, this ontological model is more consistent with treatment of the species as a phyletic lineage. As to the "specieshood", it can be generally understood from this perspective as basically an ability of stable reproduction of species-specific epigenetic systems (in sense of [108]) in the course of their evolution. This reproduction is carried out through mechanisms that provide (a) certain closeness of the species gene pools, and (b) transfer of the genetic information with minimal distortion from generation to generation [109-110]. Cleavage of these gene pools (speciation) leading to the divergent phylogeny is, from the synergetic standpoint, a consequence of structuring the biota at the ecosystem level.

This model implies the following general picture of the evolution of both *the* "species" as a natural phenomenon and the "specieshood" as its essential characteristics. First, *the* species as a unit of the biotic structure was formed not immediately, but gradually with the evolution of biota. Second, the main direction of evolution of *the* species, as a biological phenomenon, was perfection of mechanisms for maintaining the integrity and stability of this unit at the epigenetic level. Finally, these mechanisms may be different in different groups of organisms, which expose different manifestations of the specieshood.

Specifying to a degree this evolutionary scenario, one can assume the following. At the beginning of historical formation of *the* species, there were loosely organized units of the prokaryotic diversity without effective mechanisms of epigenetic stability maintenance, so they cannot be strictly distinguished as ecomorphs or species proper [111]. At the end of this evo-

lution, there are units with highly developed mechanisms of maintenance and transfer of relatively stable integrated epigenetic systems by means of bisexual reproduction. Thus, the peak of the specieshood evolution appears to be the biospecies in its "reproductive" understanding, i.e. that of Dobzhansky—Mayr.

5.2. So many kinds of species…

According to the above model, two main conclusions about ontology of the "species in Nature" can be drown.

First, a general framework for consideration of the species ontology in its general sense should be the process-structuralism treating the species as a "process-system" [112]. In a more particular version, the species such understood can be considered as a more or less tightly organized "historical group" [113]. The latter amendment allows to emphasize phylogenetic parameter as one of the key characters of the specieshood.

Second, this model can serve as one of the ways of ontological justification of *the* species being endowed objectively with different kinds of ontology. Indeed, both the "species in Nature" as a unit of the biotic structure and the specieshood as its essential characteristic change with the evolution of the biota. This results in that both degree and ways of integration of the species such understood may be different due to various natural history of the particular groups of organisms. So *the* species (even in its narrow phylogenetic meaning) appears to be a heterogeneous unit, and its heterogeneity is quite objective, though at least in part it does reflect different ways of looking at nature. In the traditional terms, this heterogeneity is referred to as different "kinds of species".

From the standpoint of ontology, the least integrated historical groups may correspond to "natural kinds" with an added historical dimension [104], this case is partly fits the category of "kumatoid" [114]. The most integrated groups may correspond to the ontological category of the individual or rather the "quasi-individual" [10, 39, 99, 113, 115-120].

Going back to the core of the species problem (see 2.1), it becomes more than clear that the ontological model just presented involves recognition of the "species pluralism" as an irremovable part of that problem. It should be acknowledged as a part of the objective reality, so it seems to be reasonable not to "fight" with it but to reflect it somehow in the thesaurus of the above "eidology" (see 1). This means, among other things, that recognition of heterogeneity of the "species in Nature" requires to fix different "kinds of species" terminologically to make the above thesaurus more adequate to that reality. An example with A. Dubois' "mayron", "simpson", "kyon", etc. [121] indicates that there is a big room for a "term-creativity". But do new terms actually provide any solution? [122].

A part of this issue should be terminological separation of different stages and forms of "being" of the species unit proper. A radical response to this question is a suggestion to call "species" only those units which meet the reproductive criterion and to treat any other forms of organismal diversity at this level of generality as simply "non-species" [8, 28, 109]. A more moderate and therefore more sensible would be to use existing apt terms such as

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"quasi-species", "para-species" and "eu-species" [10, 13, 109, 123-124] to refer to different stages and results of evolution of the specieshood.

Another part of the same issue is clarification of conditions of correct comparison of different species concept. For instance, routine direct contrasting phylogenetic (genealogical) and biological (reproductive, genetic) species concepts seems to be incorrect, because they are relevant not to the same but to clearly different aspects of the specieshood. Using the formalized terminology introduced above (see 3.2), they correspond to projection of the same notion of *the* species to different "sub-axes" of ontological axis of the conceptual space. Indeed, the phylogenetic species concept considers respective unite from the phenomenological point of view, fixing its place in the sequence of phylogenetic events. Unlike this, reproductive concept considers the species from the causal point of view, pointing to a specific mechanism that maintains integrity and isolation of the species. Therefore, they cannot directly compete in the same conceptual space. In order to eliminate this confusion, it seems reasonable to fix the term "biological" for the "species in Nature" of any living organisms in its general (mostly evolutionary) sense, and to use a special term for the species outlined by the Dobzhansky—Mayr's concept to refer correctly to its principal character; it might be *co*species, with its prefix borrowed from the *co*hesion concept of Tempelton [125].

For such a terminological fixation of various "kinds of species" to be sound, it is requested first of all to make it clear whether there actually is some fundamental unit in biotic structure, viz. the "species in general", which may be designated as a "logical generic" notion with respect to the "logical species" notions of the different "kinds of species". If supposedly there does not exist such a unit proved conclusively to be the same for the various aspects of the biotic structure (ecological, phylogenetic and occasionally any other), then perhaps it is unjustified to use a single rooted notion of the "species" (or "specion" of Duboi [121]), albeit with different prefixes.

To put this question a little bit more formally, it can be considered as a matter of semantics of the term "species". It seems to be clear that, for the latter to be really a rigid designator, as Ereshefsky [73] supposes, its denominator (referent) should be defined as strictly as possible. In this particular case, "strictly" means "narrowly"; accordingly to the terms adopted here, the subspace occupied by the species notion within the general conceptual space (see 3.2) should be restricted to a certain fixed meaning minimizing its different treatments. Otherwise, the term "species" will remain a non-rigid designator distinguishing different entities in each of possible worlds construed by either phylogenetic or ecological or ethological or else variables.

In such a case, the species notion should probably be restricted to the phylogenetic (genealogical, generational) understanding of the species. Accordingly, for the units recognized in the ecological hierarchy at the level of generality comparable to that of the species, it is possible to use such a term as "ecomorph" or any other proposed, say, in the framework of biosystematics (see 4.1).

As for the "species in classification" belonging to the "third world" of Popper (see 3.4), it makes sense to use the term "*taxo*species" to designate it. This allows to fix terminologically that single level of common structure of biota, which refers to different partial manifestations of a hypothetical "species in Nature" of the same, though also hypothetical, "species rank".

6. What if not the species?

One aspect of the overall species problem is the strong embeddedness of the species notion in the thesaurus of many fundamental and applied biological disciplines. This seems to prevent any actually radical solution of that problem presuming rejection of the species notion (as suggested in [126]), because it would lead to a substantial reorganization of the conceptual apparatus at the expense of that rejection. The reason is quite obvious; such a rejection entails necessarily rejection (or replacement) of other terms associated in one or another way with the species notion.

For example, replacing species by phylogroup should entail in an obvious way replacing of speciation by some other, such as phyliation [127]. Generally speaking, there is nothing critically wrong with such a change in case of strictly phylogenetic interpretation of biological evolution. However, it is not evident that other biological disciplines taking the latter in a more extended sense will enjoy abandon the concept of speciation in their descriptions of historical changes of the biological objects studied by them.

In ecology, as noted above (see 3.3), the species notion is not obligatory for description of the structure of local ecosystems, it is enough to deal with ecomorphs. However, in comparative analysis of different ecosystems, there is an evident need for some basic units of comparison that allow to relate soundly ecomorphs, recognized in each of the local ecosystems, to each other. It occurs that it is the species that fulfills currently such a function; for evolutionary ecologists, ecomorphs exist in the local ecosystems not by themselves but as manifestations of the local populations of widespread (different or same) species [128].

It seems to me that this particular aspect of the species problem is not just a consequence of conservatism of the conceptual apparatus of biology, but reflects one of the universally valid epistemological principles. According to the latter, in order to explore any differences between the objects, one must have some basis for comparison by which these objects can be considered as components of a single commonality (elements of the same set, tokens of the same natural kind, etc.) possessing some fundamental feature(s) in common. For many research tasks in biology, this basis means conspecificity, i.e. belonging of organisms, differing from each other in some way, to the same species as objectively existing natural unit possessing some unique particular manifestation of the specieshood. From this perspective, it is clear that, in order to get rid of the species notion in biology, it is necessary to introduce other basis for comparison, with substantiating such a replacement by reference to some biologically meaningful and sufficiently general theory.

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7. In conclusion

Development of the species problem seems to be directed toward a better understanding of the following biologically meaningful questions: what is the species in its general (biological rather than formal) understanding, viz. if there is *the* species as a universal (all-embracing) unit of the biotic structure, or it has but a partial character; why and what are manifestations of this "species in general" and what are the causes of existence of both such "species in general" and its particular manifestations ("kinds of species").

It seems to me that a necessary condition for development of the species problem in such a way should be comprehension of its complexity, not allowing for any radical and simple (including purely empirical) solutions. This complexity of the problem in question reflects complexity of both the entire cognitive situation, in which this problem is explored, and that fragment of the ontological component, which corresponds to the general species concept.

One of manifestations of the species problem is arrangement of the species concepts and definitions of different levels of generality into a conceptual pyramid. Its "ultimate beginner" should be a kind of ontological model, in which a causally based conception of the species is inferred as one of the structural elements of the biota as an evolving non-equilibrium system.

The impetus for the further effective development of the species problem in the direction just pointed may be its consideration within the context of non-classical scientific paradigm. In particular, of great importance should be understanding of the cognitive situation as a conceptual space that is shaped by interaction of three components, viz. objective (ontological), epistemic and subjective [129]. Such a consideration provides eventually understanding of the species concept in its both general and partial senses as a particular cognitive construct. This will give a fresh look at the content of the entire multi-dimensional species problem, at its structure and key questions, as well as at relationships between different species concepts as "forms of being" of this problem.

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