What is the species concept most currently accepted by zoologists?

[1,2]Eniko Kovacs, [2,3,4]I. Valentin Petrescu-Mag

[1] Faculty of Horticulture, University of Agricultural Sciences and Veterinary Medicine, Cluj-Napoca, Romania; [2] Bioflux SRL, Cluj-Napoca, Romania; [3] Department of Environmental Engineering and Protection, Faculty of Agriculture, University of Agricultural Sciences and Veterinary Medicine, Cluj-Napoca, Romania; [4] University of Oradea, Oradea, Romania.
Corresponding author: I. V. Petrescu-Mag, zoobiomag2004@yahoo.com

Abstract. The paper aims to discuss the current trends regarding the species concept in a zoological context, according to the most recent and most accepted opinions of zoological taxonomists. The study also describes the evolution over time of the meaning of the term species in a zoological context. The definition of the species in zoology is a problem far from being solved. With the development of knowledge of biology, ecology and evolution, new and new species concepts appear, seemingly justified, but which prove to be equally ephemeral. It is difficult to reach a consensus with the entire scientific community. However, the evolutionary species concept seems to be the most accepted among zoologists at the present time, replacing the biological species concept and the pluralistic species concept.
Key Words: evolutionary species concept, biological species concept, pluralistic species concept.

Introduction. The paper aims to discuss the current trends regarding the species concept in a zoological context, according to the most recent and most accepted opinions of zoological taxonomists. The study also describes the evolution over time of the meaning of the term species in a zoological context. Because there are several meanings of the species concept, there are also several definitions of the species concept, as we will show in the following.

How the species has been viewed over time. At the beginning, the separation of species was done with great difficulty. How do we know if two populations belong to the same species or not? Initially, appearance, color, shape were discriminating elements, but not for long. For example, a brown horse and a white horse belong to the same species, even if one is a pony and the other is a large horse.

For the first time in history, someone managed to put order in the living world in 1735. In that year Carl von Linne published the work Sistema Naturae (Linne 1735), where the basic taxonomic unit was the species. Linnaeus' work has been continued by many enlightened minds of the time, until today. Nevertheless, the species remained the basic taxonomic unit.

Although Linnaeus is the best known of the pioneers of the systematics of the living world, there were other important ones even before him. Of these, it would be relevant to mention here John Ray (1627–1705).

In his major work, entitled Historia Plantarum, John Ray stated: "No matter what variations occur in the individuals or the species, if they spring from the seed of one and the same plant, they are accidental variations and not such as distinguish a species permanently; one species never springs from the seed of another nor vice versa" (Ray 1686).

Both Ray and Linnaeus approaches in defining species were typological (Aldhebiani 2018) (see below the typological species concept); they believed that under natural intraspecific variations exists a fixed unchangeable type of each species and this

refute the Ancient Greek idea of transmission of species which was widely believed in those days (Briggs & Walters 1984; Aldhebiani 2018).

Those initial writings had to pass through the hands of several generations of scholars for the species to be clearly and correctly delineated. There followed a time, close to the times in which we live, in which the delimitation of species was made on the basis of interfecundity and fertility of offspring. To these were added aspects of anatomy, morphology, biogeography and behaviour. The result: a fairly precise delimitation of species. These were the beginnings of the biological species concept (but, having a tinge of a pluralistic species concept).

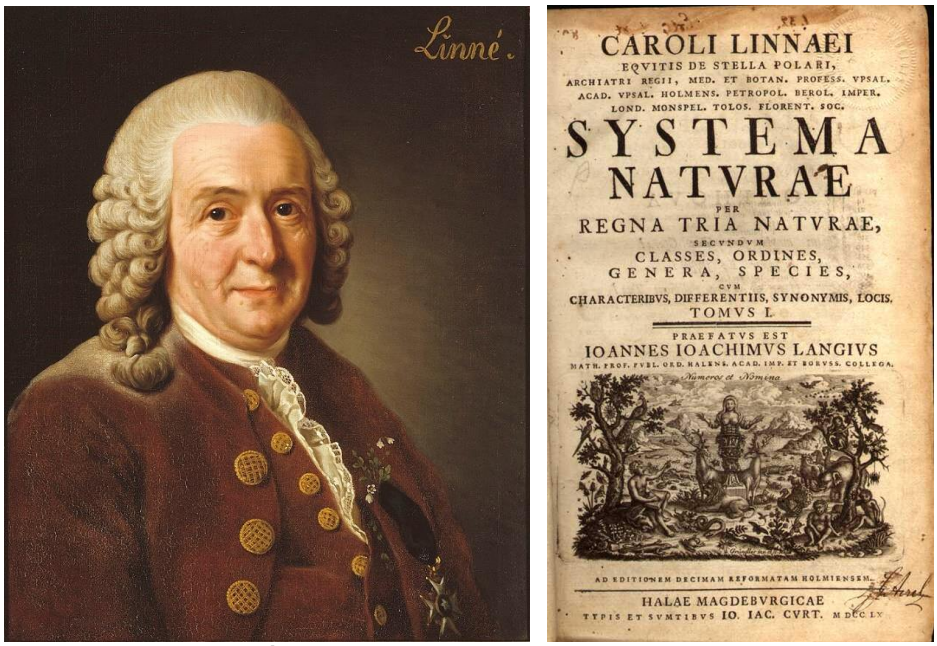

Figure 1. Left: Carl von Linné (photo: Alexander Roslin - Nationalmuseum press photo, cropped with colors slightly adjusted), right: Cover of the 1760 edition of Systema Naturae (wikipedia.org).

The most accepted species concepts among zoologists. Currently, the transition is being made from the biological species concept to the evolutionary species concept.

The biological concept of species. This was until recently the most accepted species concept. The delimitation between species was done according to morphology, anatomy, behavior, biogeography, interfecundity and, in recent years, even based on molecular biology research (as a secondary criterion). The academician zoologist Petru Bănărescu was a follower of this concept, and his work as a zoologist and taxonomist was among the most appreciated throughout the world for a long time. It should be noted that this broader sense is not the strictly biological species concept, but rather resembles the pluralistic species concept.

The biological concept of species in the strict sense says that: "species are groups of actually or potentially interbreeding natural populations which are reproductively isolated from other such groups" (Mayr 1942, 1976, 2000). This species concept has at least two disadvantages. 1) it is inapplicable onto asexual organisms, 2) it is impractical in instances of allopatric populations (which are geographically isolated) (Cronquist 1978; Stace 1989; Aldhebiani 2018).

Because science evolved, this concept gradually became obsolete with the development of molecular biology (taxonomy based on molecular evidence), but even the latter did not last long and were dismantled. DNA analyzes used alone to classify animals showed a high degree of relatedness between populations that were no longer even interfertile; totally wrong conclusions.

The evolutionary concept of species. According to the majority opinion of current zoologists and taxonomists (supporting the views expressed by Simpson 1961; Wiley & Mayden 2000; Kottelat & Freyhof 2007), subspecies have disappeared from

nomenclature, being either raised to the rank of species, or lowered to the rank of variety or breed. The evolutionary species concept was suggested by Simpson (1961) (and reconsidered by Wiley 1978, 1981) to adapt the biological species concept to the paleontological context: "a species is a single lineage of ancestor-descendant populations of organisms which maintains its identity from other such lineages (in space and time) and which has its own evolutionary tendencies and historical fate".

For example, the thermal rudd was scientifically referred to by some zoologists of the generation of the biological species concept as *Scardinius erythrophthalmus racovitzai* (i.e., a subspecies of rudd), while followers of the evolutionary species concept will call it *Scardinius racovitzai* Müller, 1958 (i.e., an independent species, the Peţea rudd).

This splitter tendency of elevating subspecies to the rank of species appears to be accepted by most zoologists specializing in vertebrate zoology. The evolutionary species concept has been accepted, for example, in the taxonomy of fish (Nowak et al 2009), of ungulates (Proorocu & Petrescu-Mag 2022), but not entirely in the taxonomy of amphibians and reptiles.

For instance, entomologists and beekeepers still haven't all agreed with the new trend, that's why some groups of bees still appear sometimes as breeds, sometimes as subspecies of the honey bee *Apis mellifera* (Stoian et al 2018).

Other species concepts and definitions. There are many concepts that define the species, each version of the concept defining it from a different point of view. However, they are less accepted by zoologists today. We will list the most representative ones.

Typological species concept (Ray 1686; Linne 1735). It is the most primitive species concept. This concept considers that under natural intraspecific variations exists a fixed unchangeable type of each species.

Phenetic species concept. It is a primitive species concept. "A species is a set of organisms that look similar to each other and distinct from other sets" (Ridley 1993). "The term phenetic is applied to classification system which relies on similarities between present properties of organisms with no consideration or references in how they possess them. Morphology, cytology, phytochemistry, anatomy, embryology and even some generic features are considered to be source data for phenetic way" (Aldhebiani 2018, in a retrospective paper on species concepts and speciation).

Morphological species concept. "A species is a community, or a number of related communities, whose distinctive morphological characters are, in the opinion of a competent systematist, sufficiently definite to entitle it, or them, to a specific name" (Regan 1926).

Cladistic species concept (Ridley 1989). When the relationship describes the pathways of ancestry (how the characters of organisms arose in evolution regardless their present day state) it is called cladistic (Heywood 1976; Aldhebiani 2018).

Phylogenetic species concept (Mishler & Brandon 1987). It is the same, or very similar to cladistic species concept.

Cohesion species concept. A cohesion species is "an evolutionary lineage that serves as the arena of action of basic micro evolutionary forces, such as gene flow (when applicable), genetic drift and natural selection" (Templeton 1994). See also Mallet (2001), Hausdorf (2011), Aldhebiani (2018).

Competition species concept, in which species are "the most extensive units in the natural economy such that reproductive competition occurs among their parts" (Ghiselin 1974, cited by Salerno 2013).

Ecological species concept. "A species is a number of related populations the members of which compete more with their own kind than with members of other species" (Colinvaux 1986).

Isolating species concept. This concept stresses on reproductive isolation as the mechanism responsible for discontinuity between species (each species is reproductively isolated from all other species, precluding them from mixing their genes and their traits) (Aldhebiani 2018).

Recognition species concept. This concept stresses on reproductive coherence as the factor responsible for continuity within species. Both isolating species concept and recognition species concept can be part of biological concept or genetic concept because both see the species as a field for gene recombination (Aldhebiani 2018).

Pluralistic species concept. The need to use more than one species concepts in order to be applicable arose the idea of a pluralistic species concept (Aldhebiani 2018). This concept recognizes that "the factors that are most important for the cohesion of individuals as a species vary" (Campbell & Reece 2002).

Pragmatic species concept (Seifert 2014). It was replaced in 2020 by gene and gene expression species concept (Seifert 2020) (see below).

Gene and gene expression (GAGE) species concept - a universal approach for all eukaryotic organisms (Seifert 2020). It is an improved version of pragmatic species concept. GAGE species concept, is based on the following four theses:

1) Species identities have to be defined by nuclear DNA sequences and / or their expression products;
2) Species have to be defined as nothing but separable clusters and not as metapopulation lineages;
3) The sole criterion for heterospecificity is having passed a threshold of evolutionary divergence;
4) Numeric description of character systems is obligatory to determine clusters and thresholds in order to control oversplitting and lumping (Seifert 2020).

Conclusions. The definition of the species in zoology is a problem far from being solved. With the development of knowledge of biology, ecology and evolution, new and new species concepts appear, seemingly justified, but which prove to be equally ephemeral. It is difficult to reach a consensus with the entire scientific community. However, the evolutionary species concept seems to be the most accepted among zoologists at the present time, replacing the biological species concept and the pluralistic species concept.

Conflict of interest. Authors declare that there is no conflict of interest.

References

Aldhebiani A. Y., 2018 Species concept and speciation. Saudi Journal of Biological Sciences 25(3):437-440.

Briggs D., Walters S. M., 1984 Plant variation and evolution. Second edition. Cambridge University Press, Cambridge, 416 p.

Campbell N., Reece J., 2002 Biology. Benjamin Cummings, 468 p.

Colinvaux P., 1986 Ecology. John Wiley and Sons, New York, 688 p.

Cronquist A., 1978 Once again, what is a species? In: Biosystematics in agriculture. Knutson L. V. (ed), pp. 3–20, Allenheld Osmin, Montclair, New Jersey, U.S.A.

Hausdorf B., 2011 Progress toward a general species concept. Evolution 65(4):923-931.

Heywood V. H., 1976 Plant taxonomy. The Camelot Press Ltd, Southhampton, 63 p.

Kottelat M., Freyhof J., 2007 Handbook of European freshwater fishes. Kottelat, Cornol and Freyhof, Berlin, 646 p.

Mallet J., 2001 Species, concepts of. Encyclopedia of Biodiversity 5:427-440.

Mayr E., 1942 Systematic and the origin of species. Columbia University Press, New York.

Mayr E., 1976 Species concepts and definitions. In: Topics in the philosophy of biology. Springer Netherlands, pp. 353-371.

Mayr E., 2000 The biological species concept. Species concepts and phylogenetic theory: a debate. Columbia University Press, New York, pp. 17-29.

Mishler B. D., Brandon R. N., 1987 Individuality, pluralism, and the phylogenetic species concept. Biology and Philosophy 2:397-414.

Nowak M., Petrescu-Mag I. V., Mierzwa D., Popek W., 2009 On some interesting Romanian gudgeons (Cyprinidae: Romanogobio) found in the collection of Museum and Institute of Zoology PAS. AES Bioflux 1(2):81-88.

Proorocu M., Petrescu-Mag I. V., 2022 On the genus Babyrousa: biology, ecology, conservation. Porc Res 12(1):12-19.
Ray J., 1686 Historia plantarum, vol 1–3. London, Clark.
Regan C. T., 1926 Organic evolution. Report of the British Association for the Advancement of Science 1926:75–86.
Ridley M., 1989 The cladistic solution to the species problem. Biology and Philosophy 4:1-16.
Ridley M., 1993 Evolution. The Journal of Evolutionary Biology 6:615–617.
Salerno D. W., 2013 Microbial source tracking of *Escherichia coli* in Cassadaga Lake. PhD Thesis. Available at: http://hdl.handle.net/20.500.12648/153
Seifert B., 2014 A pragmatic species concept applicable to all eukaryotic organisms independent from their mode of reproduction or evolutionary history. Soil Organ 86:85–93.
Seifert B., 2020 The Gene and Gene Expression (GAGE) species concept: an universal approach for all Eukaryotic organisms. Systematic Biology 69(5):1033-1038.
Simpson G. G., 1961 Principles of animal taxonomy (No. 20). Columbia University Press.
Stace C. A., 1989 Plant taxonomy and biosystematics, second edition. Edward Arnold, a division of Hoddoer and Stoughton, London.
Stoian R. O., Botha M., Petrescu-Mag I. V., 2018 Beekeeping in Romania and artificial insemination of honey bee, Apis mellifera. State of the art. ABAH Bioflux 10(2):93-121.
Templeton A. R., 1994 In and out of breeding problems. Conservation Biology 8:608–610.
von Linné C., 1735 Systema naturae sive regna tria naturae systematice proposita per classes, ordines, genera et species. Haak.
Wiley E. O., 1978 The evolutionary species concept reconsidered. Systematic Zoology 27(1):17-26.
Wiley E. O., 1981 Remarks on Willis' species concept. Systematic Zoology 30:86–87.
Wiley E. O., Mayden R. L., 2000 The evolutionary species concept. In: Species concepts and phylogenetic theory. Wheeler Q. D., Meier R. (eds), pp. 70-89, Columbia University Press, New York.
*** https://ro.wikipedia.org/wiki/Carl_Linn%C3%A9 [Last view: 01 December 2022].

Received: 07 October 2022. Accepted: 18 November 2022. Published online: 05 December 2022.
Authors:
Eniko Kovacs, University of Agricultural Sciences and Veterinary Medicine, Cluj-Napoca, Romania, Faculty of Horticulture, Department of Economic Sciences, 3-5 Calea Mănăştur Street, 400372 Cluj-Napoca, Romania, e-mail: eniko.kovacs@usamvcluj.ro
Ioan Valentin Petrescu-Mag, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Faculty of Agriculture, Department of Environmental Engineering and Protection, 3-5 Calea Mănăştur Street, 400372 Cluj-Napoca, Romania, e-mail: zoobiomag2004@yahoo.com

How to cite this article:
Kovacs E., Petrescu-Mag I. V., 2022 What is the species concept most currently accepted by zoologists? AES Bioflux 14(2):57-61.