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To name or not to name: Criteria to promote economy of change in Linnaean classification schemes

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Abstract

The Linnaean classification system provides the universal reference system for communicating about the diversity of life and its hierarchic history. Several limitations that challenge the stability of this system have been identified and, as a result, alternative systems have been proposed since its early inception. The revolution caused by molecular phylogenetics has, more than ever, exemplified that Linnaean classification schemes are subject to a degree of instability that may hamper their significance and communication power. Our analysis of recent changes in the classification of several groups of organisms, with a focus on amphibians and reptiles, reveals two main sources of instability: (i) revisionary, objective (empirical) changes based on the discovery of unambiguous instances of non-monophyly and on progress in the Globe's species inventory, and (ii) subjective changes based on author preferences or on a poor analysis of the advantages and limitations of new classification schemes. To avoid subjective taxonomic instability, we review and elaborate proposals for the assignment of Linnaean rank to clades, and thereby for the naming of these clades as Linnaean taxa (Taxon Naming Criteria: TNCs). These are drafted from the perspective of practicing taxonomists and can help choosing among alternative monophyly-based classifications under a premise of economy of change. We provide a rationale for each TNC along with real and theoretical examples to illustrate their practical advantages and disadvantages. We conclude that not all TNCs lead to equally informative and stable taxonomies. Therefore, we order the various TNCs by the generality of their implications and provide a workflow scheme to guide the procedure of taxonomic decisions concerning the creation or modification of supraspecific classifications. The following criteria are considered primary when naming taxa: (i) Monophyly of the taxon in an inferred species tree; (ii) Clade Stability, i.e., the monophyly of a clade to be named as taxon should be as strongly supported as possible by various methods of tree inference, tests of clade robustness, and different data sets; and (iii) Phenotypic Diagnosability, i.e., ranked supraspecific taxa should be those that are phenotypically most conspicuous although in phenotypically cryptic groups of organisms it can be warranted to name taxa based on molecular differences alone. We consider various other criteria as secondary (i.e., the Time Banding, Biogeography, Adaptive Zone, and Hybrid Viability TNCs) and refute using them as sole arguments for the modification of established classifications or proposal of new ones. Taxonomists are encouraged to be explicit and consistent when applying TNCs for creating or modifying classifications. We emphasize that, except for monophyly, the priority TNCs are not proposed as mandatory requisites of a Linnaean taxon but as yardsticks to allow for an informed choice among various clades in a tree that could alternatively be named as Linnaean taxa. Despite a need for plurality, classifications should avoid deliberately violating any of the three primary TNCs because taxa of unstable monophyly or poor diagnosability reduce the information content and hence the utility of the Linnaean system.

Key words: Linnaean system, taxon naming criteria, taxonomic inflation, taxonomy, phylogenetics, rank, category, nomenclature, divergence times, evolutionary species concept

> *"It is a truly wonderful fact — the wonder of which we are apt to overlook from familiarity — that all animals and all plants through all time and space should be related to each other in group subordinate to group ..."* (Darwin 1859).

> *"Can you see the shape of a tree developing in your mind as you read this description of the sequence of groupings? It is a family tree: a tree with many branches, each branch having sub-branches, and each sub-branch having sub-branches. The tips of the twigs are species. The other groupings—class, order, family, genus—are the branches and sub-branches. The tree is all of life on Earth."* (Dawkins 2011)

Introduction

Taxonomy, the science of identifying, classifying and naming organisms, has undergone fundamental conceptual changes over the last century. For some time, taxonomy has been marginalized and neglected as a mere bookkeeping and pigeon-holing activity without epistemological underpinning (Wheeler 2008). In contrast, the emerging new taxonomy is fundamentally grounded on evolutionary theory and increasingly makes use of modern bioinformatic tools (e.g., Wheeler *et al.* 2004; Wilson 2003, 2004; Schram 2004).

The first taxonomic aim, identifying species-level taxa, nowadays follows a conceptual framework that considers species as separate population-level lineages (Simpson 1961; Wiley 1978; Mayden 1997; De Queiroz, 1998, 2007) and relies on the use of multiple lines of evidence to delimit them (Dayrat, 2005; Padial *et al.*, 2010). The second practice, classifying species into higher-level taxa, is currently based on the inference of relationships