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Letter

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21 What is a "species"? As central players in evolution, species with their
22 taxonomy, classification and grouping among higher taxa provide a basis to
23 understand patterns and structure of biodiversity and the nature of the biosphere
24 in space and time. Medical and veterinary sciences require scientific names,
25 particularly to discriminate pathogenic organisms in our living environment.
26 Various species concepts have been proposed for metazoan animals [1].
27 There are, however, constant controversies over their validity because of lack of
28 a common criterion to define species across different phyla. Taxonomists can
29 or often select the most suitable concept for their target species. Molecular
30 phylogenies based on nucleotide sequences of genomic DNA now play a key
31 role in judging the identity of species. Species delimitation, the process of
32 identifying species boundaries, remains very difficult in morphologically
33 indistinguishable populations showing slightly different genetic profiles, and
34 adjunct operational criteria linked to ecology, biogeography and evolution come
35 into play [1].

36 The genus *Echinococcus* (Cestoda: Taeniidae) is an evolutionarily young
37 group in which speciation and global radiation occurred rapidly [2].
38 *Echinococcus canadensis* is the most difficult species with respect to
39 recognizing clear delimiting boundaries relative to other congeners. In the
40 course of taxonomic revision of *Echinococcus granulosus* sensu lato, Nakao *et*
41 *al.* [3] demonstrated that the domestic camel and pig strains (genotype G6/G7)
42 and the sylvatic cervid strain (genotypes G8 and G10) were genetically very
43 closely related. Collectively these genotypes were unified as *E. canadensis* by
44 elevating the subspecies *E. granulosus canadensis* [4] to specific rank, based on
45 a phylogenetic species concept [1]. The extremely close genetic relatedness of
46 G10 to G6/G7 clearly invalidates treatment of the sylvatic cervid strain (G8 and
47 G10) as an independent species while concurrently referring the domestic camel
48 and pig strains (G6/G7) as another species [3].

49 Based on an evolutionary species concept [1], Lymbery *et al.* [5] recently
50 published their opinion on the genotypes G6/G7, G8, and G10. They
51 recommended that *E. canadensis* should be split into three species. That is
52 *Echinococcus intermedius* for G6/G7, *Echinococcus borealis* for G8, and *E.*
53 *canadensis* for G10. This taxonomic opinion, however, is highly premature.

54 Certainly the mitochondrial DNA sequence of G8 is more divergent than those of
55 G6/G7 and G10 [3], but the sympatric distribution of G8 and G10 in Eastern
56 Europe, Far East Russia, and North America suggests that cross hybridization
57 between them is easily possible. Lymbery *et al.* [5] elevated *E. granulosus*
58 *borealis* [4] to a specific rank, without showing ecological and genetic data
59 supporting its segregation from *E. canadensis* G10. Additionally, this proposed
60 decision was misleading, given an absence of new comparative data to link
61 these genotypes to prior morphological descriptions of the respective
62 subspecies [5]. Historically, *E. granulosus canadensis* and *E. granulosus*
63 *borealis* became regarded as invalid taxa [6] because of their recognized
64 sympatric occurrence. Rausch [7] treated them collectively as "the Northern
65 biotype" of *E. granulosus*. We can agree with his treatment in which the
66 parasites were not split into two different populations, because currently
67 available DNA sequences of nuclear genetic markers are almost identical
68 between G8 and G10 [8]. The mtDNA distinctiveness of G8 from the other
69 genotypes suggests a possibility that allopatric speciation was in progress in the
70 recent past but its process was interrupted due to natural or artificial invasion of
71 host animals. A similar case has been observed in a species of *Taenia* in
72 spotted hyenas [9].

73 The resurrection of *E. intermedius* for G6/G7, however, is the most
74 problematic in the opinion and taxonomic proposal outlined by Lymbery *et al.* [5].
75 This singular proposition for resurrection should not be overlooked. In 1995,
76 Thompson *et al.* [10] stated their views on the name of G7 (pig strain) as follows:
77 "as far as we are aware, this taxon has not previously named, although the
78 descriptions given by Vogel (1957) and Verster (1965) for *E. granulosus* of pig
79 origin could be used as the type". In 2008, Thompson [11], however, changed
80 his statement as follows: "it may be more realistic to consider the domestic pig
81 and camel forms of *Echinococcus* as a single species (*E. intermedius* as
82 originally proposed by Lopez-Neyra & Soler Planas in 1943), or possibly as two
83 distinct subspecies since they do not appear to occur sympatrically". There is
84 obviously no foundation for resurrecting and using the name of *E. intermedius*
85 for G6/G7, because no intermediate hosts (i.e. pig or camel) were recorded in
86 the original description [12]. The species was described based on only a few

87 adult worms from a dog in Spain, and thus to a considerable degree remains of
88 unknown provenance. Further, the putative type specimen of *E. intermedius*
89 now appears lost, despite extensive efforts and continuous searches among
90 collections in Spanish museums and related institutes. In an early stage of the
91 taxonomic revision of *Echinococcus*, Rausch [6] treated *E. intermedius* as a
92 synonym of *E. granulosus* based on morphological comparisons. Considerable
93 uncertainty over specimens that would have represented *E. intermedius*, and the
94 nature of the proposed synonymy that invalidated the taxon, highlights an
95 ambiguous status, suggesting that the name should be treated as species
96 inquirenda. Designating the neotype of *E. intermedius* for G6/G7 seems to be
97 an arbitrary and unreliable action because it is now virtually impossible to
98 reconstruct the parasite life cycle and to trace the genetic profile.

99 Over the past century and more, taxonomists were often entitled to propose
100 species according to their own beliefs. In our current world, however, such
101 proposals need to be grounded in the realm of rules for zoological nomenclature
102 and operational concepts that serve to objectively delimit diversity [1]. Lymbery
103 *et al.* [5] have published an opinion to revise *E. canadensis*. Such a proposal
104 may eventually be shown to have validity, but must include an unequivocal
105 description and nomenclature for a new species that would contain G6/G7.
106 Concurrently such a proposal must be based on clear data integrating molecular
107 and morphological attributes which demonstrate historical independence and
108 biological segregation of G6/G7, G8, and G10.

109

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113 specimen in Spain.

114

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