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Six comments on the ten reasons for the demotion of viruses

Jesús Navas-Castillo

In an article recently published in *Nature Reviews Microbiology*, Moreira and López-García expressed their opinion about the nature of viruses and their place and role in 'nature' (Ten reasons to exclude viruses from the tree of life. *Nature Rev. Microbiol.* **7**, 306–311 (2009))[1]. This opinion opposes the recent virus world concept of Koonin *et al.*, which is based on comparative genomics and describes the role of viruses in life origin and evolution[2]. Instead of using the strictly scientific approach of Koonin *et al.*[2], Moreira and López-García[1] offer their readers an essentialist stance that revolves around one major point: viruses are not alive and are therefore irrelevant to life history depicted as the 'tree of life'. I am certain that my fellow virologists will compare the arguments of Moreira and López-García[1] with those of Koonin *et al.*[2] and make their own verdict. However, following the fondness of Moreira and López-García for syllogisms and conundrums, I would like to point out some of their incongruities.

First, the idea of linking vague philosophical definitions of 'life' to inclusion in the tree of life seems dubious at best. Are ribosomes alive? And if not, should ribosomal proteins and RNAs be excluded from phylogenetic reconstructions? Furthermore, few evolutionary biologists would now agree with the soundness of a tree of life concept. Paraphrasing Doolittle and Bapteste[3], it is a quixotic pursuit to find a single and 'true' tree of life, and such phylogenetic Don Quixote would be better off looking for a dark and dense forest. Even the vision of the life origin on this planet as a singular event meets with formidable criticism[4].

Second, according to Moreira and López-García, "no cells, no viral evolution". So, no hosts, no parasite evolution; does this mean that fleas and bedbugs are not alive?

Third, we consider the sterile planet insemination issue. According to Moreira and López-García[1], "If we inseminate [a sterile planet] with populations of all the viral lineages that are known on Earth, it is evident that nothing will happen," but if "we inseminate such a planet with populations of, for example, all known bacterial species [they will colonize] the planet in a stable way." But what about the other taxa of cellular organisms? What would happen if we were to inseminate the sterile planet with all known fungi or mammals? They are certain to vanish in 'the blink of an eye', and, following the logic of Moreira and López-García[1], are not alive and do not belong in the tree of life.

Fourth, Moreira and López-García[1] state that "Given such a high frequency of cell-to-virus (as well as of virus-to-virus) horizontal gene transfer and the high recombination rates in viruses, a set of genes that is found together in a viral genome at a given time has little chance to remain linked after a small number of generations." However, comparative genomics does not support such volatility: the well-defined virus-specific gene ensembles hold together for aeons, as has been shown for the nucleocytoplasmic large DNA viruses[5] and picorna-like RNA viruses[6]. Along the same lines, experimental studies show, perhaps counterintuitively, that even the fast-evolving RNA viruses are able to maintain nearly identical genome sequences for high numbers of generations[7].

Fifth, we consider the assertion that "Viruses do not split any diploid genetic content into haploid gametes." (REF. 1) This discussion of the differences between virions and spermatozoids is not entirely correct. Even though most virus species are indeed haploid, the reverse-transcribing lentiviruses, including HIV, are diploid, whereas the double-stranded RNA infectious bursal disease virus has been shown to be functionally polyploid[8].

Sixth, Moreira and López-García[1] argue that viruses do not have sex. In a broad sense, sex can be defined as the exchange of genetic material. If so, viruses definitively do have sex, through recombination. In the case of viruses with multipartite genomes, the genome reassortment is indeed an automatic consequence of reproduction, with offspring being the product of more than two parents[9,10].

In conclusion, I find the 'ten reasons' of Moreira and López-García[1] less than compelling to change either my devotion to studying viruses or my strong belief that, alive or not, viruses are an inalienable part of life's history. I am also left with the thought that the demotion of viruses suggested by Moreira and López-García would involve something as impenetrable to an analytic mind as arachnophobia.

Jesús Navas-Castillo is at the Estación Experimental "La Mayora", Consejo Superior de Investigaciones Científicas, 29760 Algarrobo-Costa, Málaga, Spain.
e-mail: jnavas@eelm.csic.es

1. Moreira, D. & López-García, P. Ten reasons to exclude viruses from the tree of life. *Nature Rev. Microbiol.* **7**, 306–311 (2009).
2. Koonin, E. V., Senkevich, T. G. & Dolja, V. V. The ancient virus world and evolution of cells. *Biol. Direct* **1**, 29 (2006).
3. Doolittle, W. F. & Bapteste, E. Pattern pluralism and the Tree of Life hypothesis. *Proc. Natl Acad. Sci. USA* **104**, 2043–2049 (2007).
4. Vermeij, G. J. Historical contingency and the purported uniqueness of evolutionary innovations. *Proc. Natl Acad. Sci. USA* **103**, 1804–1809 (2006).
5. Iyer, L. M., Balaji, S., Koonin, E. V. & Aravind, L. Evolutionary genomics of nucleo-cytoplasmic large DNA viruses. *Virus Res.* **117**, 156–184 (2006).
6. Koonin, E. V., Wolf, Y. I., Nagasaki, K. & Dolja, V. V. The Big Bang of picorna-like virus evolution antedates the radiation of eukaryotic supergroups. *Nature Rev. Microbiol.* **6**, 925–939 (2008).
7. Fraile, A. *et al.* A century of tobamovirus evolution in an Australian population of *Nicotiana glauca*. *J. Virol.* **71**, 8316–8320 (1997).
8. Luque, D. *et al.* Infectious bursal disease virus is an icosahedral polyploid dsRNA virus. *Proc. Natl Acad. Sci. USA* **106**, 2148–2152 (2009).
9. Chao, L. Evolution of sex in RNA viruses. *J. Theor. Biol.* **133**, 99–112 (1988).
10. Chao, L. Levels of selection, evolution of sex in RNA viruses, and the origin of life. *J. Theor. Biol.* **153**, 229–246 (1991).