Telencephalon expansion and enhanced cognitive abilities in guppy fish (*Poecilia reticulata* Peters 1859): A model for brain evolution and executive functions

[1] Adela Maria Dăescu, [2,3,4] I. Valentin Petrescu-Mag

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

Abstract. A recent study by researchers from Stockholm University examined the relationship between telencephalon size and executive cognitive abilities in guppy fish (*Poecilia reticulata*). Using artificial selection over five generations, guppy lines with larger or smaller telencephalons were developed. The study assessed cognitive flexibility, self-control, and working memory across these groups. Guppies with larger telencephalons exhibited superior performance in all executive tasks, such as reversal learning and inhibitory control, while showing no difference in basic associative learning tasks. Findings revealed that telencephalon size is directly linked to advanced cognitive functions, highlighting parallels with mammalian neocortex roles. This study underscores the utility of guppies as a model for investigating cognitive evolution and provides insights into energy-efficient brain adaptations through mosaic evolution.
Key Words: cognitive evolution, mosaic brain evolution, artificial selection, behavioral ecology, brain morphology.

The guppy fish (*Poecilia reticulata* Peters 1859) (Figure 1) serves as a versatile model organism for research across various biomedical, biological, sociological, and environmental fields, offering valuable insights into a wide range of scientific disciplines (Gavriloaie 2023; Petrescu-Mag 2023ab). The purpose of this news and views article is to highlight recent advancements in understanding the evolutionary role of brain morphology by summarizing a groundbreaking study on guppy fish that demonstrates how selective enlargement of the telencephalon enhances executive cognitive abilities, offering insights into cognitive evolution and parallels with mammalian brain functions.

A recent study, conducted by Zegni Triki, Stephanie Fong, Mirjam Amcoff, Sebastian Vàsquez-Nilsson, and Niclas Kolm at Stockholm University, set out to investigate the relationship between telencephalon size—a critical brain region—and executive cognitive abilities, using guppies as a model species (Triki et al 2023). Their research was driven by a significant knowledge gap in understanding the evolutionary mechanisms underlying advanced cognitive functions, which are essential for adaptation and survival (Triki et al 2019, 2020).

The researchers hypothesized that the telencephalon might serve as the "executive brain" in fish, much like the neocortex does in mammals. To test this, they created experimental guppy lines through artificial selection over five generations, resulting in substantial differences in telencephalon size relative to the rest of the brain. Guppies in the "up-selected" line had relatively larger telencephalons, while those in the "down-selected" line had smaller ones. The aim was to assess whether these structural differences influenced performance in three core domains of executive functions: cognitive flexibility, self-control, and working memory (Triki et al 2023).

Figure 1. The guppy fish (*Poecilia reticulata* Peters 1859) (source: Petrescu-Mag 2007).

The findings were striking. Across all tasks that required executive functions, guppies with larger telencephalons outperformed their counterparts with smaller telencephalons. For instance, in the cognitive flexibility test (reversal learning), up-selected guppies were significantly better at adapting to new reward contingencies after previously learned associations were reversed. Similarly, in the detour task, which measured self-control, guppies with larger telencephalons showed superior inhibitory control by consistently navigating around a transparent barrier to reach a reward without making impulsive errors. In the working memory task (object permanence), these guppies also demonstrated a better ability to track and locate hidden objects, indicating enhanced cognitive processing (Triki et al 2023).

Importantly, the study found no significant differences in basic associative learning tasks, such as the initial color discrimination test, which did not require complex executive processing. This reinforced the idea that telencephalon size specifically influenced higher-order cognitive abilities. Furthermore, the researchers observed that the selective enlargement of the telencephalon did not lead to major energetic trade-offs, such as reduced gut size or changes in other brain regions, except for a slight decrease in optic tectum size. This suggests that mosaic brain evolution—where specific brain regions adapt independently—can be an energy-efficient pathway for enhancing advanced cognitive abilities (Triki et al 2023).

These results have broad implications. They provide experimental evidence that the telencephalon is a key driver of executive functions in fish and highlight parallels with the neocortex in mammals, suggesting that similar evolutionary principles may operate across vertebrates. The study also demonstrates the utility of artificial selection as a tool for investigating cognitive evolution and offers insights into how brain morphology can shape behavior and adaptability in response to environmental demands.

References

Gavriloaie C., 2023 Kin recognition in guppies, *Poecilia reticulata* Peters, 1859. Poec Res 13(1):17-18.

Petrescu-Mag I. V., 2007 [Manipulation of the sexes in guppyculture]. AcademicPres, Cluj-Napoca, 253p. [in Romanian]

Petrescu-Mag I. V., 2023a Neophilia in guppies, *Poecilia reticulata* Peters, 1859. Poec Res 13(1):14-16.

Petrescu-Mag I. V., 2023b Guppy, *Poecilia reticulata* Peters, 1859, a model species for behavioral ecology. Poec Res 13(1):19-21.

Triki Z., Emery Y., Teles M. C., Oliveira R. F., Bshary R., 2020. Brain morphology predicts social intelligence in wild cleaner fish. Nat Commun 11:6423.

Triki Z., Fong S., Amcoff M., Vàsquez-Nilsson S., Kolm N., 2023 Experimental expansion of relative telencephalon size improves the main executive function abilities in guppy. PNAS Nexus 2(6):pgad129.

Triki Z., Levorato E., McNeely W., Marshall J., Bshary R., 2019 Population densities predict forebrain size variation in the cleaner fish *Labroides dimidiatus*. Proc R Soc B Biol Sci 286:20192108.

Received: 29 November 2024. Accepted: 29 December 2024. Published online: 30 December 2024.

Authors:
Adela Maria Dăescu, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Faculty of Veterinary Medicine, Department of Cell Biology, Histology and Embryology, 3-5 Calea Mănăştur Street, 400372 Cluj-Napoca, Romania, e-mail: adela.daescu@yahoo.com
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:
Dăescu A. M., Petrescu-Mag I. V., 2024 Telencephalon expansion and enhanced cognitive abilities in guppy fish (*Poecilia reticulata* Peters 1859): A model for brain evolution and executive functions. Poec Res 14(1):9-11.