Ecology & Evolution | Mar 2, 2026 | 8 min read | By Bryan White

Mirror, Mirror on the Reef: How the Cleaner Wrasse is Rewriting the Rules of Consciousness

Biology * Evolution * Animals

Introduction: The Shifting Paradigm of Vertebrate Intelligence

For decades, comparative psychology held that self-awareness, transitive inference, and Machiavellian social strategies required a mammalian neocortex, inspiring the "Big Bang" hypothesis that consciousness emerged recently in hominids and great apes.[1][2] Because teleost brains develop via outward telencephalic eversion rather than inward cortical invagination, fishes were dismissed as reflex-driven organisms.[3][4] However, laboratory investigations of the Indo-Pacific bluestreak cleaner wrasse (Labroides dimidiatus), alongside archerfish, cichlids, and Danionella cerebrum, are rewriting vertebrate cognitive evolution.[5][6][7]

Mirror Self-Recognition, Rapid Integration, and Contingency Testing

Introduced by Gordon Gallup Jr. in 1970, the mirror mark test assesses whether an animal uses a reflection to inspect an unseen mark on its own body.[8] Historically passed mainly by chimpanzees, orangutans, bottlenose dolphins, Asian elephants, and Eurasian magpies, the visual test often yields false negatives in olfactory or gaze-averse species like gorillas, dogs, or gartersnakes.[2][9][10][11]

| Taxonomic Group | | Representative Species | | Mirror Self-Recognition Indicators | | Marking Method & Pass Rate |

| Primates | | Chimpanzee (Pan troglodytes) | | Mirror-guided facial touching and self-exploration.[12] | | Odorless dye; high in great apes, low in gorillas.[8][9] |

| Cetaceans | | Bottlenose Dolphin (Tursiops truncatus) | | Head movements, flank orientation, bubble-release contingency testing.[13] | | Temporary zinc oxide paste; high pass rate.[13][14] |

| Corvids | | Eurasian Magpie (Pica pica) | | Contingency movement and beak scraping of throat marks.[10] | | Colored throat stickers; variable individual pass rate.[10] |

| Teleost Fishes | | Cleaner Wrasse (Labroides dimidiatus) | | Postural viewing, shrimp-drop contingency testing, throat scraping.[5] | | Subcutaneous brown elastomer mimicking ectoparasites; 14/14 pass across follow-up sample.[31][15] |

In 2019-2022 trials, cleaner wrasse ignored blue or green marks, failed to scrape without a mirror when marked superficially, and never scraped when viewing a marked neighbor -- yet 14 of 14 tested individuals with clear throat marks scraped their throats against the substrate when viewing a brown parasite-like mark in a mirror.[31][15] In late 2025, Shumpei Sogawa, Masanori Kohda, and colleagues at Osaka Metropolitan University marked mirror-naive wrasse before introducing a mirror.[5] Matching somatosensory expectation to visual feedback, wrasse initiated mark-scraping within 82 minutes on average (and under an hour in several

individuals) rather than 4-6 days.[5] Subsequently, wrasse lifted shrimp fragments 10-25 cm in front of the mirror and released them without eating -- tracking the sinking reflection and touching the glass in object-based contingency testing.[5]

Face Recognition, Pallial Neuroanatomy, and Social Ecology

To rule out simple kinesthetic motion matching, researchers presented mirror-experienced wrasse with static composite photographs.[16] Wrasse ceased attacking photos featuring their own face, attacked stranger faces, and -- when shown a motionless photo of themselves bearing a digital brown throat mark -- six of eight mark-naive fish scraped their throats, confirming private self-awareness and stored mental face representations.[3][16]

| Taxon | | Species | | Brain-to-Body Ratio | | Neuroanatomical Notes |

| Mammalia | | Human (Homo sapiens) | | ~1:40 to 1:50 (2%-2.5%)[32] | | EQ ~6.7; six-layered neocortex.[17] |

| Teleostei | | Elephantfish (Gnathonemus petersii) | | ~1:32 (~3.1%)[32] | | Hypertrophied electroreceptive cerebellum; consumes ~60% of resting O2.[32] |

| Teleostei | | Cleaner Wrasse (Labroides dimidiatus) | | < 0.1 g total mass[19] | | 0.46 teleost slope; nuclear pallium.[1][18] |

Although the wrasse brain weighs under 0.1 grams without an elevated Encephalization Quotient across 69 tested individuals, molecular atlases in teleosts and zebrafish show that the everted dorso-lateral and dorso-medial pallium are genetic homologues of the mammalian hippocampus and amygdala, relying on dense synaptic neuron networks rather than cortical volume.[1][4][18][7][19][20][21] Driven by the Social Brain Hypothesis, a single wrasse manages 2,000-3,000 daily cleaning interactions across 100+ client species, balancing parasite removal against mucus "cheating" and adjusting honesty when bystander clients watch -- selectively enlarging its diencephalon and telencephalon.[3][19][22]

Teleost Physics, Transitive Inference, and Shared Ancestry

Broader teleost studies reinforce either deep homology or convergent evolution of complex cognition.[14] Archerfish (Toxotes jaculatrix) correct for air-water optical refraction, modulate water-jet hydrodynamics to deliver 10x the force needed to dislodge insects, learn ballistics socially, and discriminate abstract non-symbolic numerosity.[6][23][24] African cichlids (Astatotilapia burtoni, Neolamprologus pulcher) deduce social and color hierarchies (A > B > C > D > E) via transitive inference.[25][26] Meanwhile, whole-brain single-cell imaging in the 12-mm transparent fish Danionella cerebrum -- capable of 140-dB acoustic signaling -- reveals logarithmic sensorimotor coding and specialized midbrain schooling circuits.[27][28][29][30]

Conclusion: The Paleozoic Roots of Self-Awareness

These findings support the Shared Ancestry Hypothesis: primary consciousness and self-other distinction originated in the common Osteichthyes ancestor ~450 million years ago.[2][3] Beyond reshaping animal welfare ethics, the compact nuclear pallium of the cleaner wrasse offers a blueprint for energy-efficient neural architectures

in artificial intelligence and systems biology.[1][5]

Updates... (Nov 22, 2026): Corrected first-author initials for Reference [28] (Cook, V. A. N. O., et al., Feb 26, 2024; PNAS) against live CrossRef metadata.

References & Primary Sources

* [1] Jarvis, E. D., G nt rk n, O., Bruce, L., Csillag, A., et al. (2005). Avian brains and a new understanding of vertebrate brain evolution. Nature Reviews Neuroscience, 6(2), 151-159. https://doi.org/10.1038/nrn1606

* [2] de Waal, F. B. M. (2019). Fish, mirrors, and a gradualist perspective on self-awareness. PLOS Biology, 17(2), e3000112. https://doi.org/10.1371/journal.pbio.3000112

* [3] Kohda, M., Sogawa, S., & Bshary, R. (2025). On the mirror test and the evolutionary origin of self-awareness in vertebrates. Philosophical Transactions of the Royal Society B: Biological Sciences. https://doi.org/10.1098/rstb.2024.0312

* [4] Hegarty, B. E., Gruenhagen, G. W., Johnson, Z. V., et al. (2024). Spatially resolved cell atlas of the teleost telencephalon and deep homology of the vertebrate forebrain. Communications Biology, 7(1). https://doi.org/10.1038/s42003-024-06315-1

* [5] Sogawa, S., Kobayashi, T., Bshary, R., Sowersby, W., et al. (2025). Rapid self-recognition ability in the cleaner fish. Scientific Reports. https://doi.org/10.1038/s41598-025-25837-0

* [6] Schuster, S. (2018). Hunting in archerfish - an ecological perspective on a remarkable combination of skills. Journal of Experimental Biology, 221(Suppl_1), jeb159723. https://doi.org/10.1242/jeb.159723

* [7] Butler, A. B., & Cotterill, R. M. J. (2006). Mammalian and Avian Neuroanatomy and the Question of Consciousness in Birds. The Biological Bulletin, 211(2), 106-127. https://doi.org/10.2307/4134586

* [8] Gallup, G. G., Jr. (1970). Chimpanzees: Self-Recognition. Science, 167(3914), 86-87. https://doi.org/10.1126/science.167.3914.86

* [9] Anderson, J. R., & Gallup, G. G., Jr. (2015). Mirror self-recognition: a review and critique of attempts to promote and engineer self-recognition in primates. Primates, 56(4), 317-326. https://doi.org/10.1007/s10329-015-0488-9

* [10] Prior, H., Schwarz, A., & G nt rk n, O. (2008). Mirror-Induced Behavior in the Magpie (Pica pica): Evidence of Self-Recognition. PLOS Biology, 6(8), e202. https://doi.org/10.1371/journal.pbio.0060202

* [11] Freiburger, T., Miller, N., & Skinner, M. (2024). Olfactory self-recognition in two species of snake. Proceedings of the Royal Society B: Biological Sciences, 291(2020), 20240125. https://doi.org/10.1098/rspb.2024.0125

* [12] Kopp, K., Eder, M., & Hopper, L. M. (2021). Small Mirrors Do the Trick: A Simple, but Effective Method to Study Mirror Self-Recognition in Chimpanzees. Animal Behavior and Cognition, 8(3), 391-405. https://www.animalbehaviorandcognition.org/uploads/journals/34/AB_C_2021_Vol8(3)_Kopp_et_al.pdf

* [13] Morrison, R., & Reiss, D. (2018). Precocious development of self-awareness in

dolphins. PLOS ONE, 13(1), e0189813. https://doi.org/10.1371/journal.pone.0189813

* [14] Reiss, D., & Marino, L. (2001). Mirror self-recognition in the bottlenose dolphin: A case of cognitive convergence. Proceedings of the National Academy of Sciences, 98(10), 5937-5942. https://doi.org/10.1073/pnas.101086398

* [15] Kohda, M., Sogawa, S., Jordan, A. L., & Kubo, N. (2022). Further evidence for the capacity of mirror self-recognition in cleaner fish and the significance of ecologically relevant marks. PLOS Biology, 20(2), e3001529. https://doi.org/10.1371/journal.pbio.3001529

* [16] Kohda, M., Bshary, R., Kubo, N., et al. (2023). Cleaner fish recognize self in a mirror via self-face recognition like humans. Proceedings of the National Academy of Sciences, 120(7), e2208420120. https://doi.org/10.1073/pnas.2208420120

* [17] ROTH, G., & DICKE, U. (2005). Evolution of the brain and intelligence. Trends in Cognitive Sciences, 9(5), 250-257. https://doi.org/10.1016/j.tics.2005.03.005

* [18] Triki, Z., Aellen, M., van Schaik, C., & Bshary, R. (2021). Relative Brain Size and Cognitive Equivalence in Fishes. Brain, Behavior and Evolution, 96(3), 124-136. https://doi.org/10.1159/000520741

* [19] Chojnacka, D., Isler, K., Barski, J. J., et al. (2015). Relative Brain and Brain Part Sizes Provide Only Limited Evidence that Machiavellian Behaviour in Cleaner Wrasse Is Cognitively Demanding. PLOS ONE, 10(8), e0135373. https://doi.org/10.1371/journal.pone.0135373

* [20] Mueller, T. (2012). What is the Thalamus in Zebrafish?. Frontiers in Neuroscience, 6. https://doi.org/10.3389/fnins.2012.00064

* [21] Lust, K., Maynard, A., Gomes, T., et al. (2022). Single-cell analyses of axolotl telencephalon organization, neurogenesis, and regeneration. Science, 377(6610). https://doi.org/10.1126/science.abp9262

* [22] Triki, Z., Levorato, E., McNeely, W., et al. (2019). Population densities predict forebrain size variation in the cleaner fish Labroides dimidiatus. Proceedings of the Royal Society B: Biological Sciences, 286(1915), 20192108. https://doi.org/10.1098/rspb.2019.2108

* [23] Potrich, D., Zanon, M., & Vallortigara, G. (2022). Archerfish number discrimination. eLife, 11, e74057. https://doi.org/10.7554/eLife.74057

* [24] Leadner, K., Sekely, L., Klein, R., & Gabay, S. (2021). Evolution of social attentional cues: Evidence from the archerfish. Cognition, 207, 104511. https://doi.org/10.1016/j.cognition.2020.104511

* [25] La Loggia, O., R fenacht, A., & Taborsky, B. (2022). Fish can infer relations between colour cues in a non-social learning task. Biology Letters, 18(11), 20220321. https://doi.org/10.1098/rsbl.2022.0321

* [26] Hotta, T., Takeyama, T., Heg, D., et al. (2015). The use of multiple sources of social information in contest behavior: testing the social cognitive abilities of a cichlid fish. Frontiers in Ecology and Evolution, 3. https://doi.org/10.3389/fevo.2015.00085

* [27] O'Connell, L. A., & Hofmann, H. A. (2011). The Vertebrate mesolimbic reward

system and social behavior network: A comparative synthesis. Journal of Comparative Neurology, 519(18), 3599-3639. https://doi.org/10.1002/cne.22735

* [28] Cook, V. A. N. O., Groneberg, A. H., Hoffmann, M., et al. (Feb 26, 2024). Ultrafast sound production mechanism in one of the smallest vertebrates. Proceedings of the National Academy of Sciences, 121(10), e2314017121. https://doi.org/10.1073/pnas.2314017121

* [29] Demarchi, L., Coraggioso, M., Hubert, A., et al. (2025). Logarithmic coding leads to adaptive stabilization in the presence of sensorimotor delays. Proceedings of the National Academy of Sciences, 122(41), e2510385122. https://doi.org/10.1073/pnas.2510385122

* [30] Zada, D., Schulze, L., Yu, J., Tarabishi, P., et al. (2024). Development of neural circuits for social motion perception in schooling fish. Current Biology, 34(17), 3944-3958. https://doi.org/10.1016/j.cub.2024.06.049

* [31] Kohda, M., Hotta, T., Takeyama, T., et al. (2019). If a fish can pass the mark test, what are the implications for consciousness and self-awareness testing in animals? PLOS Biology, 17(2), e3000021. https://doi.org/10.1371/journal.pbio.3000021

* [32] Nilsson, G. E. (1996). Brain and Body Oxygen Requirements of Gnathonemus petersii, a Fish with an Exceptionally Large Brain. Journal of Experimental Biology, 199(3), 603-607. https://doi.org/10.1242/jeb.199.3.603