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Pressemitteilung

Universität Heidelberg
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14.02.2025
http://idw-online.de/de/news847509

Forschungsergebnisse, Wissenschaftliche Publikationen
Biologie
überregional

Complex Evolution: Advanced Cognitive Abilities in Birds

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Press Release
Heidelberg, 14 February 2025

Complex Evolution: Advanced Cognitive Abilities in Birds
Heidelberg researchers map the responsible brain regions and gain new insights into their development and evolution

The brains of birds and mammals have diverged substantially during the course of evolution. A research team led by Prof. Dr Henrik Kaessmann at the Center for Molecular Biology of Heidelberg University has investigated how similar cognitive functions could still arise in some bird species. Analyses on the composition, development and evolution of the pallium – the brain region in birds and mammals largely responsible for memory, learning, and thinking – show that some brain cell types remained nearly unchanged over hundreds of millions of years, whereas others evolved quite differently.

Bird brains differ fundamentally in structure from those of reptiles and especially mammals. Yet some bird species possess complex cognitive abilities similar to apes, and the pallium plays a key role in this. This region in the forebrain consists primarily of the folded cerebral cortex in humans but is structured quite differently in birds, despite supporting similar functions. Prof. Kaessmann's team studied the cellular composition and evolution of the pallium in chickens. Using ultramodern single-cell technologies, the biologists mapped the cell types represented in this brain structure and compared the information with similar datasets in mice and reptiles.

The analyses show that in spite of the dissimilar brain architectures, the neurons that regulate brain activity are remarkably similar across the species studied – unlike the neurons responsible for signal transmission, which followed a more dynamic evolutionary pathway, explains Dr Bastienne Zaremba. Whereas some barely changed, like those in the hippocampus, which is responsible for learning and memory, others evolved in dramatically different ways or reorganized themselves anatomically. What the researchers did not expect: "Certain excitatory neurons probably possess a common evolutionary origin across species. This applies to the neurons in the deeper layers of the neocortex, which is responsible for higher cognitive functions in mammals, and the neurons in the mesopallium in birds. This finding calls into question existing assumptions about the evolution of these brain regions," states the scientist, a member of Prof. Kaessmann's "Evolutionary Genomics" research group.

The research also provides new insights into the hyperpallium, a structure unique to birds within the pallium. Until now, researchers assumed that the avian hyperpallium corresponds to the mammalian neocortex. The Heidelberg researchers were able to demonstrate that although some neurons are similar, others are fundamentally different. “Our findings challenge previous theories that proposed a simple one-to-one correspondence between brain regions in birds and mammals based on their location,” explains Dr Zaremba. Instead, what emerges according to the scientist is a considerably more complex evolutionary mix of conservation, divergence, and convergence. Some features have remained remarkably similar, others have changed dramatically, and still others have become more similar over time.

The researchers also found that certain neurons in two distant regions of the bird brain are surprisingly similar, even though they originate from different locations in the embryo. “We need to rethink the idea that a neuron’s final role is strictly determined by where it forms in the embryonic brain,” says Prof. Kaessmann. “To gain a differentiated understanding of brain evolution and the development of complex cognitive abilities in birds and mammals, molecular data that takes developmental processes into account is crucial,” adds the Heidelberg evolutionary biologist.

The research was carried out in close collaboration with Dr Fernando García-Moreno of the University of the Basque Country (Spain). Researchers from Sweden also participated. The European Research Council, the government of the Autonomous Community of the Basque Country, and the Swedish Research Council provided funding. The research results were published in the journal “Science”.

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Originalpublikation:

B. Zaremba, A. Fallahshahroudi, C. Schneider, J. Schmidt, I. Sarropoulos, E. Leushkin, B. Berki, E. Van Poucke, P. Jensen, R. Senovilla-Ganzo, F. Hervas-Sotomayor, N. Trost, F. Lamanna, M. Sepp, F. García-Moreno, H. Kaessmann: Developmental origins and evolution of pallial cell types and structures in birds. Science (published online 13 February 2025), DOI: 10.1126/science.adp5182

URL zur Pressemitteilung: http://www.zmbh.uni-heidelberg.de/Kaessmann – Kaessmann research group