

## Evolution & Behavior

# Ancient origins of monogamy: Do you tolerate your partner because of your genes?

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### ABSTRACT

*Monogamy has evolved independently in all of the major lineages of vertebrates. We investigated the gene activity in the brains of monogamous male mice, voles, birds, frogs, and fish and found similar changes in gene expression each time monogamy evolves. This finding suggests that the basic molecular and neural machinery of monogamy has ancient origins in the common ancestor of vertebrates.*



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Considering the wonderful diversity of animal form, function, and behavior, it may come as a surprise that some traits have been repeatedly and independently selected throughout evolution. Monogamy – when male and female reproductive partners form a pair bond and share at least some of the work of raising and defending offspring in the face of danger – has evolved independently in each of the major lineages of vertebrates (including mammals, birds/reptiles, amphibians, and fishes) and even a few insects and arachnids!

Understanding why monogamous mating systems evolve repeatedly across these diverse lineages has captured the interest of biologists focused on the

evolution of animal behavior. For example, if females are scarce or difficult to find, it can be advantageous for a male to stick with her after mating to safeguard future reproductive opportunities. Also, if predation pressure is high and/or the environment is highly unpredictable, both male and female members of the pair might benefit from staying together and cooperating on parental care to increase the survival of their offspring. However, much less is known about the molecular mechanisms that regulate monogamy-related behavior. Our research asks to which extent similar gene activity in the brain might get recruited when a trait, such as monogamy, evolves independently in multiple species.

We studied five pairs of closely-related species – two pairs of mammals, one pair of birds, one pair of frogs, and one pair of fishes. Each pair contains one species that has independently evolved monogamy and one species with a non-monogamous mating system (for example, a promiscuous mating system). We collected brains from males of each of the 10 species and compared how their genes behaved in the monogamous versus non-monogamous male brain. This comparison allowed us to identify genes whose activity has turned up or down each time monogamy evolved. Comparing across the species pairs, we identified changes in brain-gene activity that are repeatedly associated with the evolution of monogamy across vertebrates.

We found that monogamous species of different lineages share an overall similar pattern of neural gene expression and identified a set of genes whose activity changed in similar ways with the evolution of monogamy. Importantly, other biological and evolutionary factors influence gene expression and could result in similarities among species. We tested two alternative hypotheses. First, similarities among species related to ecological attributes including diet, daily activity pattern (for example, nocturnal or diurnal activity), sociability (for example, whether a species is gregarious or not), and habitat complexity might influence neural gene activation. Second, the evolutionary relationships among species influence differences in neural gene expression patterns. Specifically, we would expect more closely related species to be more similar in their gene activation since they shared a common ancestor more recently. We did not find any support for these two alternative hypotheses and can thus reject them which provides further support for our conclusion that independent evolution of monogamy across vertebrates is accompanied by similar neural gene expression changes.

Given the distant evolutionary relationships among lineages, spanning approximately 420 million years, why might evolutionary transitions to monogamy be associated with similar gene activation patterns in the brain? One possibility is that the common ancestor of all vertebrates must already have had the ability to tolerate other individuals, at least temporarily, for reproduction or offspring care. This means that the basic molecular and neural machinery underlying more complex pair-bonding or co-parenting behavior would be shared across all vertebrates. As monogamy evolved repeatedly and independently across vertebrates, similar gene expression signatures that organize and facilitate this behavior may have been repeatedly recruited. Notably, monogamy does not mean that the male and female are exclusive to each other when it comes to mating. In fact, in most species that have been examined extra-pair mating occurs fairly regularly (including humans). Thus, the shared gene expression patterns among monogamous vertebrate species associated with the tolerance required to pairbond and co-parent are not necessarily associated with fidelity.

Broadly, this work reminds us of our deep evolutionary past. Like all other animals, humans are the product of evolution. That means that what we look like, how our bodies work, and also our behavior has an evolutionary history. Though underutilized in biomedical research and other human-centric applications, our study emphasizes the power of the comparative approach – where many species are compared – as a tool for understanding the biological processes and molecular mechanisms that regulate our development, physiology, or behavior.