Poeciliid Research

Mechanisms of achiasmatic meiosis and reproductive adaptations in the unisexual Amazon molly, *Poecilia formosa* (Girard, 1859)

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Abstract. This study critically explores the genetic and molecular mechanisms behind achiasmatic meiosis in the unisexual Amazon molly *Poecilia formosa* (Girard, 1859), a species that reproduces clonally through gynogenesis. By bypassing traditional meiosis, *P. formosa* produces diploid eggs, maintaining genome stability despite the absence of genetic input from males. Through cytogenetic analyses and transcriptomic comparisons with its parental species (*Poecilia mexicana* Steindachner, 1863 and *Poecilia latipinna* (Lesueur, 1821)), the research reveals that the failure to form bivalents and undergo homologous recombination leads to apomictic egg production. Gene expression analyses highlight the downregulation of meiosis-related genes, such as *spo11* and *tex12*, and the presence of allelic biases, which may resolve hybrid incompatibilities. These findings provide significant insights into the evolution of asexual reproduction and the mechanisms supporting clonal propagation in vertebrates.
Key Words: gynogenesis, *Poecilia formosa*, clonal reproduction, asexuality, apomixis, gene regulation, hybrid incompatibility, genome stability, meiosis-related genes.

This news and views article critically examines the genetic and molecular mechanisms underlying achiasmatic meiosis in the unisexual Amazon molly (*Poecilia formosa*). It explores how the species bypasses traditional meiosis to produce diploid eggs through gynogenesis, emphasizing the role of hybridization and gene regulation in enabling clonal reproduction while maintaining genome stability.

A study with the title: Achiasmatic meiosis in the unisexual Amazon molly, *Poecilia formosa*, was conducted by Dmitrij Dedukh, Irene da Cruz, Susanne Kneitz, Anatolie Marta, Jenny Ormanns, Tomáš Tichopád, Yuan Lu, Manfred Alsheimer, Karel Janko, and Manfred Schartl. The researchers are associated with esteemed institutions, including the University of Würzburg, the Czech Academy of Sciences, and Texas State University. Their collaborative expertise spans developmental biology, genetics, and zoology.

Dedukh et al (2022) aimed to investigate the unusual reproductive mechanism of the Amazon molly, a unisexual vertebrate that reproduces via gynogenesis—a form of parthenogenesis where egg development is triggered by sperm from related species, but without genetic contribution from the male (Cerepaka & Schlupp 2023; Cunningham et al 2024). Specifically, the study focused on understanding how this species bypasses traditional meiosis, which typically produces haploid gametes, and instead generates diploid eggs clonally. The primary objective was to uncover the cytogenetic and molecular mechanisms underlying the achiasmatic meiosis in *P. formosa* and identify the genetic pathways that enable the production of unreduced eggs (Dedukh et al 2022).

Using a combination of cytogenetic techniques, transcriptomic analyses, and comparative studies with related sexual species (*P. mexicana* and *P. latipinna*), the researchers identified several key features of *P. formosa*'s reproductive biology. Cytological observations revealed that *P. formosa* oocytes initiate the early stages of meiosis, such as chromosome alignment and synaptonemal complex formation (Dedukh et al 2022). However, they fail to complete bivalent formation or undergo homologous recombination. Instead of typical meiotic division, the chromosomes remain as univalents, resulting in diploid eggs through a process called apomixis (Dedukh et al 2022). This failure to complete meiosis is not due to the absence of key meiotic proteins but likely involves dysregulation at the protein level or novel mechanisms not yet identified.

Transcriptome analysis showed that the expression of meiosis-specific genes in *P. formosa* is similar to one of its parental species (*P. latipinna*), with some genes being downregulated compared to *P. mexicana* (Dedukh et al 2022). Notably, genes essential for chromosome pairing and recombination, such as spo11 and tex12, were expressed at lower levels, suggesting a partial suppression of meiosis. The study also uncovered evidence of allelic bias in gene expression, where certain genes preferentially expressed one parental allele over the other. This bias may play a role in resolving hybrid incompatibilities and ensuring proper oocyte development (Dedukh et al 2022).

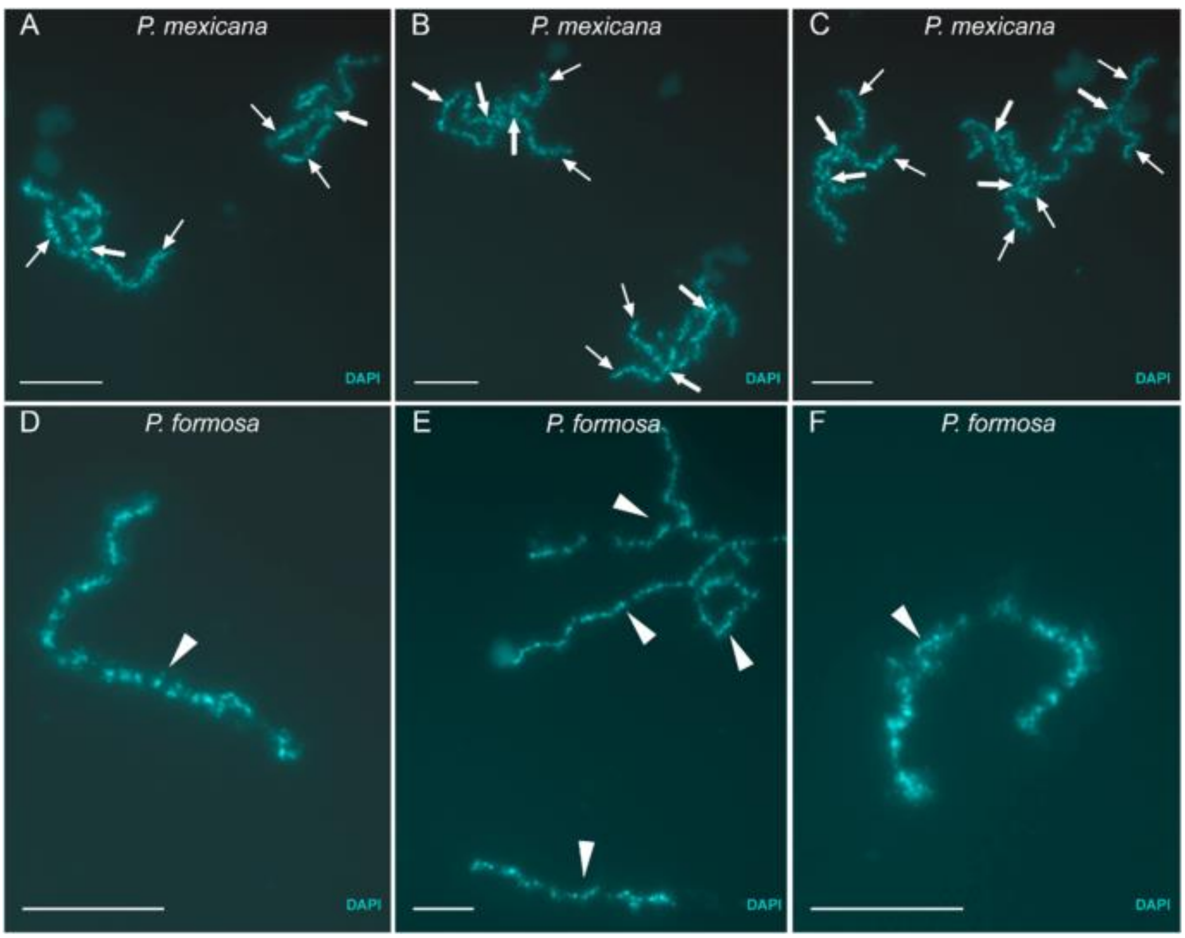

Figure 1. Examples of bivalents (A, B, C) and univalents (D, E, F) from diplotene oocytes of *P. mexicana* (A, B, C) and *P. formosa* (D, E, F) (source: Dedukh et al 2022).

The findings have profound implications for understanding the evolution of asexual reproduction in vertebrates. The ability of *P. formosa* to produce diploid eggs clonally allows it to maintain a stable population despite the lack of genetic input from males. This reproductive strategy eliminates the genetic diversity typically provided by sexual reproduction, raising questions about how the species avoids the negative effects of clonal propagation, such as the accumulation of deleterious mutations. The study's results highlight the importance of hybridization events and genetic regulation in the transition from sexual to asexual reproduction.

By elucidating the mechanisms of achiasmatic meiosis in *P. formosa*, the study contributes to broader discussions on the evolution of reproductive strategies and the genetic and molecular basis of asexuality. It also opens avenues for future research into the role of hybridization and gene expression regulation in shaping unique reproductive systems.

References

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Received: 20 November 2024. Accepted: 27 December 2024. Published online: 30 December 2024.

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How to cite this article:
Boaru A., Petrescu-Mag I. V., 2024 Mechanisms of achiasmatic meiosis and reproductive adaptations in the unisexual Amazon molly, *Poecilia formosa* (Girard, 1859). Poec Res 14(1):27-29.