Poeciliid Research

Evolutionary dynamics of the Y chromosome in the swamp guppy (*Poecilia picta* Regan, 1913): Degeneration, recombination, and sexually antagonistic gene absence

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Abstract. The evolutionary trajectories of sex chromosomes have been a focal point in genetics and evolutionary biology. In this short article (news and views), the Y chromosome of the swamp guppy (*Poecilia picta*) is explored to understand its structural degeneration, recombination dynamics, and the presence of sexually antagonistic genes. Using advanced cytogenetic techniques, including DAPI staining, C-banding, and immunofluorescence, the research reveals a highly degenerated Y chromosome characterized by reduced size and extensive heterochromatin accumulation. Interestingly, recombination persists in a pseudoautosomal region (PAR) at the distal end of the Y chromosome, ensuring meiotic stability. Moreover, the absence of Y-linked pigmentation genes suggests diminished sexual conflict in *P. picta*, contrasting with related guppy species. These findings underscore the diversity of sex chromosome evolution among poeciliid fishes and highlight how genetic degeneration and recombination shape their evolutionary paths.
Key Words: sex chromosome evolution, Y chromosome degeneration, pseudoautosomal region, *Poecilia picta*, heterochromatin, recombination dynamics.

The issue of the evolution of sex chromosomes has been extensively debated by geneticists and evolutionists (Charlesworth et al 2024), and within this debate, poeciliid fish have played a particularly important role as model organisms for behavioral ecology, genetics, and evolution (Bourne & Sammons 2008; Darolti et al 2023).

A study conducted by Indrajit Nanda and colleagues from several research institutions, explores the unique evolutionary trajectory of the Y chromosome in the swamp guppy (*Poecilia picta* Regan, 1913) (Nanda et al 2022). The researchers are affiliated with institutions such as the University of Würzburg in Germany and Texas State University in the USA, specializing in genetics and developmental biology.

The scientists (Nanda et al 2022) aimed to understand the degeneration of the Y chromosome (see details in Charlesworth & Charlesworth 2000) in *Poecilia picta* compared to closely related species, such as *Poecilia reticulata* (Petrescu-Mag & Bourne 2008). Specifically, they sought to identify the structural and functional changes in the Y chromosome, assess its recombination dynamics with the X chromosome, and examine the presence of sexually antagonistic genes that drive evolution (Nanda et al 2022). They used advanced cytogenetic techniques, including immunostaining, fluorescence microscopy, and hormone treatment (Figure 1), to investigate chromosomal composition, recombination activity, and gene expression patterns.

The results revealed a highly degenerated Y chromosome in *P. picta*, characterized by its small size (Figure 2) and extensive heterochromatin accumulation (Figure 3) (Nanda et al

2022). Unlike the Y chromosomes of related guppy species, the *P. picta* Y lacks pigmentation genes linked to sexually antagonistic traits (Nanda et al 2022). The study also demonstrated that recombination between the X and Y chromosomes, although limited, still occurs in a specific pseudoautosomal region (PAR) at the distal end of the Y chromosome (Nanda et al 2022). This recombination maintains critical pairing during meiosis, an essential process for the correct segregation of chromosomes.

Figure 1. Untreated males (left) and 17-methyltestosterone treated females (right) of M. picta (FG strain). Hormone treated females show the complete male pigmentation pattern (source: Nanda et al 2022).

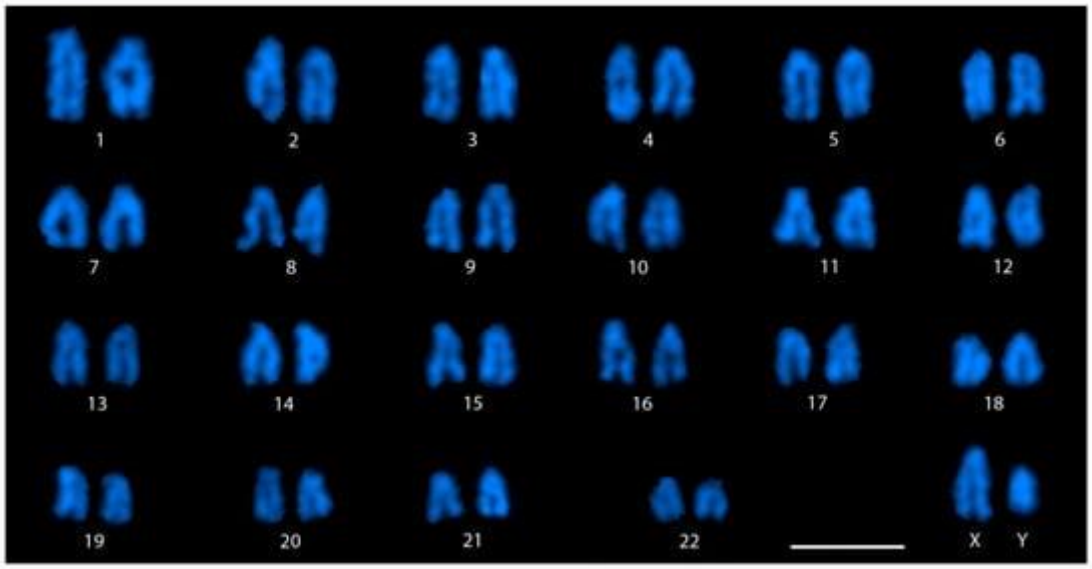

Figure 2. DAPI stained karyotype of male P. picta. Note the size difference between the X and Y. The chromosomes are arranged roughly based on their length. Bar: 3 μm (DAPI stands for 4',6-diamidino-2-phenylindole, which is a fluorescent stain that binds strongly to A-T rich regions in DNA and is commonly used for visualizing nuclear DNA under a fluorescence microscope) (source: Nanda et al 2022).

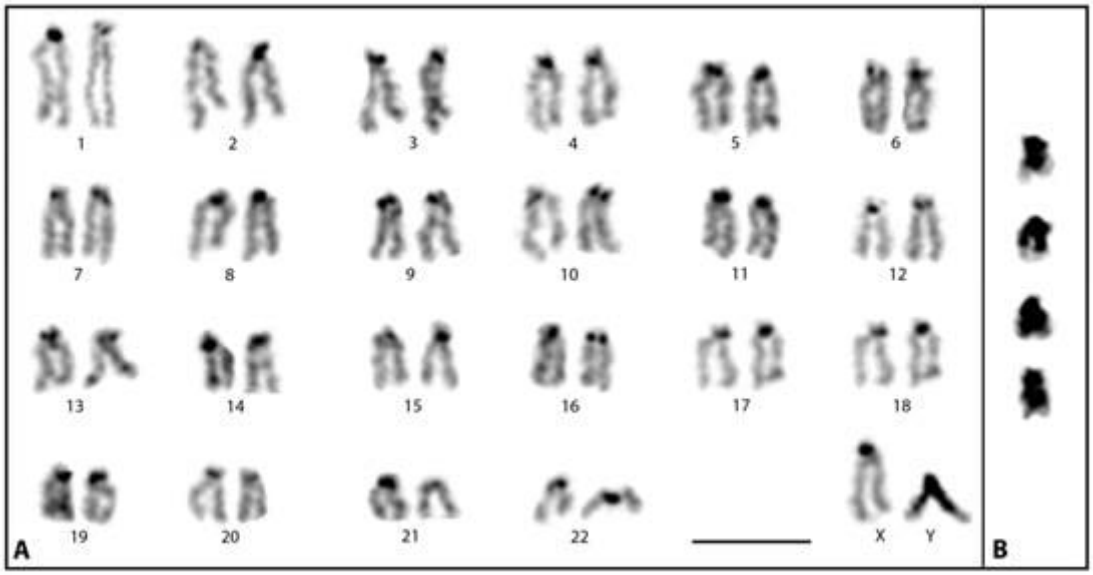

Figure 3. Heterochromatin staining of *P. picta* metaphase chromosomes. (A) C-banded karyotype of male displaying the heterochromatic region on the Y chromosome. (B) C-banded Y chromosome cut-outs from different metaphases. Note a short non-heterochromatic region at the very distal region of the long arm of the Y. Bar: 3 μm (source: Nanda et al 2022).

These findings hold significant implications for understanding sex chromosome evolution. The study underscores the variability in Y chromosome degeneration among closely related species (Petrescu-Mag 2018; Petrescu-Mag & Proorocu 2022), suggesting diverse evolutionary pressures (Nanda et al 2022). Moreover, the absence of sexually antagonistic pigmentation genes on the Y chromosome in *P. picta* (Nanda et al 2022) contrasts sharply with other guppies, where such genes play a central role (Lindholm & Breden 2002). This divergence highlights how reduced sexual conflict may influence the evolutionary trajectory of sex chromosomes.

In conclusion, the study sheds light on the unique evolutionary patterns of the Y chromosome in *P. picta*, emphasizing the role of recombination and genetic degeneration in shaping sex chromosome evolution. These insights contribute to broader discussions on the dynamics of sex chromosome turnover and the evolutionary pathways of vertebrates.

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