

Sex-chromosome cycle: Principle of sex maintenance driven by sex-chromosome turnover

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	Project Information	Project Number : 26A301 Project Period (FY) : 2026-2030 Keywords : sex chromosome, sex determination, experimental evolution, chromosome engineering, evolutionary theory

Purpose and Background of the Research

●Outline of the Research

In sexually reproducing organisms, maintaining males and females is crucial for species persistence. Sex is often determined by sex chromosomes, which enables the balanced sex ratio. However, Y and W chromosomes degenerate with time, creating a paradox in which organisms relying on them may ultimately risk losing sex or being extinct (Fig. 1, left). To address this paradox, we propose a “sex chromosome cycle,” in which organisms preserve sex by replacing their sex chromosomes over time (Fig. 1, right). This project brings diverse researchers to uncover how sex is maintained at each stage of the cycle (Fig. 2) and to experimentally drive transitions from one stage to another, aiming to transform our understanding of the evolution of sex and reproduction.

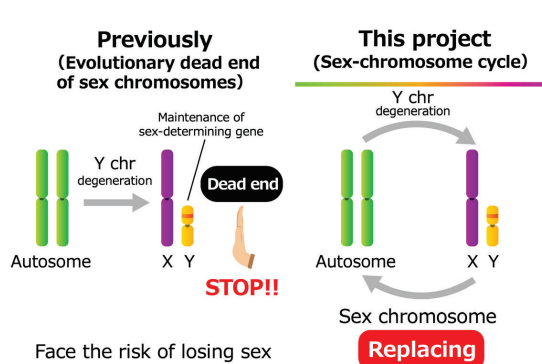


Figure 1. Conceptual framework of this transformative research area

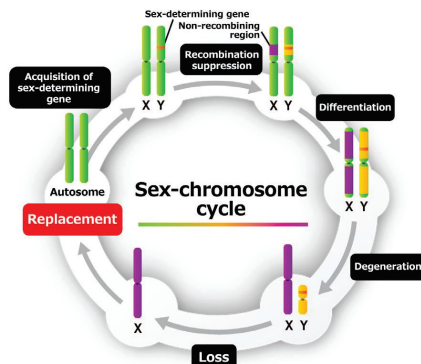


Figure 2. Major stages of sex chromosome cycle

●Background and Rationale

Previous work from our research group and related studies has provided evidence for the existence of this cycle. Building on this, we aim to clarify how organisms have maintained sex in the cycle and experimentally demonstrate it by artificially inducing transitions (Fig. 3).

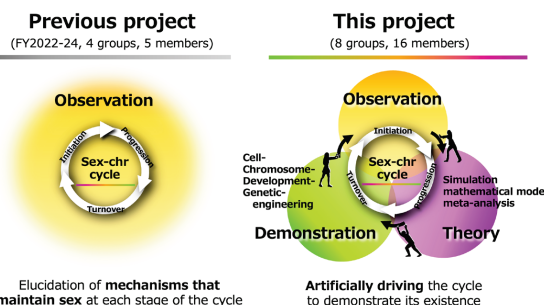


Figure 3. Breakthrough from previous project to this project

●Objectives and Research Strategy

The goal of this project is to demonstrate the sex chromosome cycle and clarify its driving mechanisms and significance. We also aim to show that sex chromosomes serve as a central framework for diverse modes of sex determination. To achieve this goal, we have set three topics (Fig. 4).

[A: Initiation] Mechanisms by which new sex chromosomes become stable
[B: Progression] Mechanisms of differentiation and degeneration leading to the loss of sex chromosomes
[C: Turnover] Mechanisms by which old sex chromosomes are replaced by new ones

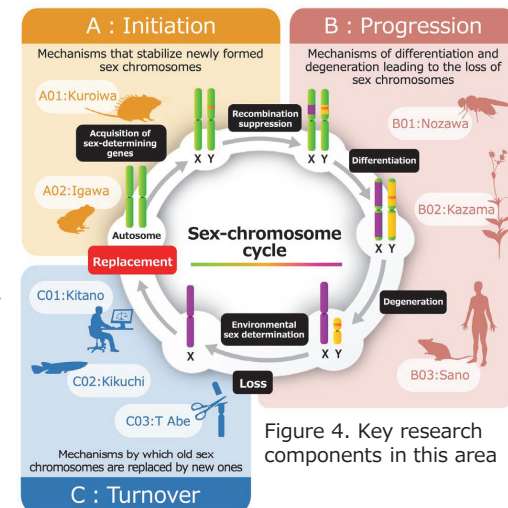


Figure 4. Key research components in this area

Expected Research Achievements

●Specific Research Plan

[A: Initiation] Mechanisms by which new sex chromosomes become stable

For newly formed sex chromosomes to become stable, sex-related genes must accumulate and be maintained on the sex chromosomes. Using species in which sex chromosome turnover has occurred, including the Amami spiny rats (A01) and frogs (A02), we clarify how newly formed sex chromosomes are stably maintained while keeping sex determination stable.

[B: Progression] Mechanisms of differentiation and degeneration leading to the loss of sex chromosomes

The loss of degenerated Y chromosomes requires processes such as the translocation of male fertility genes elsewhere from the Y chromosome and the acquisition of feminizing genes on the X chromosome. The accumulation of transposable elements may also act as a driving force for Y-chromosome loss, whereas diverse functions of sex chromosomes may act as suppressors. Using *Drosophila* (B01), *Silene latifolia* (B02), and humans and mice (B03), we elucidate the mechanisms underlying Y-chromosome loss.

[C: Turnover] Mechanisms by which old sex chromosomes are replaced by new ones

Replacement of old sex chromosomes requires the emergence of cryptic sex-determining regions on autosomes, followed by the spread of these proto-sex chromosomes within populations. Using population evolution experiments (C01) and molecular and cellular approaches (C02), we clarify how proto-sex chromosomes become established as new sex chromosomes. We also identify the minimal components required for turnover using synthetic Y chromosomes (C03). Together, these studies will elucidate the sex chromosome cycle, integrating diverse modes of sex determination.

