Divergent evolution of genetic sex determination mechanisms along environmental gradients

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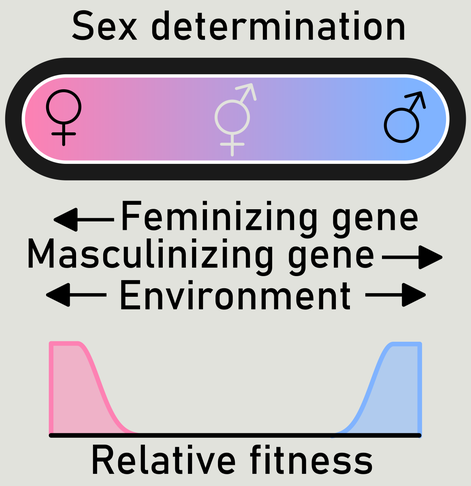
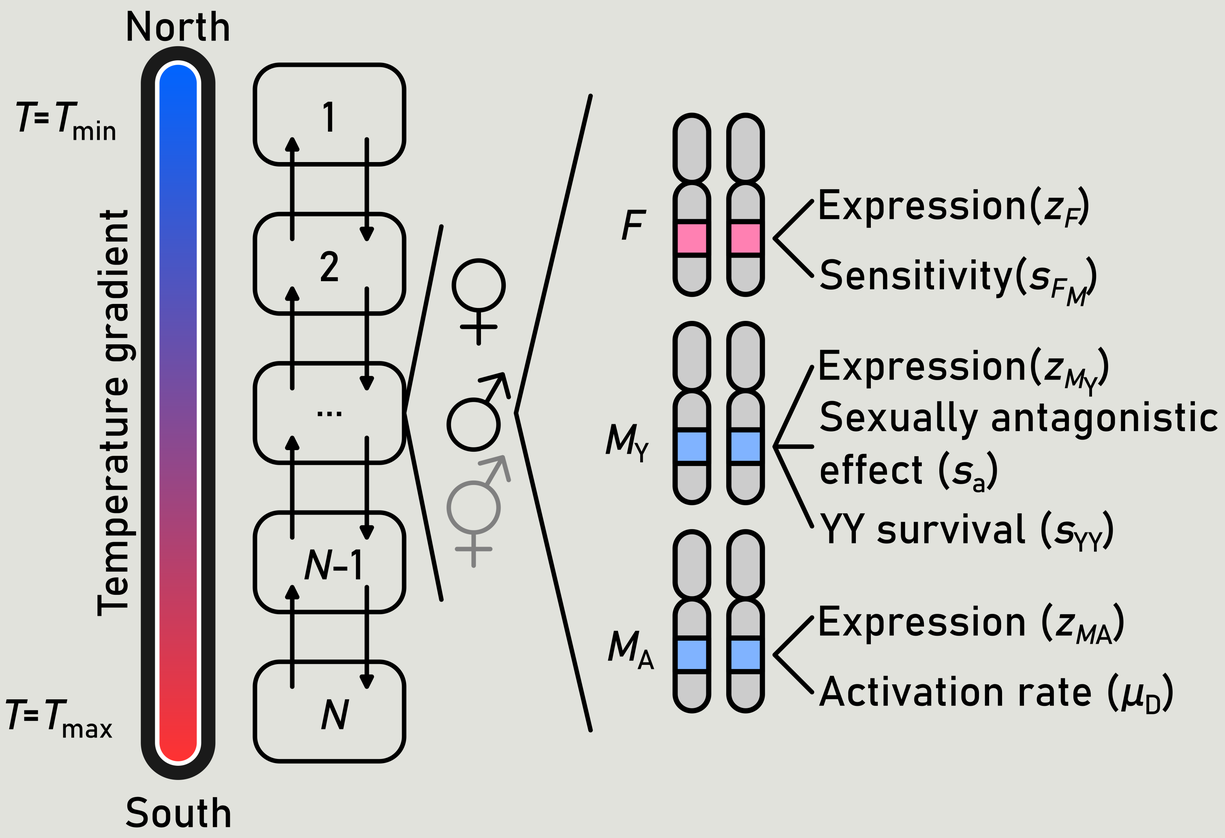
Background information

Main question: How do genetic sex determination systems evolve when gene expression is influenced by environmental conditions?



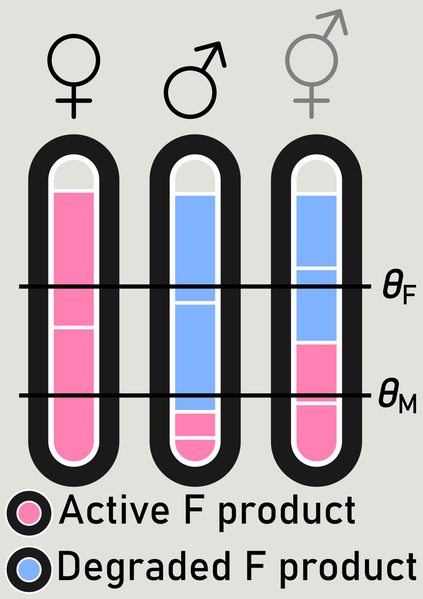
- Sex determination is often affected by genetic and environmental factors
- Environmental perturbance may lead to intersexual development with zero fitness
- Unclear how spatial heterogeneity affects evolution of sex determination systems
- Possible link between environmental variation and polygenic sex determination

Model overview



- Agent-based simulations
- Demic population with dispersal
- Non-overlapping generations
- Ancestral Y-chromosome M_Y with fitness effects
- *De novo* evolution of M_A

Sex determination gene functions and evolution



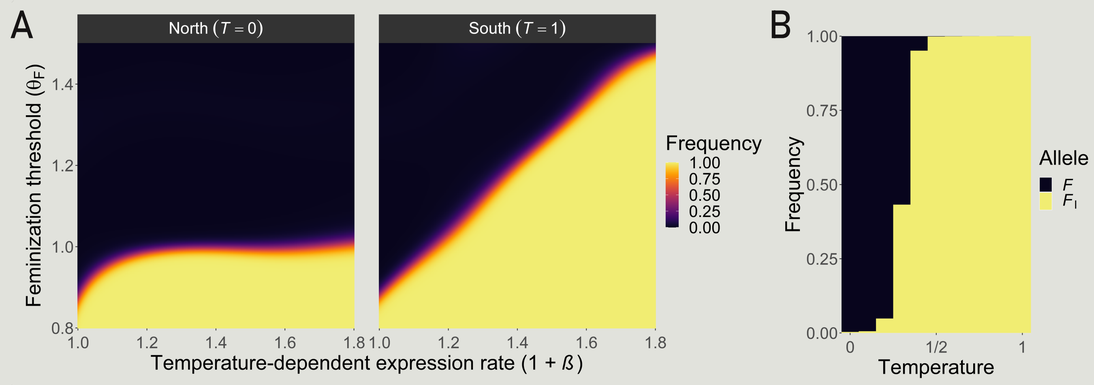
- Sex is determined based on net expression of the F gene ($\hat{z}_F$) relative to the feminization and masculinization thresholds θ_F and θ_M
- M_Y and M_A function as masculinizing genes by breaking down the feminizing F product
- Mutations can occur in F expression and sensitivity as well as M_Y and M_A expression
- Small proportion of mutations are null mutations that set trait value to 0
- M_A becomes expressed *de novo* at a rate μ_D

$$\text{Total } F \text{ product: } \hat{z}_F = \sum_{i=1}^{2} \max\Big(0, \underbrace{(z_{F_i}(1 + \beta T) + \varepsilon)}_{F \text{ expression (with temperature effects and noise)}} \underbrace{\Big(1 - s_{FM_i} \sum_{j=1}^{2} z_{MY_j} + z_{MA_j}\Big)}_{\text{Total } M \text{ expression}}\Big)$$

(z_{F_i}: F genetic expression level; T: local temperature; β: temperature effect coefficient; ε: noise (Gaussian); s_{FM_i}: sensitivity to M; z_{MY_j}: M_Y expression; z_{MA_j}: M_A expression; M-dependent breakdown rate of F)

Evolution of a dominant feminizer F_I

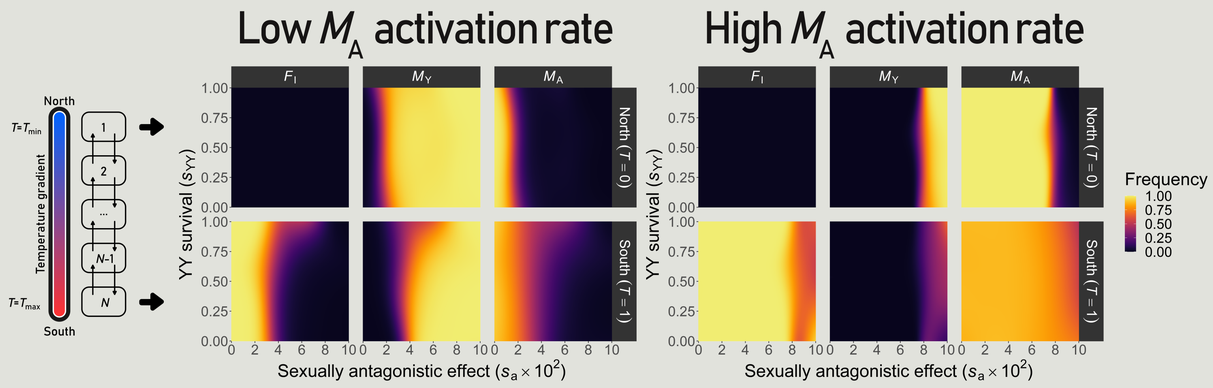
F_I: fully insensitive to M_Y and M_A, net expression exceeds θ_F, so that carriers are always female



(A) F_I evolves when feminization threshold θ_F is low (left) or when temperature-dependent overexpression becomes sufficiently strong (right)

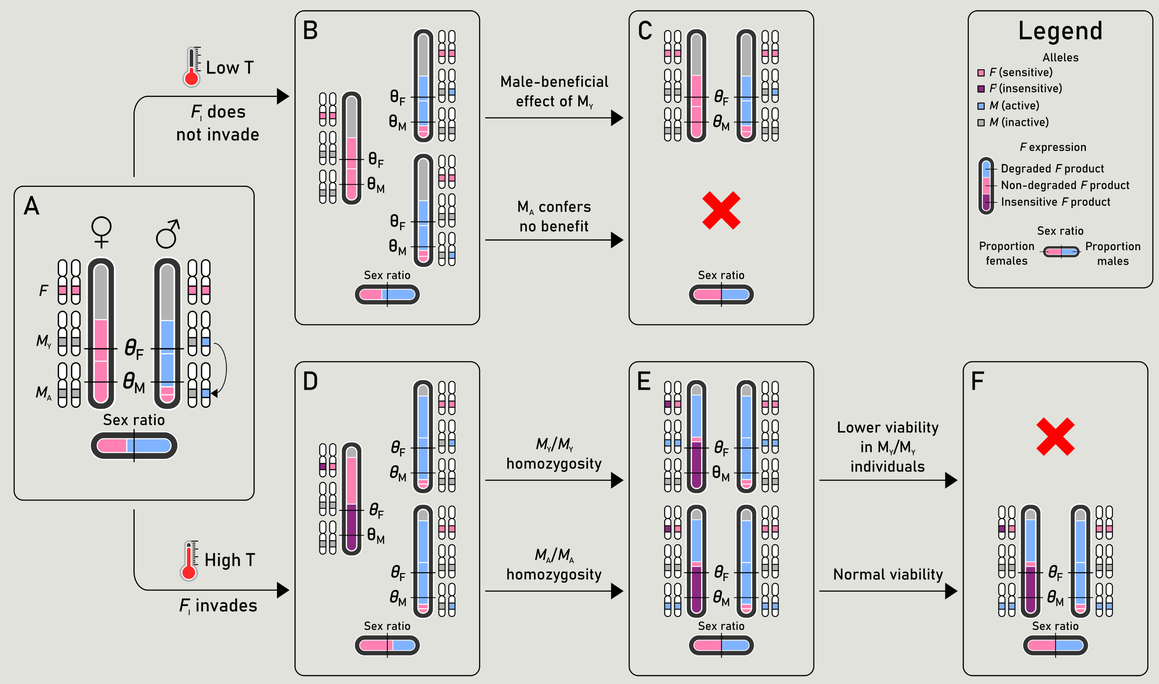
(B) Temperature-dependent invasion of F_I may be restricted to warmer demes; environmental variation leads to within-population differentiation

Frequency gradients at multiple loci



- F_I frequency gradients shaped by temperature; net expression too low at T=0 for F_I to evolve, but sufficient at higher temperatures
- M_Y versus M_A polymorphism: sexual antagonistic selection maintains M_Y over M_A in absence of F_I; costs in females and reduced viability in YY homozygotes drive M_Y loss, followed by fixation of M_A in presence of F_I

Conclusion



Environment modulates scope for evolutionary change, promoting divergent evolution leading to polygenic sex determination

Funding

Research

Travel

Read the paper!