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# Divergent evolution of genetic sex determination along environmental gradients

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# Backgroundinformation

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

Sex determination



- Feminizing gene
  Masculinizing gene Environment —
- 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

### Evolution of a dominant feminizer $F_{\rm I}$

 $F_{I}$ : fully insensitive to  $M_{v}$  and  $M_{\Delta}$ , net expression exceeds  $\theta_{F}$ , so that carriers are always female



(A)  $F_{I}$  evolves when feminization threshold  $\theta_{F}$  is low (left) or when temperature-dependent overexpression becomes sufficiently strong (right)





 Possible link between environmental variation and polygenic sex determination

> (B) Temperature-dependent invasion of  $F_1$  may be restricted to warmer demes; environmental variation leads to within - population differentiation



**Model overview** 

### Frequency gradients at multiple loci



• F frequency gradients shaped by temperature; net expression too low at 7=0 for F, to evolve, but sufficient at higher temperatures

- Agent-based simulations
- Demic population with dispersal
- Non-overlapping generations
- Ancestral Y-chromosome M, with fitness effects
- Denovoevolution of M

# Sex determination gene functions and evolution



- Sex is determined based on net expression of the F gene  $(\widehat{z}_{F})$  relative to the feminization and masculinization thresholds  $\theta_{\rm F}$  and  $\theta_{\rm M}$
- $M_{\gamma}$  and  $M_{\Delta}$  function as masculinizing genes by breaking down the feminizing F product
- Mutations can occur in *F* expression and

•  $M_{v}$  versus  $M_{\Delta}$  polymorphism: sexual antagonistic selection maintains  $M_{v}$ over  $M_{\Delta}$  in absence of  $F_{\Gamma}$ ; costs in females and reduced viability in YY homozygotes drive  $M_{v}$  loss, followed by fixation of  $M_{h}$  in presence of  $F_{I}$ 





sensitivity as well as  $M_{\gamma}$  and  $M_{\Lambda}$  expression

 Small proportion of mutations are null mutations that set trait value to 0

•  $M_{\Lambda}$  becomes expressed *de novo* at a rate  $\mu_{\Pi}$ 



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

