Sperm do not evolve to collaborate in female meiotic drive

Yaniv Brandvain* & Graham Coop
*University of Minnesota – Twin Cities
Evolution, Raleigh NC. 6/24/2014.

OR

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Sperm should evolve to make female meiosis fair

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Overview

- Introduction to female meiosis and female meiotic drive
  - Meiotic drive
  - Fertilization requirement for female meiosis
- Potential for sperm to influence female meiotic drive
- Models show sperm evolve to prevent female meiotic drive
- Speculation / Conclusion

Background – Female meiosis

en.wikipedia.org/wiki/Oogenesis

female meiosis

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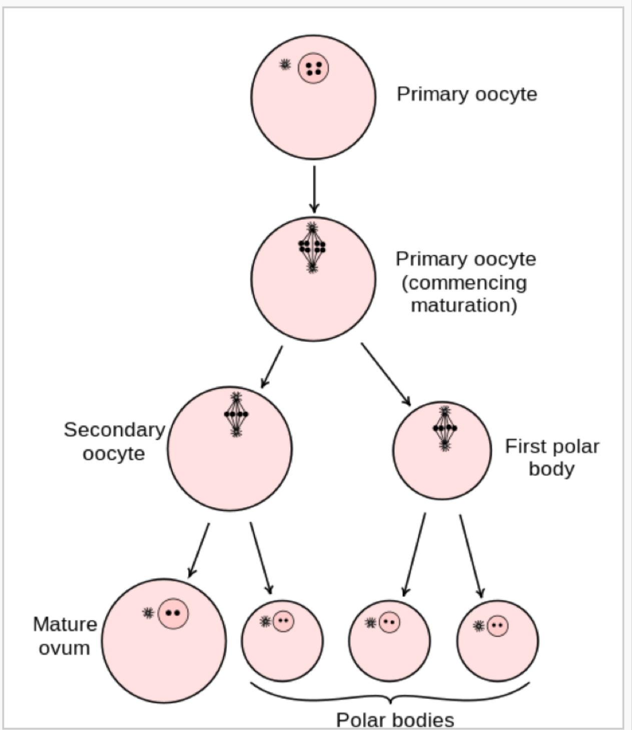
বাংলা
Беларуская
Беларуская (тарашкевіца)
Bosanski
Català
Deutsch
Eesti
Español
Français
Galego
Հայերեն
Ido
Bahasa Indonesia
Italiano
עברית
Қазақша
Lietuvių

Oogenesis in mammals [edit]

In mammals, the first part of oogenesis starts in the germinal epithelium, which gives rise to the development of ovarian follicles, the functional unit of the ovary.

Note that this process, important to all animal life cycles yet unlike all other instances of cell division, occurs completely without the aid of oo spindle-coordinating centrosomes.[2][3]

Oogenesis consists of several sub-processes: oocytogenesis, ootidogenesis, and finally maturation to form an ovum (oogenesis proper). Folliculogenesis is a separate sub-process that accompanies and supports all three oogenetic sub-processes.



			Process

Background – Female meiosis
4 products enter, 1 gamete leaves

en.wikipedia.org/wiki/Oogenesis

female meiosis

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Aragonés
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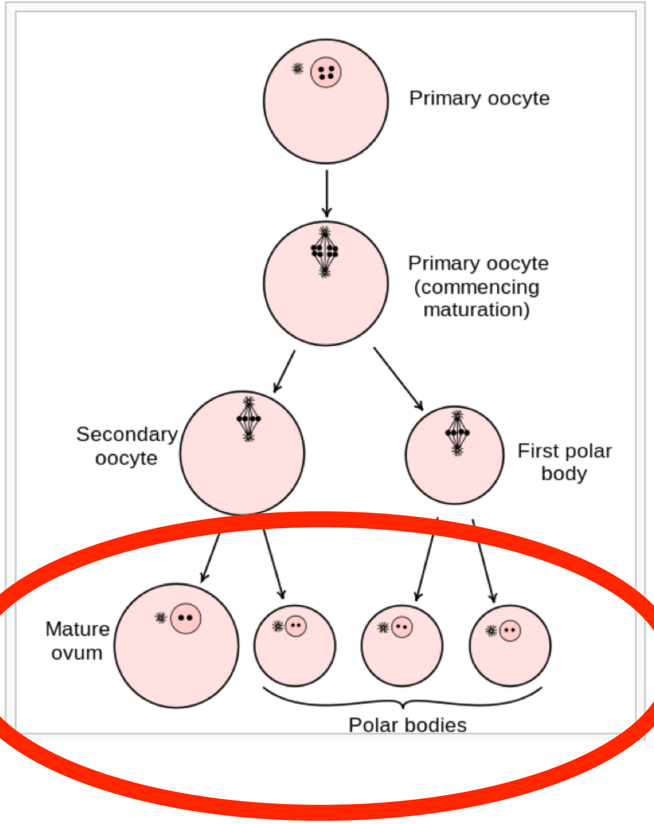
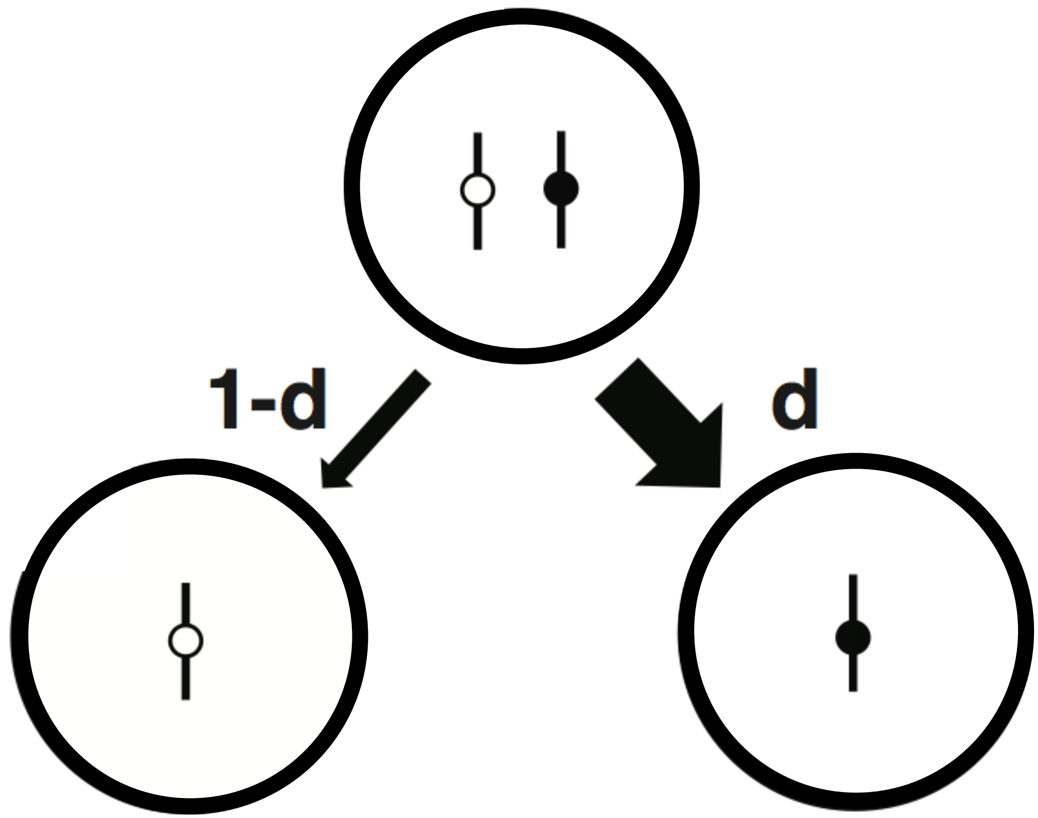


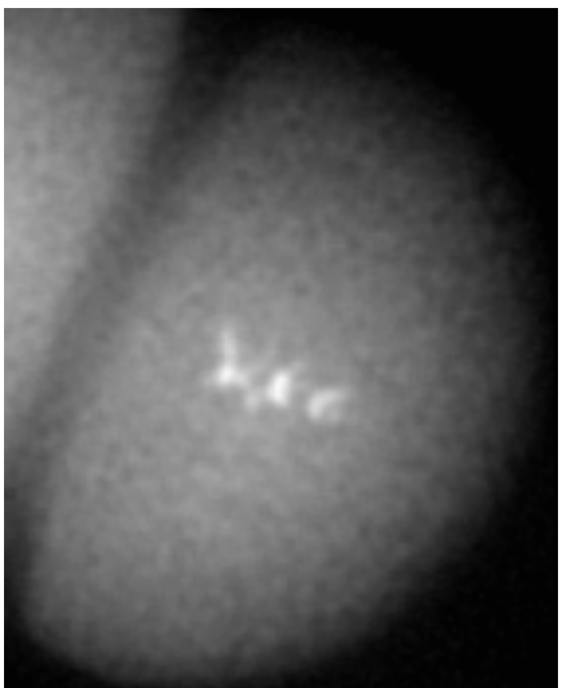
			Process

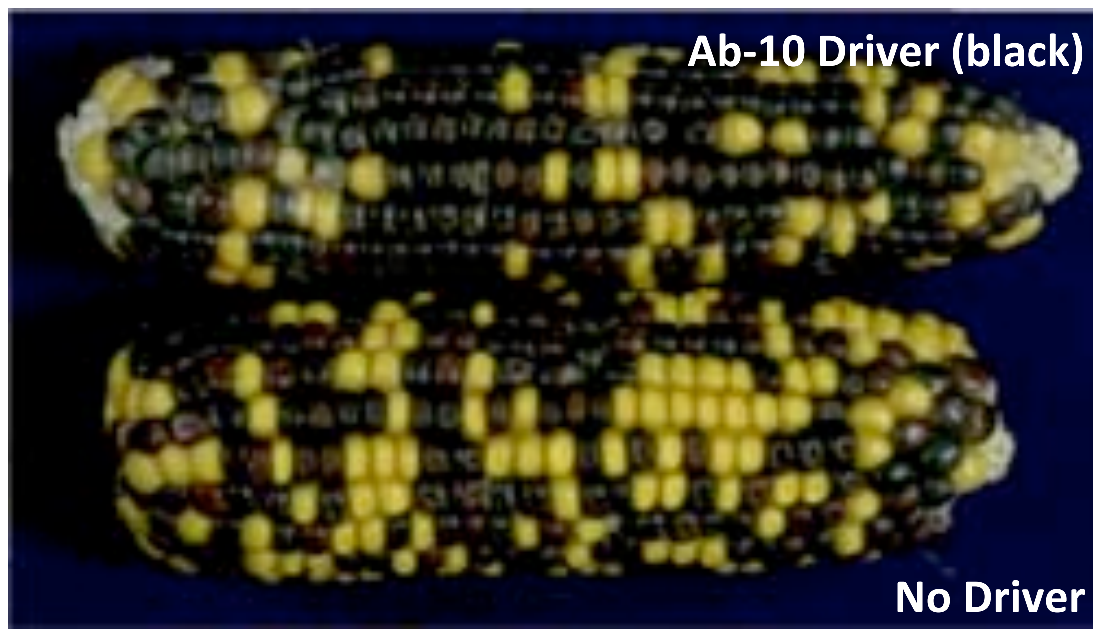
Drive Cartoon



Asymmetry in female meiosis provides an opportunity for cheating 'drivers'

- **Example:** The AB10 system in maize results in the disproportionate transmission of knobby centromeres in the 2nd meiotic division

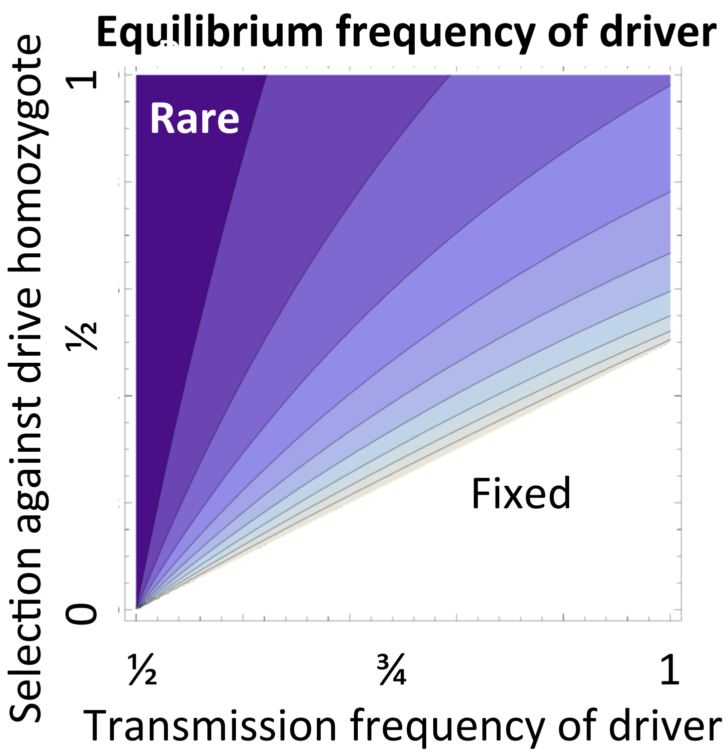




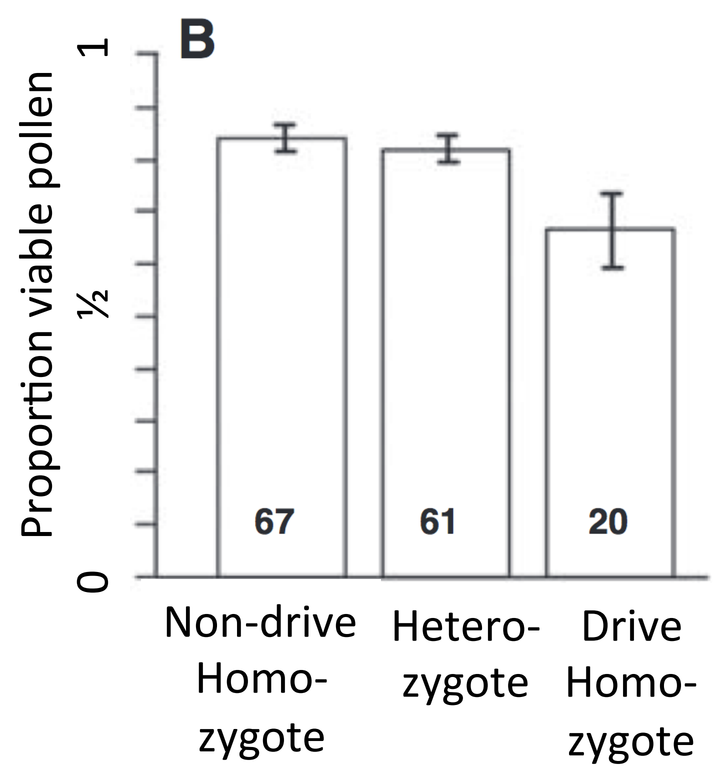
http://www.dawelab.org/neocentromeres-meiotic-drive

Polymorphic Meiotic Drivers are costly

- Theory



- Data



Fishman and Saunders. 2008.Science 322: 1559-1562

Features of (female) meiosis interpreted as defense against drive

- Genome doubling in MI

  Haig and Grafen 1991

J. theor. Biol. (1991) **153,** 531–558

Genetic Scrambling as a Defence Against Meiotic Drive

DAVID HAIG AND ALAN GRAFEN

Department of Plant Sciences, University of Oxford, South Parks Road, Oxford OX1 3RA, U.K.

(*Received on* 16 *January* 1991, *Accepted in revised form on* 10 *September* 1991)

Genetic recombination has important consequences, including the familiar rules of Mendelian genetics. Here we present a new argument for the evolutionary function of recombination based on the hypothesis that meiotic drive systems continually

- Meiotic arrest (Mira 1998)

- Sex-differences in recombination rates (Brandvain & Coop 2012)

Scrambling Eggs: Meiotic Drive and the Evolution of Female Recombination Rates

Yaniv Brandvain[1] and Graham Coop
Center for Population Biology and Department of Evolution and Ecology, University of California, Davis, California 95616

ABSTRACT Theories to explain the prevalence of sex and recombination have long been a central theme of evolutionary biology. Yet despite decades of attention dedicated to the evolution of sex and recombination, the widespread pattern of sex differences in the

Background – Female meiosis

Often requires fertilization for completion

rg/wiki/Oogenesis

female meiosis

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Cell type	*ploidy*	Process	Process completion
Oogonium	**diploid**	**Oocytogenesis** (mitosis)	third trimester (forming oocytes)
primary Oocyte	**diploid**	**Ootidogenesis** (meiosis 1) (Folliculogenesis)	Dictyate in prophase I for approximately 50 years
secondary Oocyte	**haploid**	**Ootidogenesis** (meiosis 2)	Halted in metaphase II until fertilization
Ovum	**haploid**		

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Edit links

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Provides an opportunity for sperm to influence female meiosis

- Imagine a ‘greenbearded’ sperm (`self-promoter’)
  - i.e. Alleles in sperm could facilitate drive in eggs

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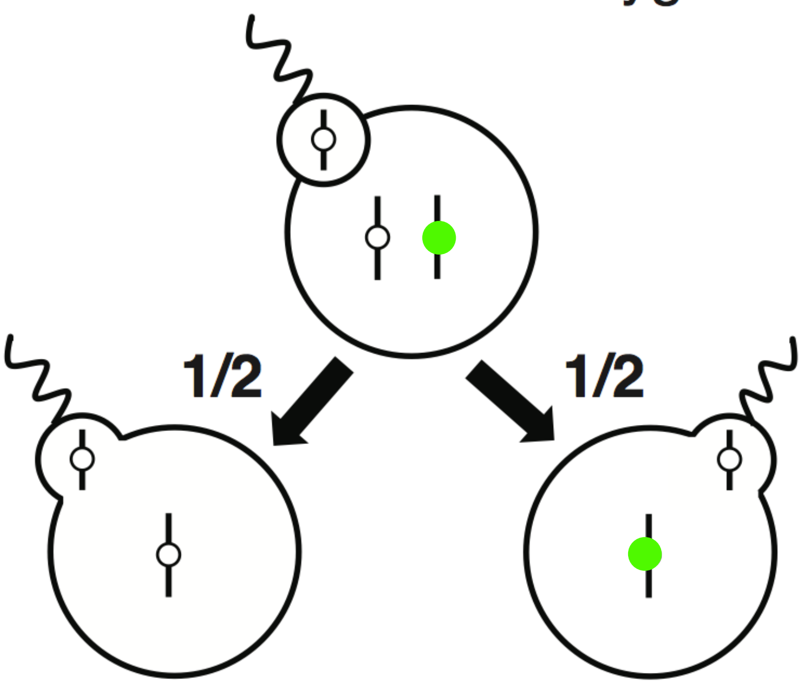
Meiosis is fair when the non-driver fertilizes a heterozygote



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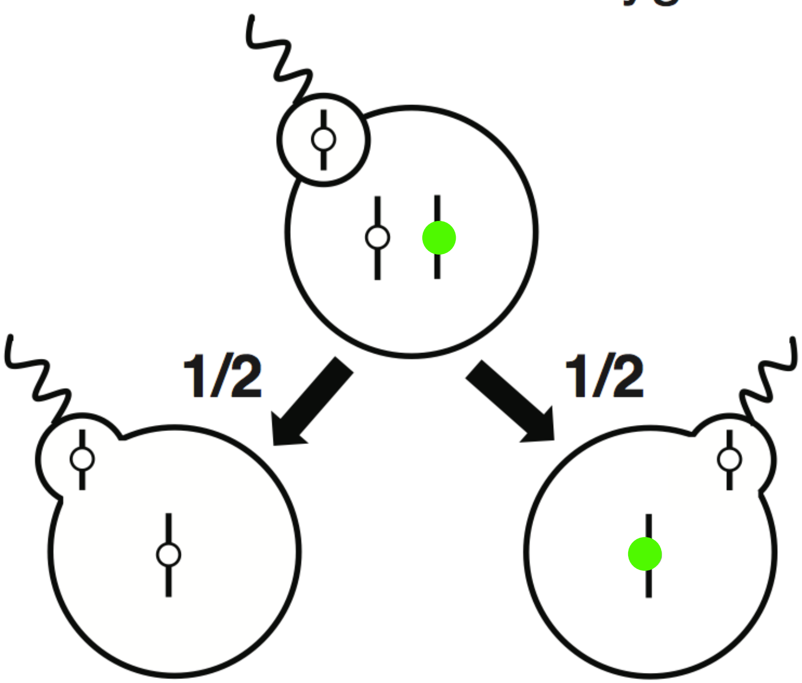
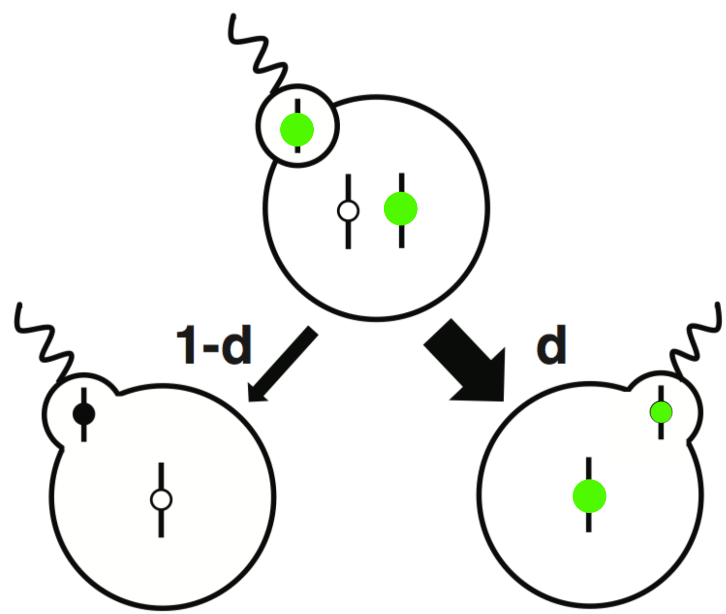


The drive allele is transmitted with probability, d when the ‘self-promoter’ fertilizes a heterozygote



Models

- Population genetic models
- Supplemented analytical approximations with exact recursions
- Specific Models
  - Single-locus
    - Sperm haplotype models
    - Paternal genotype models
  - Two-locus
    - Drive-modifier system [both tightly linked and unlinked]

`Self-promoting' drivers rarely succeed

- A self-promoting driver **often cannot invade or fix.**
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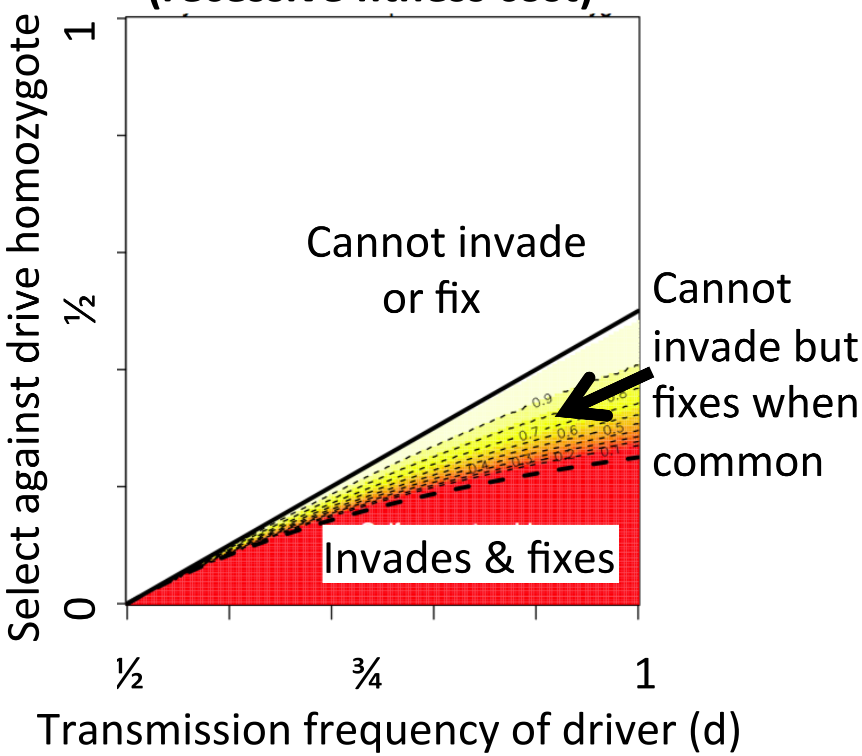
Fate of a `self-promoting' driver (recessive fitness cost)



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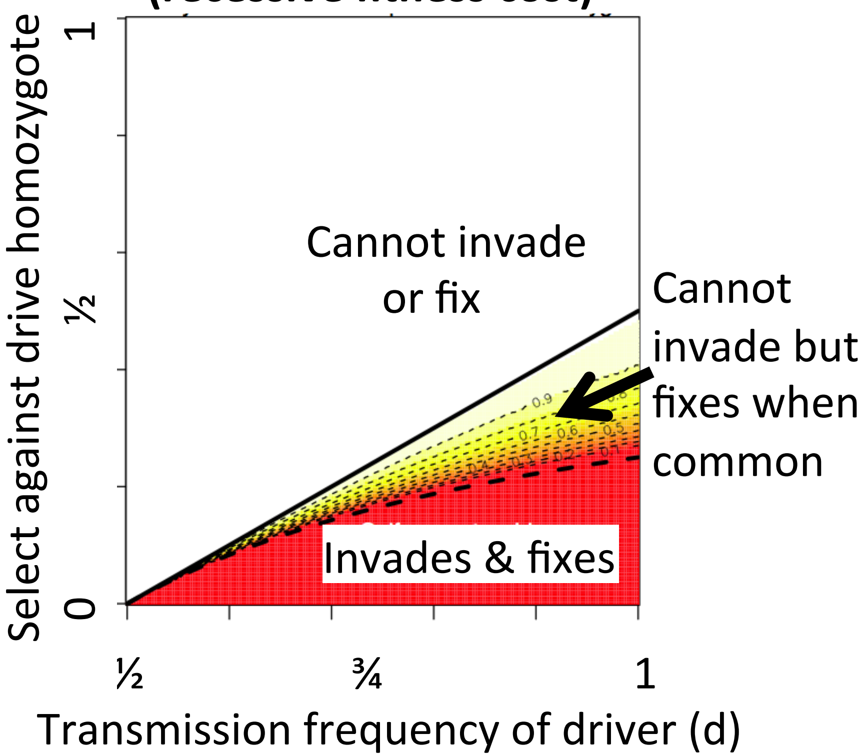
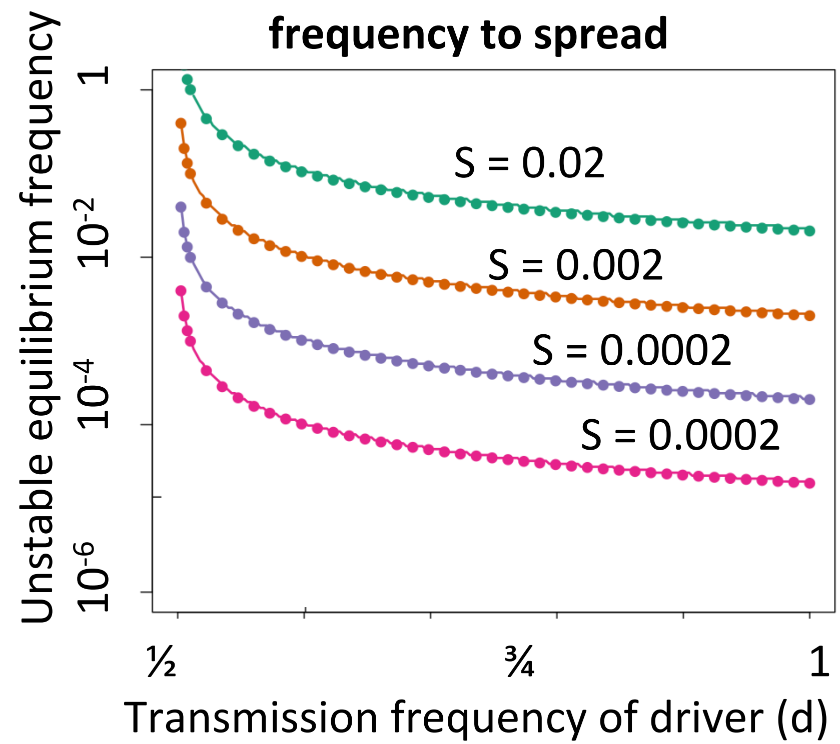


With a cost in heterozygotes, Driver must exceed some threshold frequency to spread

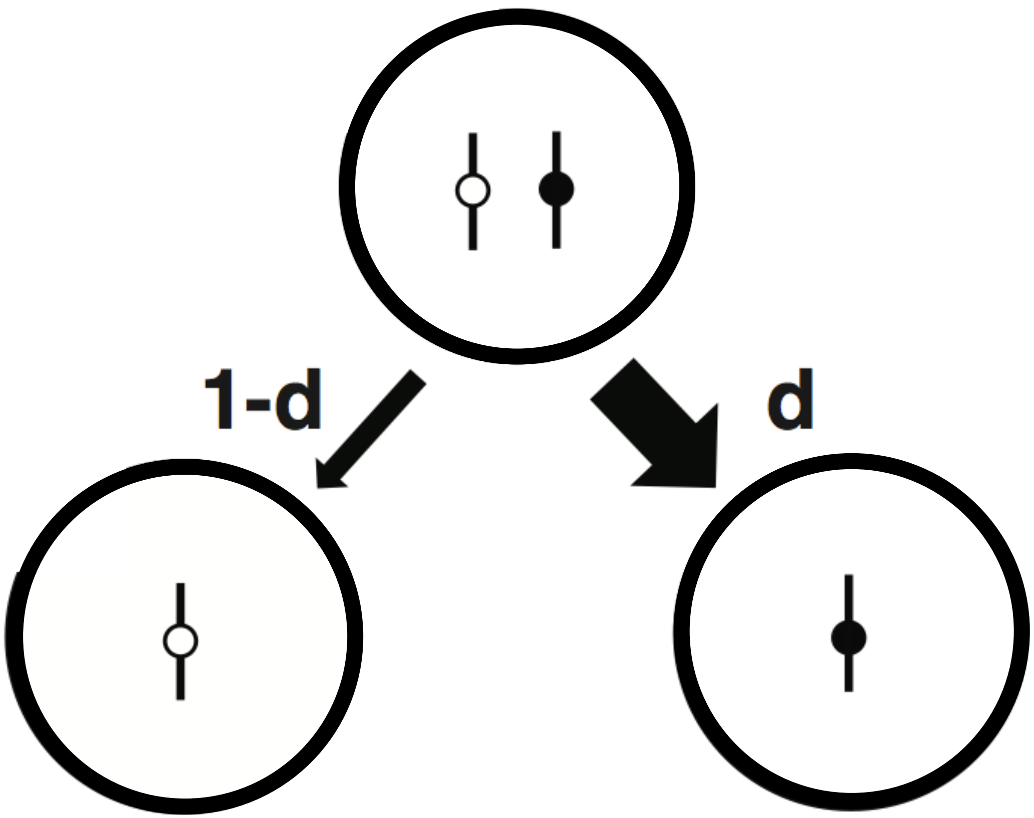


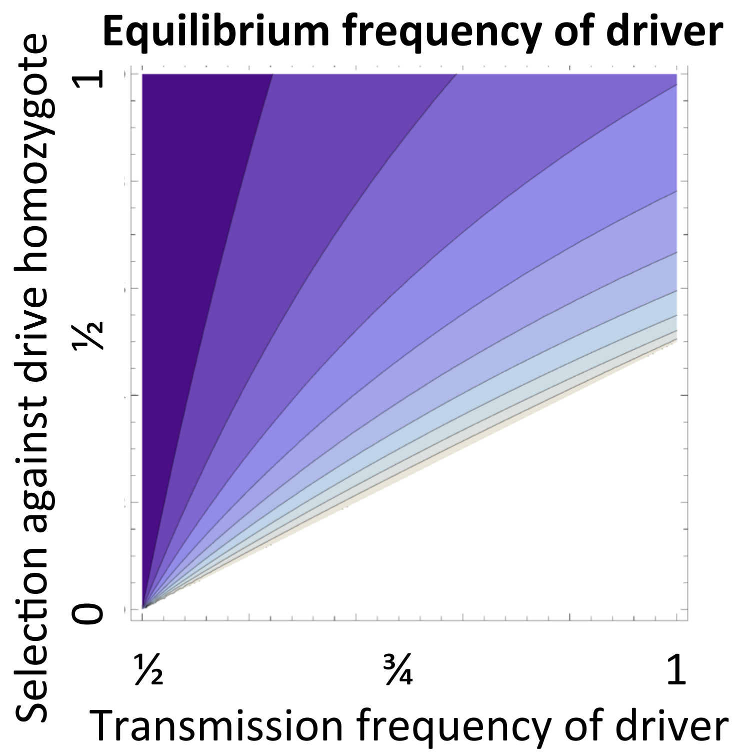
Summary of single locus model

- Self-promoting drivers have a more difficult time invading and fixing than traditional drivers
- Self-promoting drivers cannot be maintained as a stable equilibrium
- Results hold-ish for both sperm-dependent and male-genotype dependent model (not shown, a sliver of parameter space sustains a protected polymorphism)

Drive-modifier two locus model

- Standard driver starts @ drive-selection equilibrium





Drive-modifier two locus model

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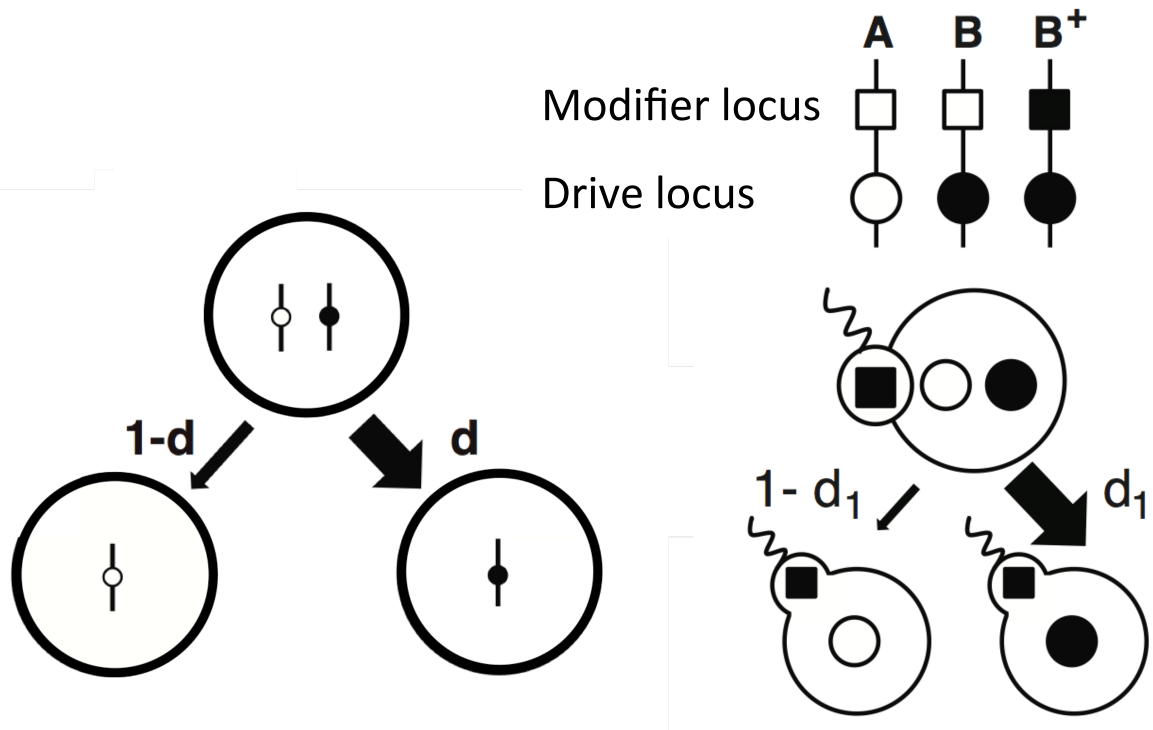

Drive-modifier two locus model

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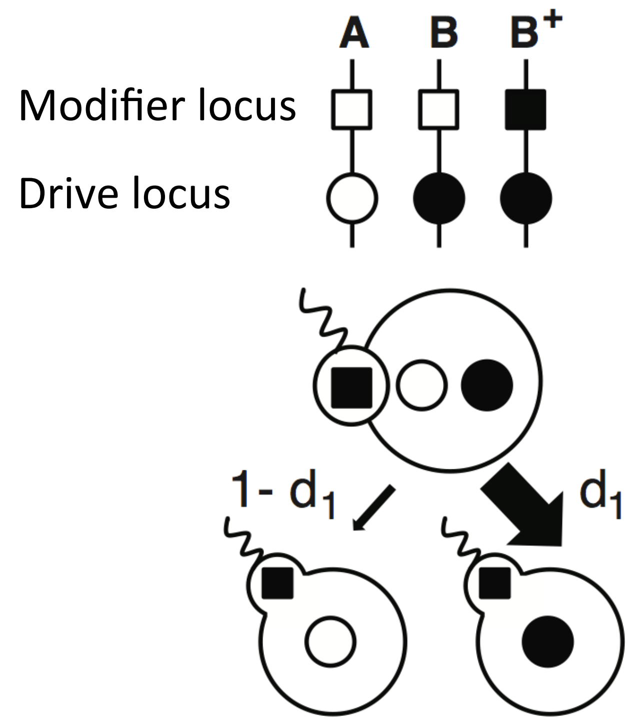
- Alternate linkage relations
  - **Tightly linked, coupling phase**



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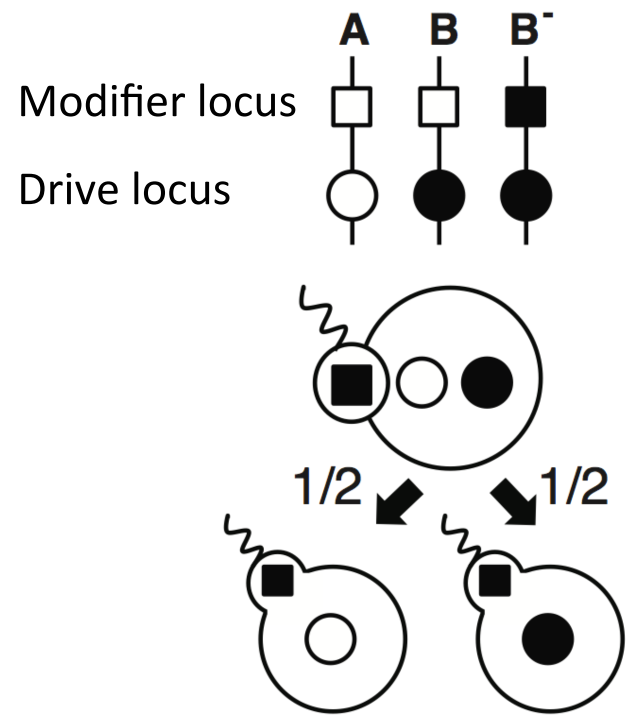

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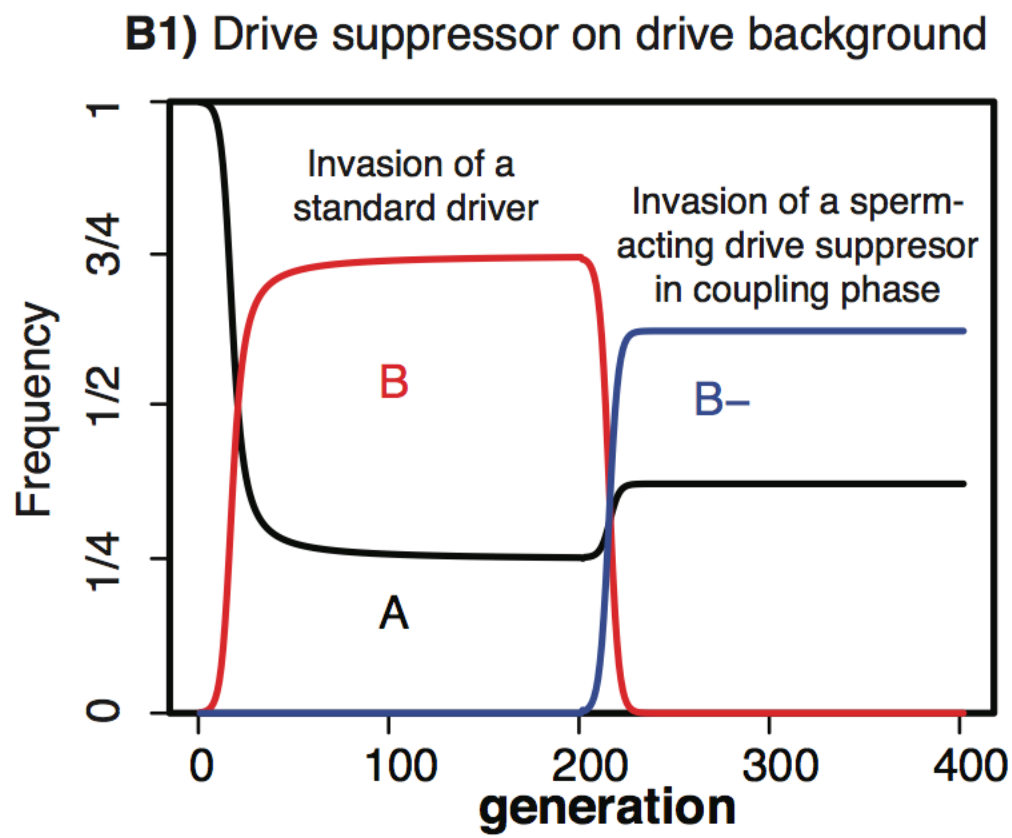
  - Tightly linked, coupling phase
  - Tightly linked, repulsion phase
  - Unlinked
- Allowed modifier to suppress or enhance drive

Results of two locus model

- Under all linkage relations the sperm acting mutation invades and fixes when it prevents drive, and cannot spread when it enhances drive.



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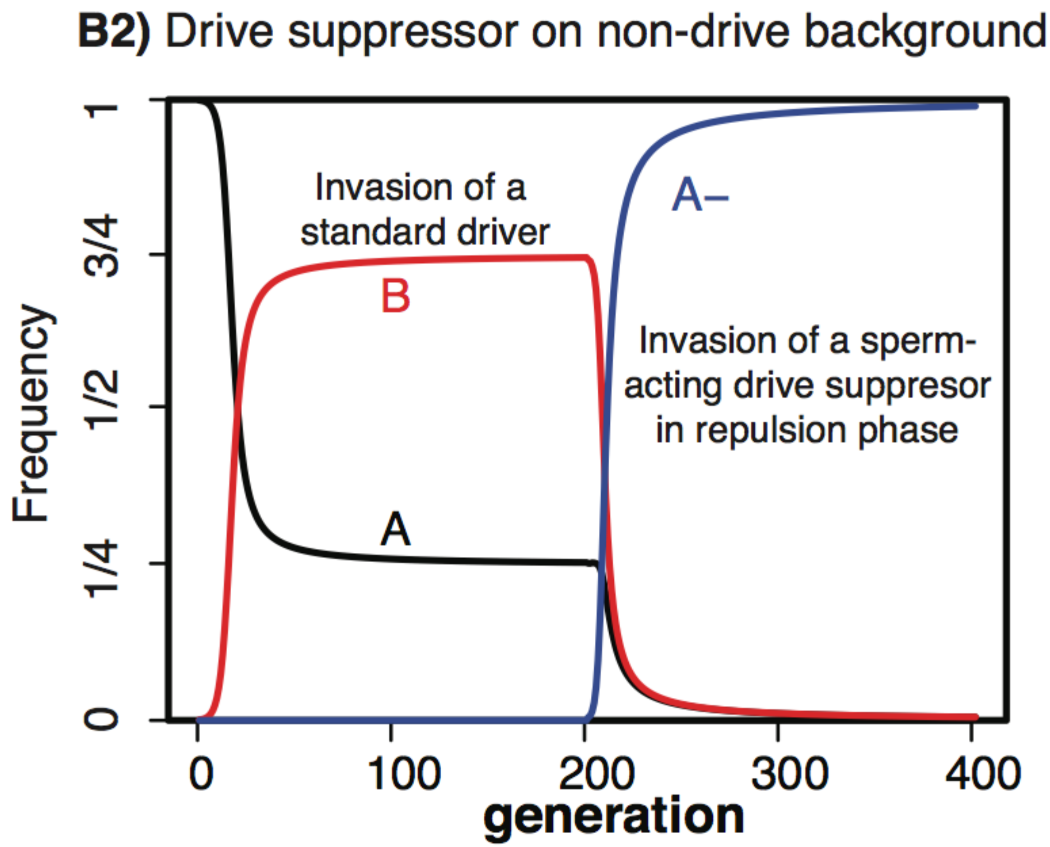


Summary

- To avoid occurring in low fitness homozygotes sperm evolve to prevent female drive, regardless of linkage relations

Previous Evidence/ Speculation

- At the In locus (mice) female drive alleles are less effective when fertilized by driving sperm
- Interpreted as a mechanism to make healthy offspring

Genet. Res., Camb. (1993), **61**, *pp.* 97–100

Effect of sperm genotype on chromatid segregation in female mice heterozygous for aberrant chromosome 1

SERGEI I. AGULNIK, IGOR D. SABANTSEV AND ANATOLY O. RUVINSKY*
Institute of Cytology and Genetics, Siberian Department of Academy of Sciences of Russia, Novosibirsk 630090 Russia
(*Received 30 January 1992 and in revised form 8 July 1992*)

NEWS AND VIEWS
EVOLUTIONARY GENETICS

Siberian mice upset Mendel

Andrew Pomiankowski and Laurence D. Hurst

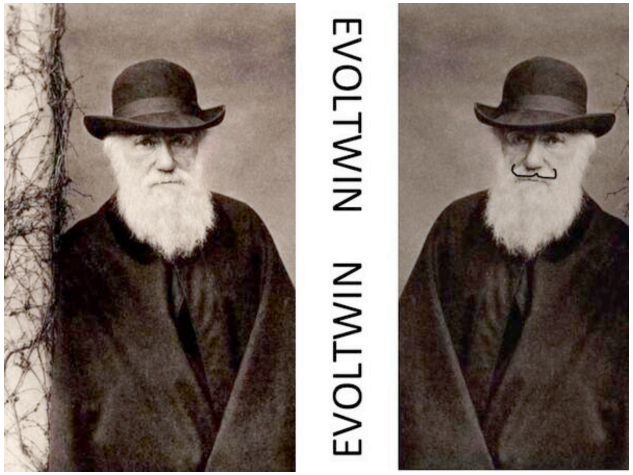
FACED with malaria, those who are heterozygous for the sickle-cell gene are immune to attack, and are at an advantage

Despite the difference in mode of distortion, *In* has at least three similarities to *SD* and the *t*-complex. First, all of the

- Not relevant to plant because of the alternation of generations ☹

Acknowledgements

- Graham Coop and the Coop lab
- University of Minnesota
- NSF



More questions?
email – ybradvain@gmail.com

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Sperm should evolve to make female meiosis fair.

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bioRxiv posted online May 21, 2014
Access the most recent version at doi: http://dx.doi.org/10.1101/005363