# 1. Heterochiasmy driven by fundamental aspects of gametogenesis

## New Definition of Heterochiasmy // (expanding the features of Heterochiasmy)

--descriptions of heterochiasmy – shouldn’t just focus on the differences in genome wide rates --- we show here that the direction of heterochiasmy can evolve rapidly

((underscores the take away that – the recombination pathway – can evolve distinct patterns (across the gametogenesis types)

(general CO position / typical landscape) heterochiasmy (male biased / female biased) while female biased is (the canonical pattern) – many male biased and equal examples.

1. (-we proposed that (as noted in sardell) --- the typical landscape is the most conserved feature of heterochiasmy, we see it across all strains regardless of the direction of heterochiasmy (this is also seen in cattle and same rate strains) )

more specific to our data / mice / mammals ... features / traits / patterns we consistently see across sexes in this dataset..

**2. SC compaction** differences also seem to be conserved features (for mammals –(birds are exceptions). Longer SC length (less dense CO placement / number)

**3. weaker interference** in females (normalized) The physical units of interference in SC seems consistent between sexes. (are the sc compaction and weaker interference connected??) (stronger interference in female cattle)

**4. more within mouse variance**! (seen in humans Lynn / Koehler et al – other species?)

What models fit with these features evolving (with in a heterochiasmy system?)

What models would be able to make predictions for all four of these features?

(holocentric, how spindle is attached to kinetochore,

To find the origin of conserved features of typical landscape (in heterochasimy ) – look to conserved features of gametogenesis

/

(many anisogamouse have identical gametes (only mating types which are defined genetically – at limited genetic loci) – development of gametes is virtually identical

## Cell Bio background review

However in dioecious species – the gametes diverge – two prominent features that distinguish the (development // cellular aspects of male and female gametes are

1. asymetrical division (final gamete size is closely connected to this (direction of the causation not clear)

2. spindle structure (refs) having or not having a centromsome (which concentrates MT ends at a point)

(there are strange exceptions (that one paper) also (these two features are also connected)

asymmetrical division

1 final bigg haploid cell instead of 4 equal (small haploid cells)

orientation of spindle, in (egg) vs out cortical (polar body)

requirement of true meiotic drive (Akira / Lampson)

spindle str

(uniparental inheritance of spindle – means that Metaphase I in eggs is diffuse – and further separation paused until the sperm brings in more centrosome material? (is this right?)

differences between centrosome and acentrosome spindle --centrosome nucleate MT (fibers, concentrates them)

CONSEQUENECES – on the SAC

The uniparental inheritance of centrosome – is a way to 'combate / suppress' parthenogenesis ---uniparental inheritance of centromere evolved, because multiple centrosomes can really mess up the division. ( the barrier to parthenogenesis is not having a centromsome)

these influence – lead back to SAC (major check point) // quality control for segregation (one of the main selective forces on CO number and placement (at the chromosome level

Is SAC more affected by cell volume (diffusion of signal) or by spindle? (

Heterochiasmy take away pattern

* Distinct recombination landscapes between sexes – suggest distinct evolutionary trajectories (relaxed vs directional)

Logic of RR not needing to be different / rec landscape not needing to be different…

## Theory Comparison Framework (mental experiments)

-indirect vs direct (define these differences)

these results – is unique one (of of the best looks at heterochiasmy patterns in short evolutionary scales – and levels (genome wide rate and bivalent landscape) the genome wide rate is not a conserved feature of heterochiasmy

(4 traits distinguish recombination in male and females):

INDIRECT (most all are base on modifier models – so they examine just the total genome wide rate)

-SACE:

typical landscape : yes

SC compaction

weaker interference:

within mouse variation (checkpoint control?)

gamete selection: (reduction principle)

typical landscape:

SC compaction:

interference:

within mouse variance:

Indirect review:

1.-Reduction hypothesis (equilibrium) / haploid selection

2. Two locus drive model (brandvain and Coop, females evolve to disrupt drive systems (Akira et al?)

3. sexual antagonism –cis epistatsis, (SACE)

DIRECT

spindle / segregation / selection at metaphase

bad / relaxed SAC in females / strong SAC in males

typical landscape (YES)

SC compaction (?)

interference (YES – the Female spindle doesn't care about number and placement)

within mouse variance (Yes relaxed selection)

**consequence of the sex differences**

(Veller rbar)

more shuffling in females

(expanding on the metaphase sex differences)...

SACE and metaphase / spindle based theories are best candidates – we can't distinguish – test between the two – prove one over the other

**caveats**

-no data on spermatocyte spindle

Caveats: (-why some ideas aren’t universal),

-age related cohesion lose

Age effects on CO number (in oocyte)

Why would more crossovers increases stability ---// prevent age related cohesin loss when the process of crossover formation / ligation / resolution involves reducing cohesion?

-Is it – something to do with PSS (precocious sister separation)

-Strange things (that might have impacts on genetic diversity)

-drive for rec for egg vs polar body

**2.B strong interference is the best predictor of gwRR evolution**

-background / logic of the negative correlation with COI and gwRR

Empirical measures from Payseur Otto

-Bauer et al (half sib lines ) pooled data(chromosomes/populations) – find significant negative correlation of gwRR and COI strength (as expected with the basic logic ) (but when data subdivided this relationship not sig (low power)

-Caveats – only type I COs – the measures of interference from ALL COs might be different –but it’s outside the scope of this study to (figure this out)

# Recombination rate evolution (males)

- (what would have driven the rapid 30% drive gwRR (enrichment of 2CO bivalents)…?

-are their gene candidates (signatures of selection (CAST / WSB/DOM vs PWD + MSM ?)

-Strain evolution – traits that change in both females and males (-- is it polymorphism (standing variation) and 3 independent instances of evolution in gwRR

OR

shared standing variation // incomplete lineage sorting, // the same history

- (distinct evolutionary trajectories – males have more directional pattern;

Within male

- evolvability, less effective in females due to the increased (within animal variance

- **CONSTRAINTS** on gwRR

House mouse – (close to the minimum) –

Most species close to minm (1-3 CO per cell )

Consequences

- linked sites (indirect)

- change in the cohesin landscape

## A. DSBs!! (plus moderate support for SC length differences

**2.A** the DSB differences have proportional CO differences – this suggests that the changes (evolution) happened before the DMC1 foci are laid down.

This evidence shifts the support away from evolution at the point of CO:NCO decision to earlier, when the str of meiotic chromosomes is build (the programming of the // the initial restructuring of the meiotic chromosomes )

## B. INTERFERENCE

<gamma metric – the gamma metric also incorporates the variance of interfocal differences – we observe that – outliers IFD weigh / effect the gamma estimate (to a large degree)>

(strong interference (gamma) – not just larger IFDs, but also low variance across IFDs), --

- Evolution of interference (how expectations for evolution of gwRR translate)

Otto Payseur – present empirical measures of interference and gwRR for a bunch of species and find a negative correlation (this is also a logical prediction)

**(review in Otto Payseur – of Goldstein et al simulations,**

when the (total recombination rate or number of COs is held constant – evolution of crossover interference and recombination rate in the same direction (positive correlation)

(our results / findings of the 2CO IFDs – (artificially?) hold the number of crossovers constant

(tie into the functional (direct) selection predictions from the HetC section) ---

-caveats on the chromosome size and chromosome specific effects -- (independent of chromosome identity) (haenel et al 2018)

-can any of the models from above be re-used here?

**(holocentric chromosomes have strongest – interference) – limit kinetochore point of attachment)**

# Future steps

Don’t use sex-averages / acknowledge that sex average data can obscure distinct patterns (Haenel et al biggest offenders)

-focus on interference