Roadmap

- Inversions
- Translocations
- Changes in chromosome number
- Meiotic drive

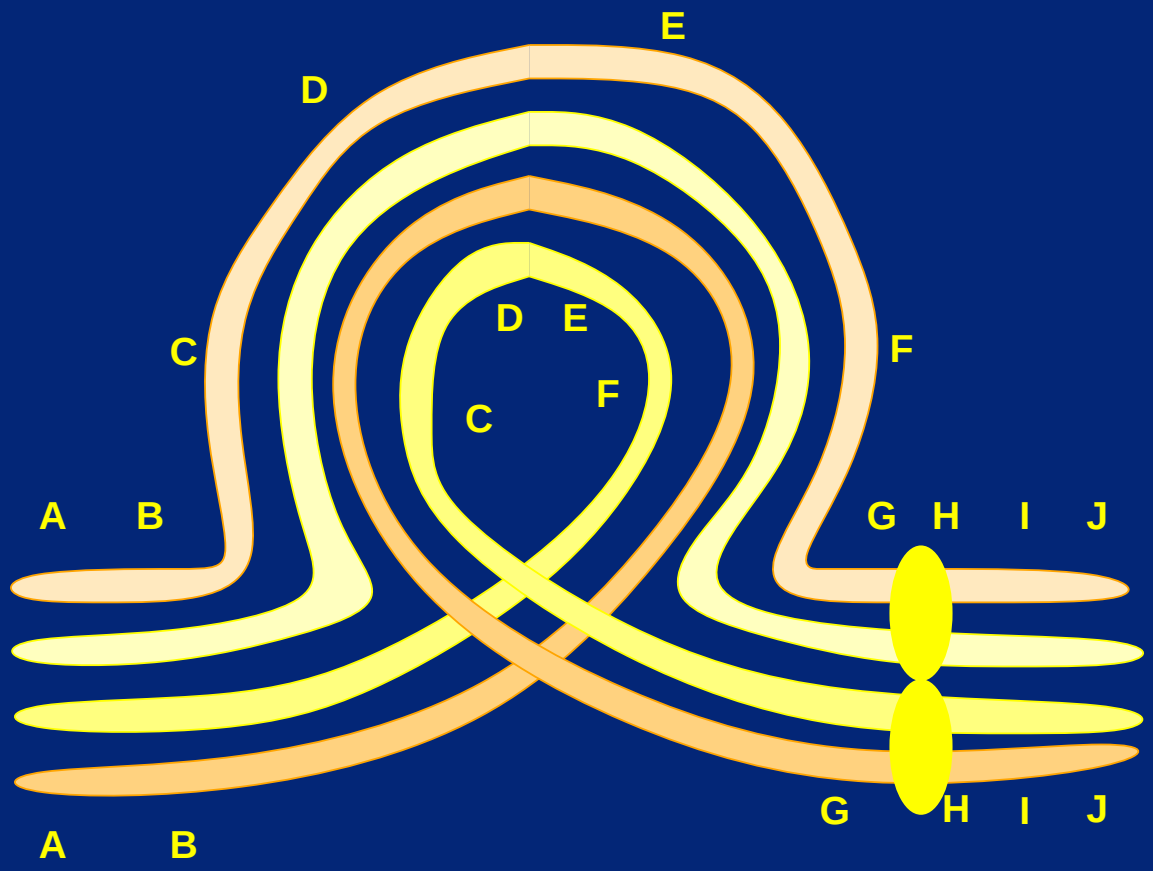
Inversions

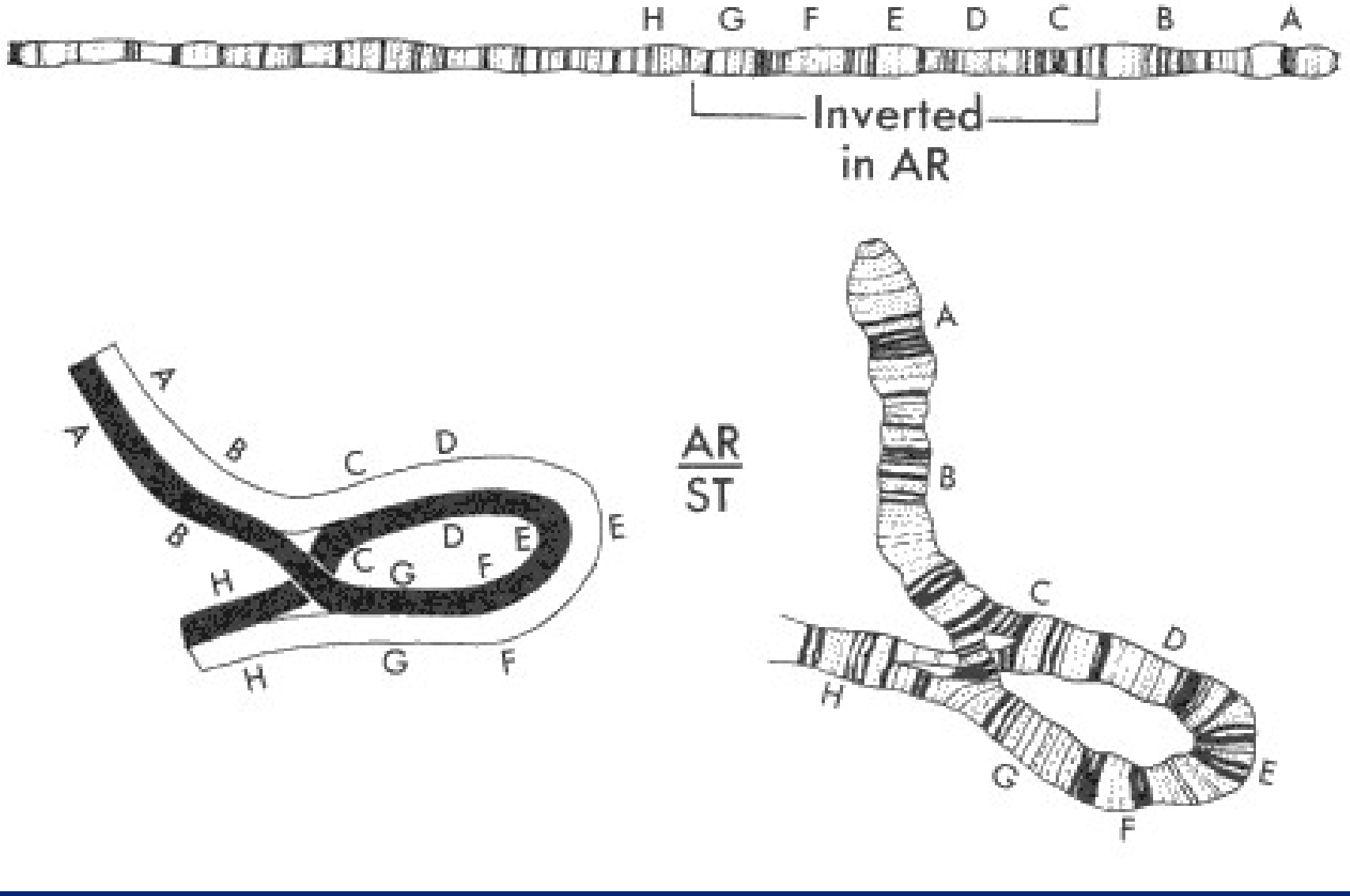
Paracentric inversion (does not include centromere)

Pericentric inversion (includes centromere)

I prefer not to use these words as they sound too similar to me!

Pairing in a paracentric inversion heterozygote




H G F E D C B A
Inverted
in AR
A
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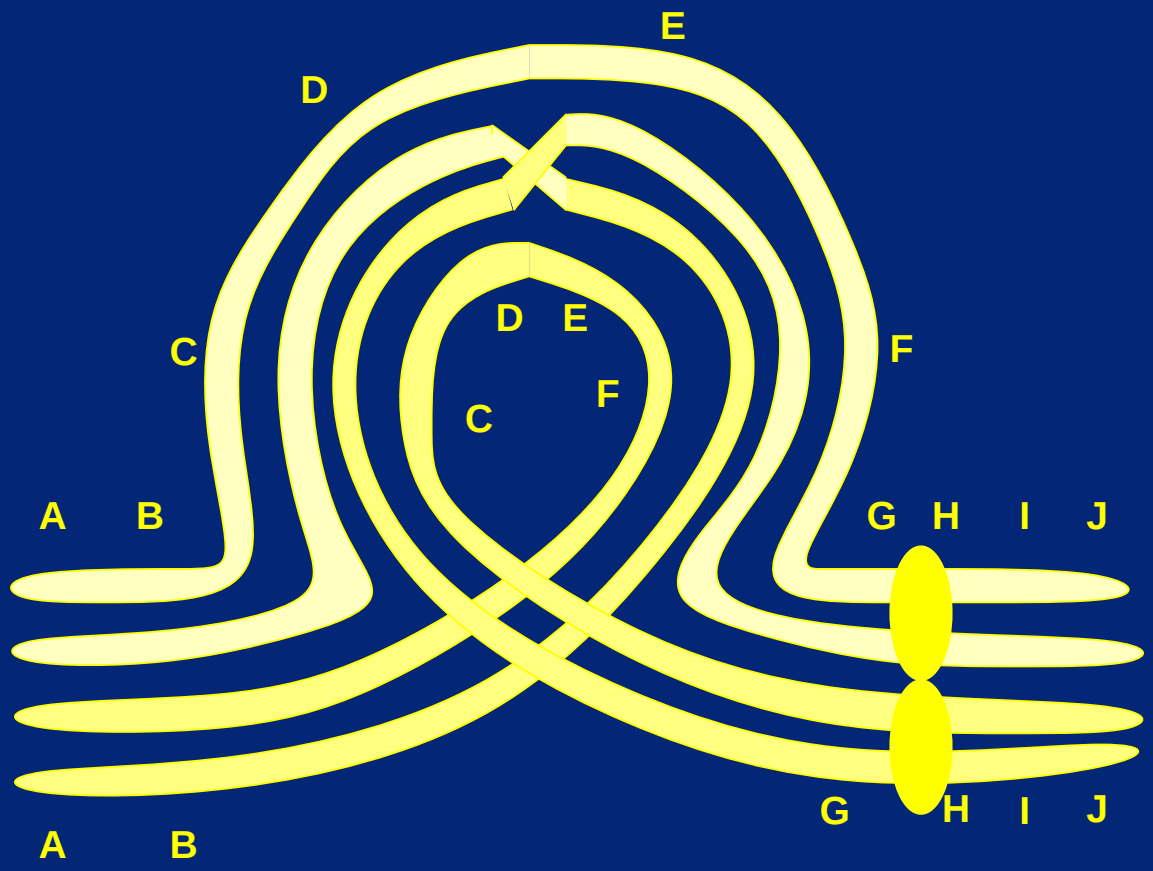
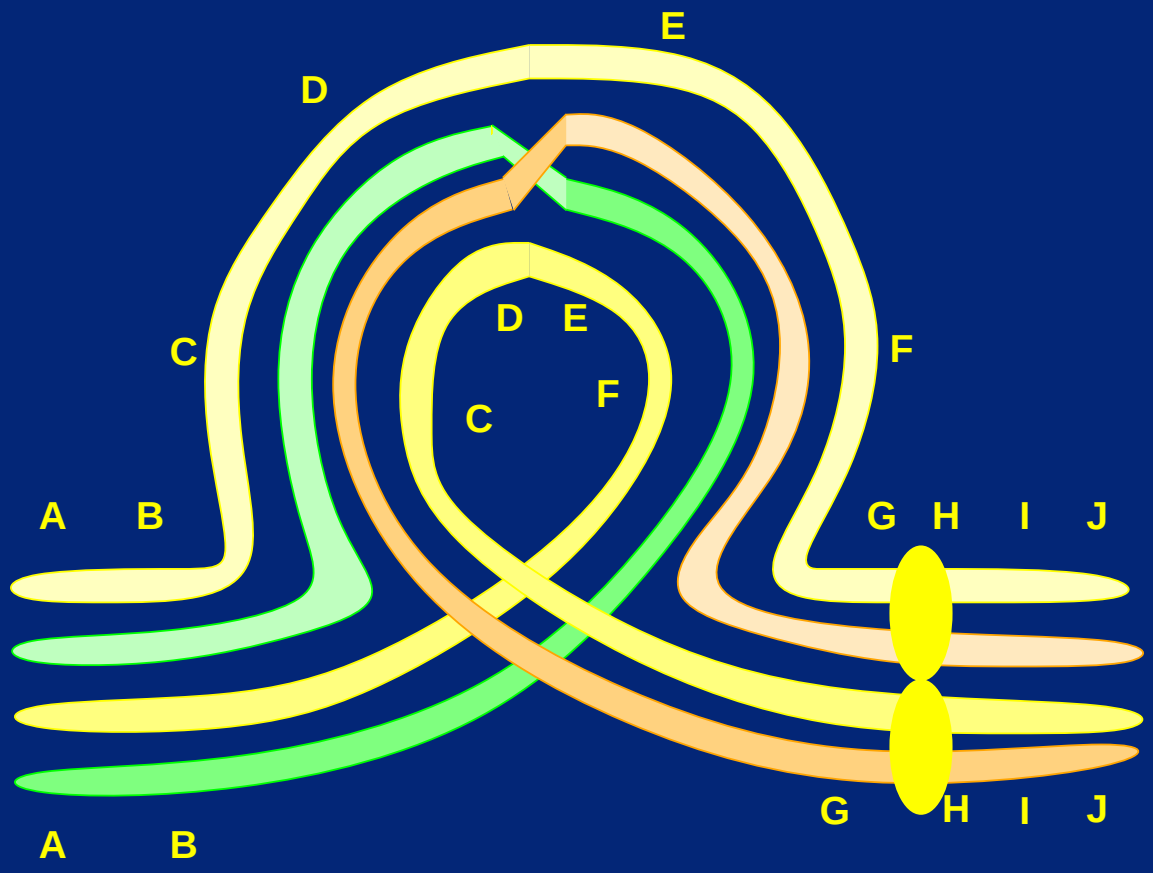
Crossing−over in a paracentric inversion heterozygote



Crossing−over in a paracentric inversion heterozygote



Paracentric inversion heterozygote – Outcome

We produce one of each:

Normal chromosome

`A-B-C-D-E-F-G-CEN-H-I-J`

Inverted chromosome

`A-B-F-E-D-C-G-CEN-H-I-J`

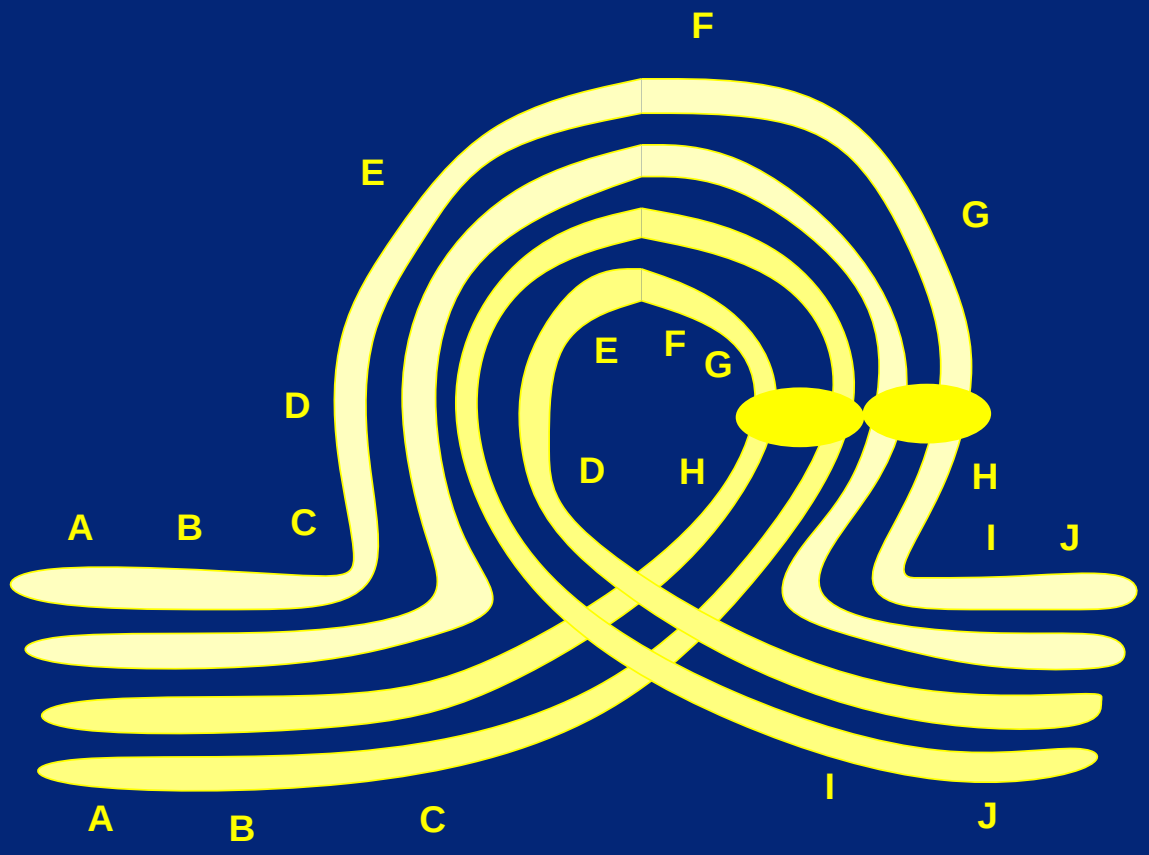
No centromere

`A-B-C-D-E-F-G-B-A`

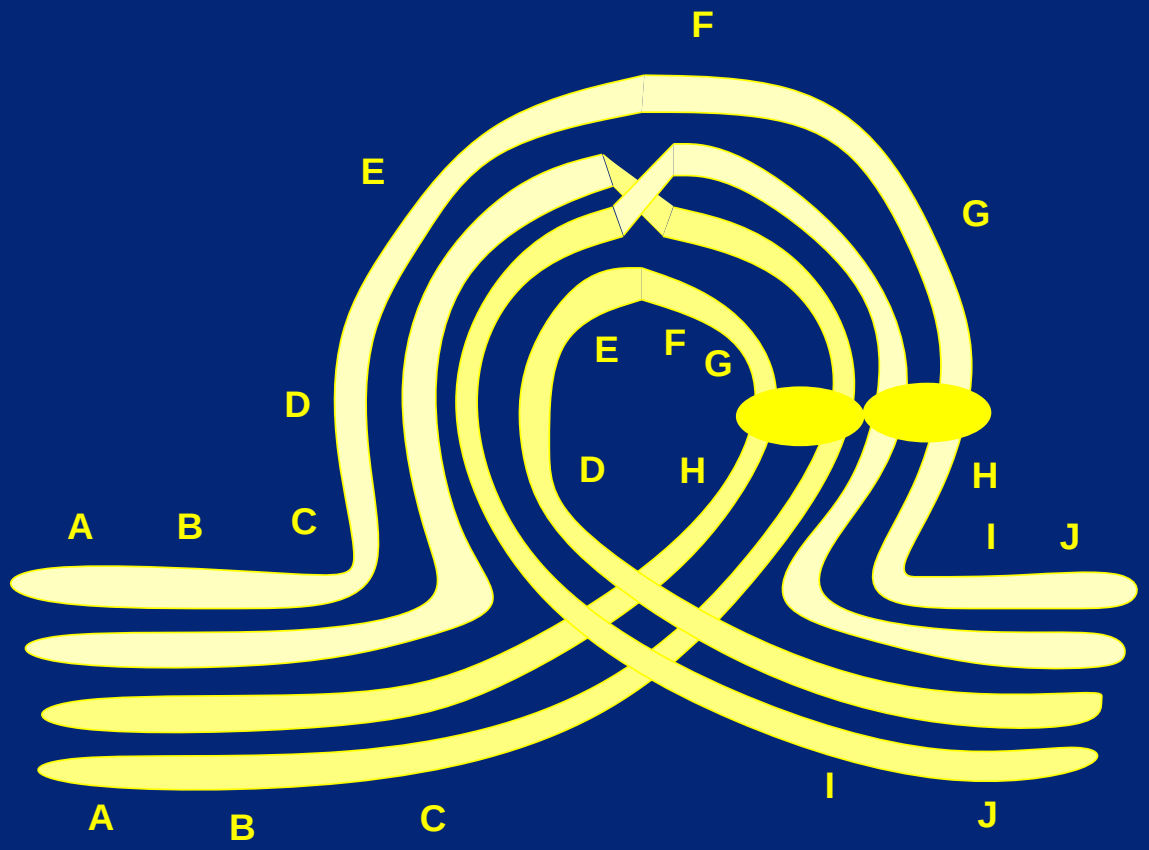
Two centromeres (breaks randomly)

`J-I-H-CEN-G-C-D-E-F-G-CEN-H-I-J`

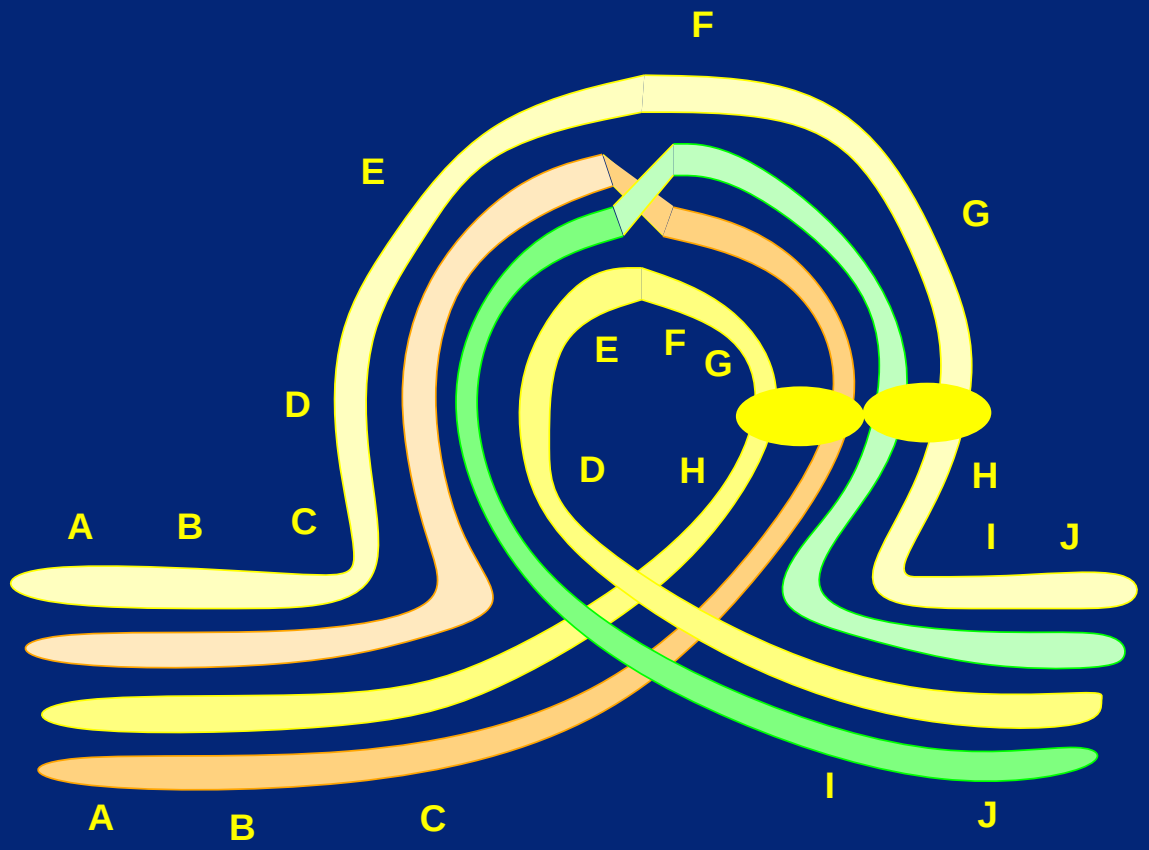
Pairing in a pericentric inversion heterozygote



Crossing−over in a pericentric inversion heterozygote



Crossing−over in a pericentric inversion heterozygote



Pericentric inversion heterozygote – Outcome

We produce one of each:

Normal chromosome

`A-B-C-D-E-F-G-CEN-H-I-J`

Inverted chromosome

`A-B-C-H-CEN-G-F-E-D-I-J`

Duplicate ABC, delete IJ

`A-B-C-D-E-F-G-CEN-H-C-B-A`

Duplicate IJ, delete ABC

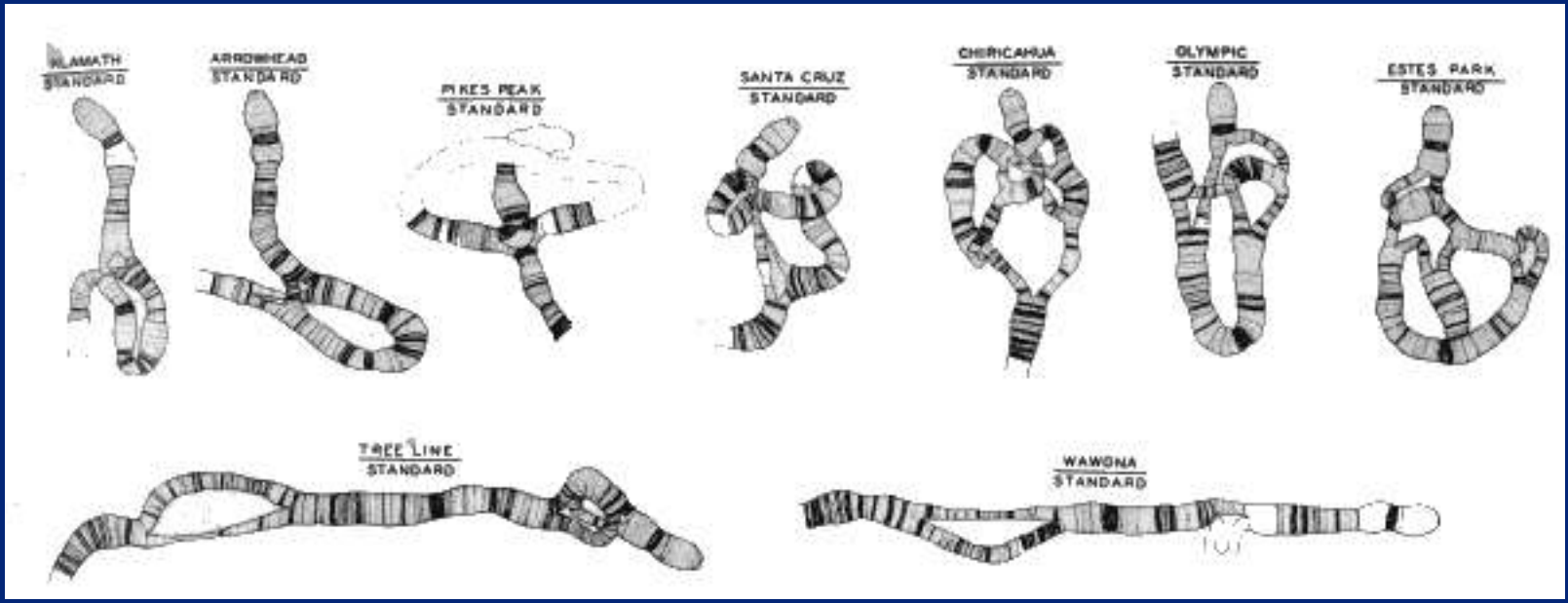
`J-I-D-E-F-G-CEN-H-I-J`

Inversion summary

- Paracentric (doesn't include centromere)
  - Recombination produces two-centromere and no-centromere chromosomes
  - Recombinant gametes almost always die
- Pericentric (includes centromere)
  - Recombination produces duplications and deletions
  - Recombinant gametes might be viable if affected area is small
- If there is only one recombination, two of the four chromatids will be okay (but non-recombinant)

Evolutionary consequences of inversion

- Inversions "suppress recombination" – really they kill recombinants
  - Reduced fertility – bad
  - Preserve favorable groupings of alleles – possibly good
- In most species, fixing an inversion requires drift or strong positive selection
- Some species have genetic systems more permissive of inversions

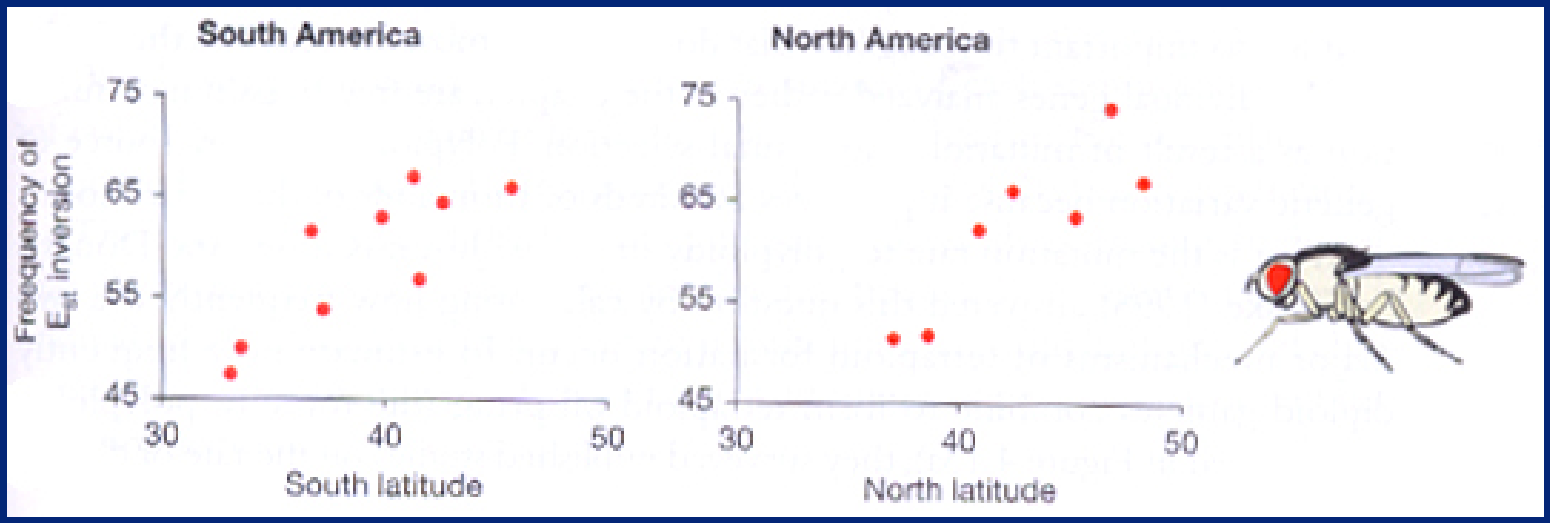


(c) Steven M. Carr

Multiple inversions have happened between different lineages of *Drosophila*

Drosophila inversion clines

- *Drosophila subobscura* shows many inversions in the south relative to the north
- This cline was recreated in Chile and the West Coast of the USA after introduction of flies from Spain.



Drosophila inversion clines

- Inversions are unusually common in Drosophila – why?
  - No recombination in males
  - Female oogenesis preferentially uses a cell with no broken chromosomes
  - Populations often established by a single female – strong genetic drift

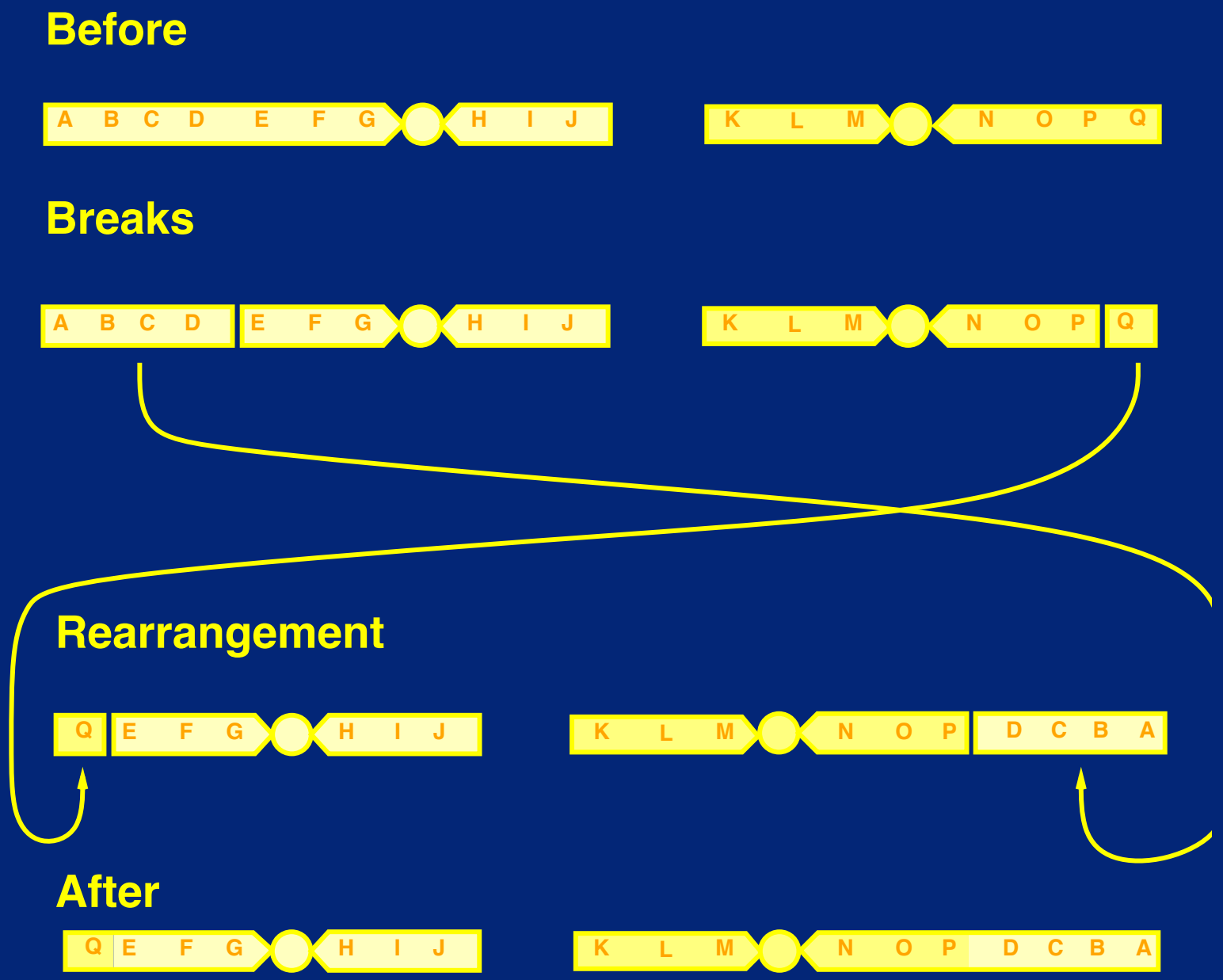
Practice problem

What, if any, problems arise for:

- A male Drosophila inversion heterozygote?
- A female Drosophila inversion heterozygote?
- A human inversion heterozogyote?
- A human inversion $homozogyote$?

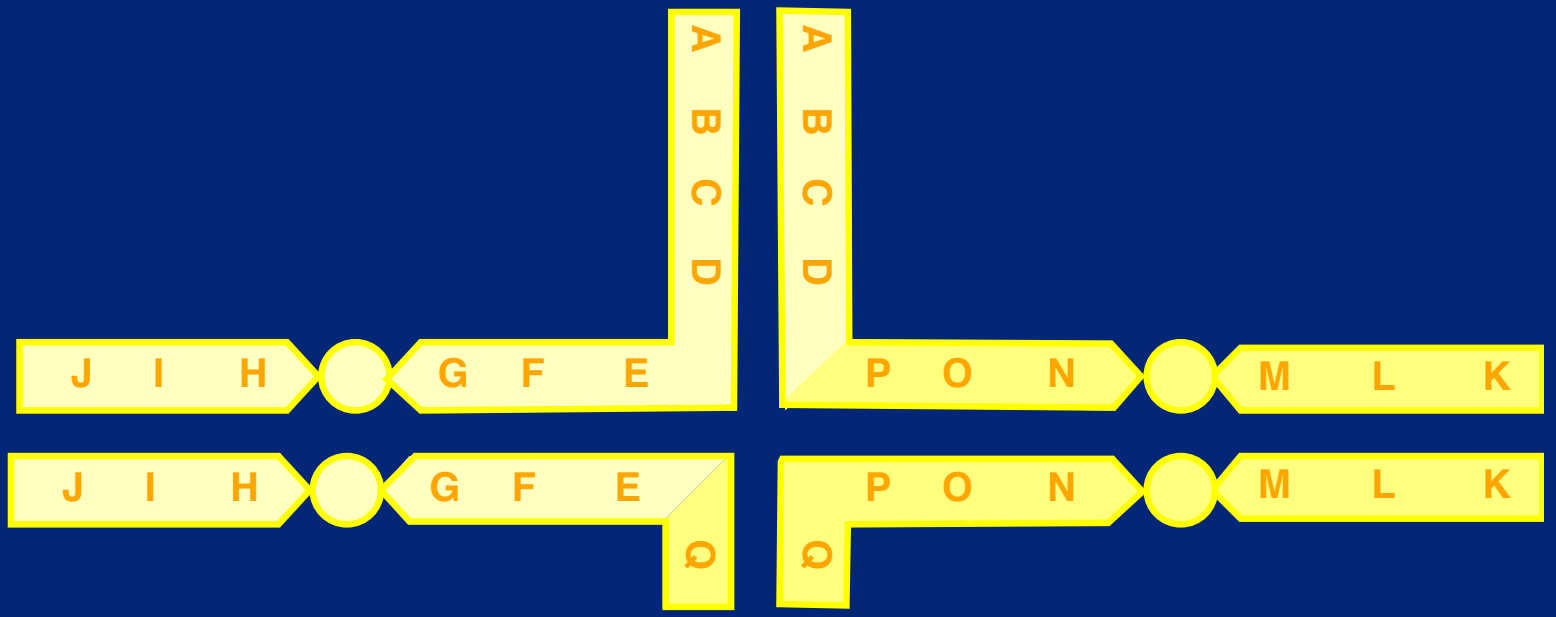
Assume no genes were damaged by creation of the inversion

A translocation



A translocation heterozygote

at first division of meiosis metaphase



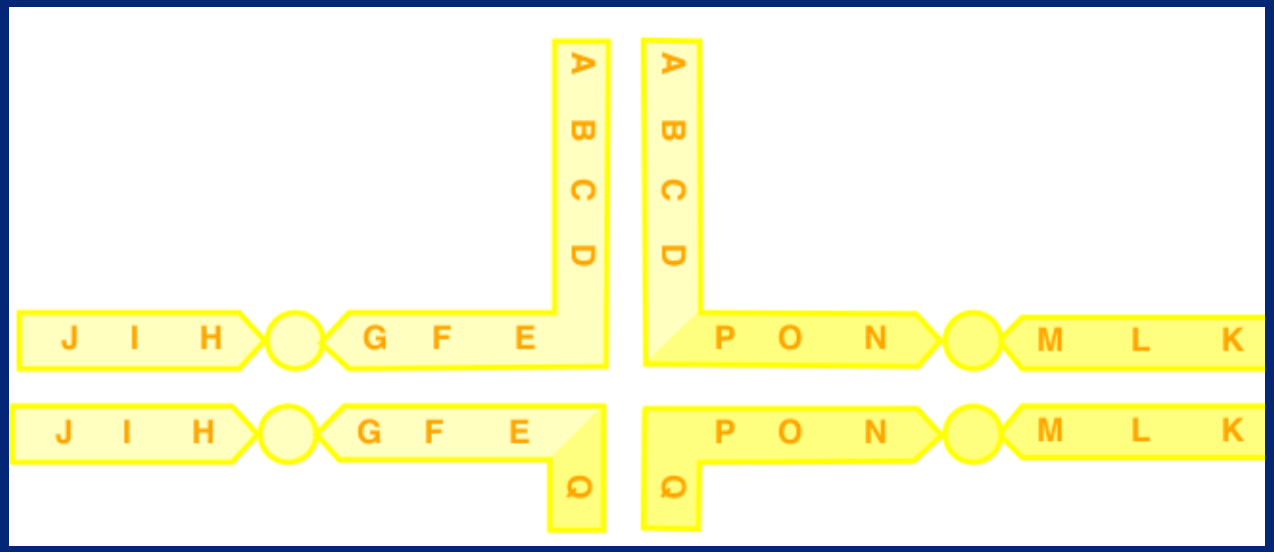
A pair of translocated chromosomes
pairs with a pair of untranslocated chromosomes

Translocation

- Translocation arises from:
  - Breakage and repair
  - Illegitimate recombination between different chromosomes
- Translocation is usually reciprocal because every chromosome end must have a telomere
- *Even without recombination,* translocation heterozygotes mis-segregate their chromosomes in meiosis
- Translocations almost always underdominant
- Only drift or strong selection can allow one to spread

Why is translocation a problem?

- The strange pairing is fine in itself
- Recombination is fine
- Separation of the chromosomes in meiosis can have two outcomes:
  - Two translocated chromosomes go to one daughter and two normal to the other – fine
  - Each daughter gets one translocated and one not – not good
  - Approximately 50/50 chance



Possibility 1	Possibility 2
A-B-C-D-E-F-G-CEN-H-I-J	A-B-C-D-E-F-G-CEN-H-I-J
K-L-M-CEN-N-O-P-Q	Q-E-F-G-CEN-H-I-J
A-B-C-D-P-O-N-CEN-M-L-K	A-B-C-D-P-O-N-CEN-M-L-K
Q-E-F-G-CEN-H-I-J	K-L-M-CEN-N-O-P-Q

Practice problem

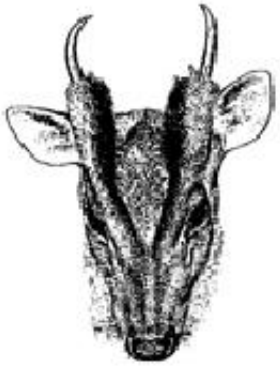
What, if any, problems arise for:

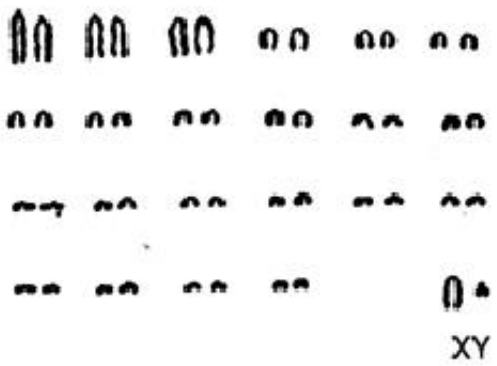
- A male Drosophila translocation heterozygote?
- A female Drosophila translocation heterozygote?
- A human translocation heterozogyote?
- A human translocation $homozogyote$?

Chromosome fission and fusion

Chromosome fusion probably explains why domestic horses have 64 chromosomes. . .

. . . and the closest living wild species and probable ancestor of domestic horses, Przewalski's horse, has 66 chromosomes.





Chinese muntjac deer
Muntiacus reevesi

Indian muntjac deer
Muntiacus muntjak

Translocation, chromosome fusion, and/or fission explain why these two very similar species of hoofed mammal, the Chinese and Indian muntjac deer, have such different karyotypes.

Chromosome fission and fusion

- Fissions and fusions may begin as translocations where the reciprocal product is lost
- Generally underdominant
- This contributes to the sterility of mules (hybrids between two closely related species which differ in chromosome number)
- Closely related species often differ in chromosome number
- This may represent an early step in reproductive isolation

Meiotic drive

- In mice, sperm from Tt heterozygous male carries t 85% of the time
- The t chromosome damages its T pairing partner in meiosis
- However, tt is lethal so this cannot fix
  - Lethality is actually due to tightly linked recessive lethals
  - Inversions suppress recombination in this area so that t does not escape from its lethals
- Multiple different t haplotypes, all with lethals, found in the wild

Why are there lethals linked to t?

- Could be Muller's Rachet:
  - Inversions suppress recombination
  - Without recombination, the t region evolves asexually
  - Muller's Rachet predicts it will accumulate bad mutations
- My theory:
  - Without lethals t would fix almost instantly
  - Without inversions, it would shed its lethals and then fix
  - t without lethals and inversions fixes so quickly we never see it happening

Y-linked meiotic drive

- The mosquito *Aedes aegypti* has a driver on the Y, called Distorter
- In caged populations Distorter can destroy a population
- Attempts to use this for pest control failed:
  - Wild populations have loci that can suppress Distorter
  - These are rapidly selected when Distorter arrives
  - Wild populations end up with Distorter as a stable polymorphism
  - I bet they've seen it before....
- No human examples are known

A tricky X

Several South American mouse species have a variant X chromosome called X^*
X^*Y is a fertile *female*

Akodon azarae

Variant X in genus $Akodon$

If an X^*Y female mates with an XY male:

	X^*	Y
X	X^*X female	XY male
Y	X^*Y female	YY inviable

This does not cause infertility, because female mice always start more embryos than necessary, and the YY will abort. But it distorts the sex ratio significantly.

Why does this persist?

- Data:
  - The trait is old (X^* chromosomes are quite diverse)
  - It arose independently several times
  - X^*Y females start breeding at a younger age and continue breeding for a longer time than XX females.
  - X^* has a meiotic drive advantage

- Mathematical modeling of these numbers predicts the observed sex ratio fairly well

Friday

- Mobile genetic elements
- Meiotic drive
- “Selfish DNA”

One-minute responses

- Please:
  - Tear off a slip of paper
  - Give me one comment or question on something that worked, didn't work, needs elaboration, etc.