Roadmap

- Final exam schedule question
- From Wednesday:
  - Book recommendation for speciation
  - Polytene chromosomes
  - Muntjacs
- Multi-gene families and concerted evolution
- Transposable elements

Final exam

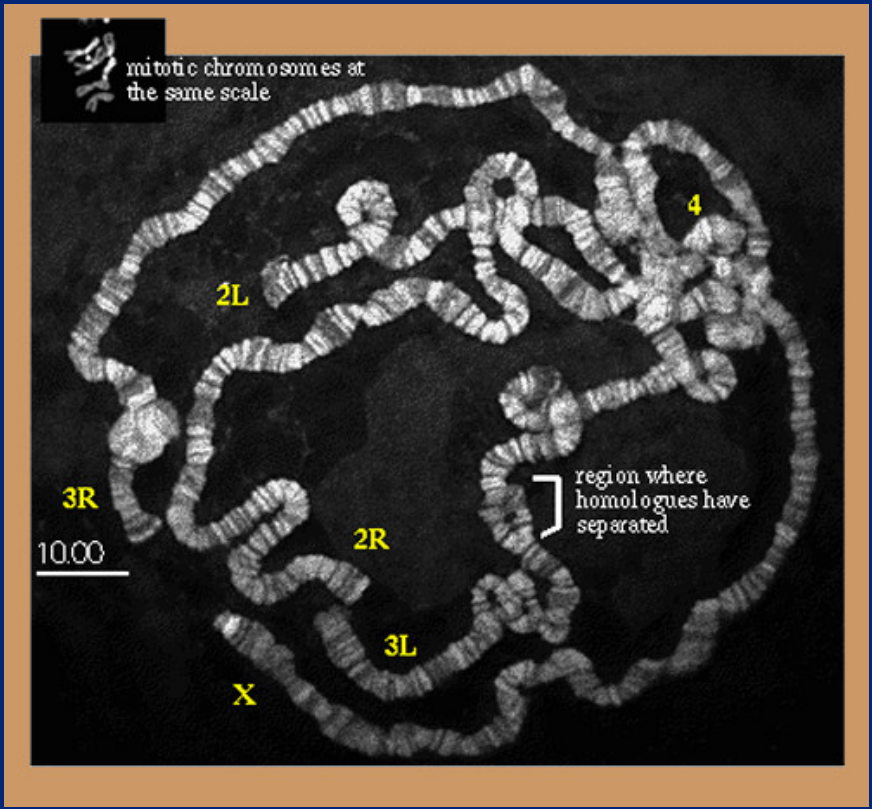
- Currently scheduled for 2:30-4:20 Wednesday March 20
- 3/7 students have issues with time or date!
- Options:
  - Can we do it earlier in the week?
  - Last session of class? (Would be only 1 hour unless everyone agreed on a longer time)

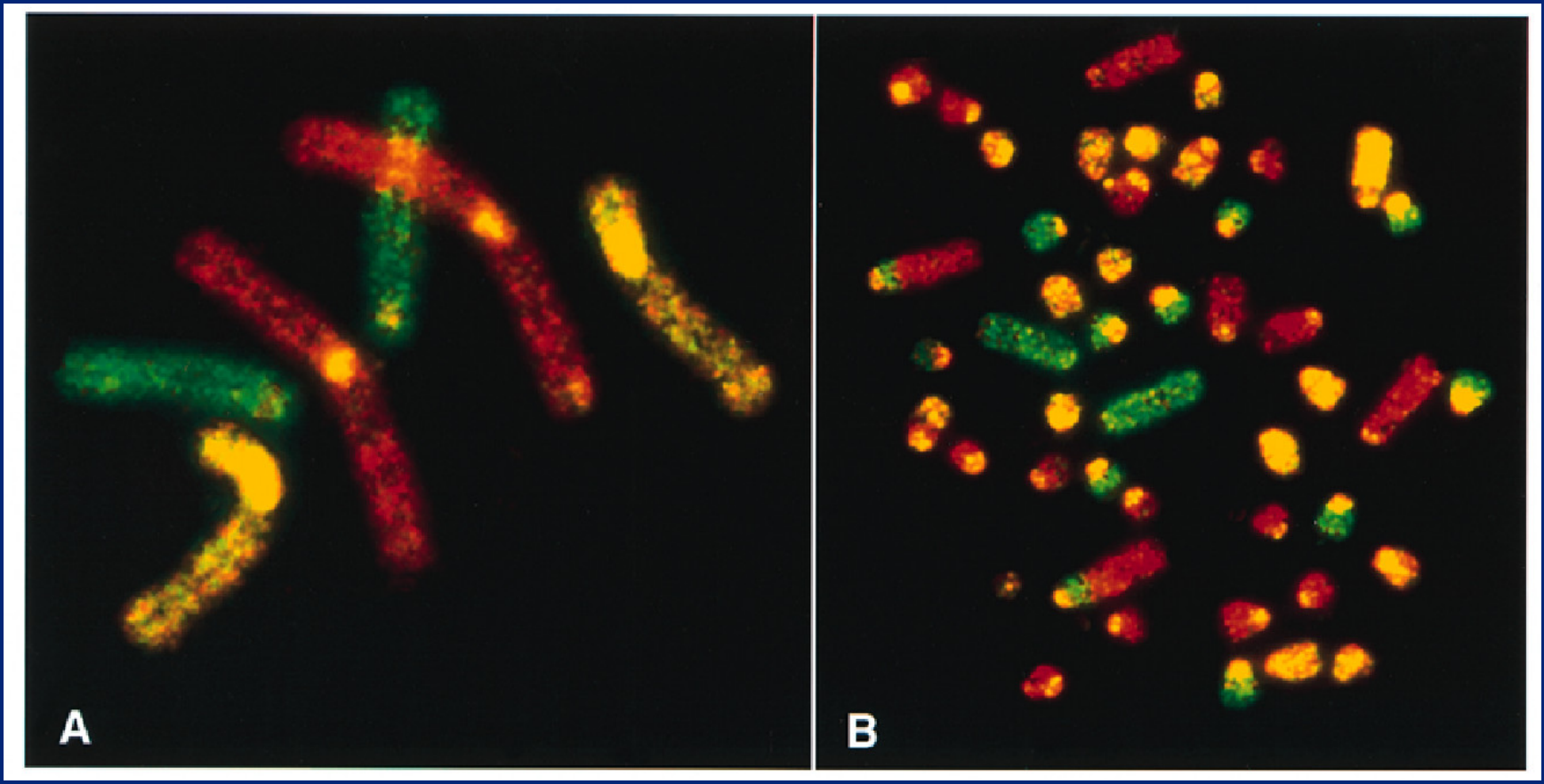
Speciation book recommendation

Joe Felsenstein recommends *Speciation* by Allen Orr and Jerry Coyne, 2004

Polytene chromosomes

- Found in dipteran flies and a few other groups
- In flies, normally found in non-dividing salivary gland cells
- Chromosomes pair, then replicate repeatedly without cell division
- Replicated copies remain together
- Differences in chromatin state easily visualized as banding patterns



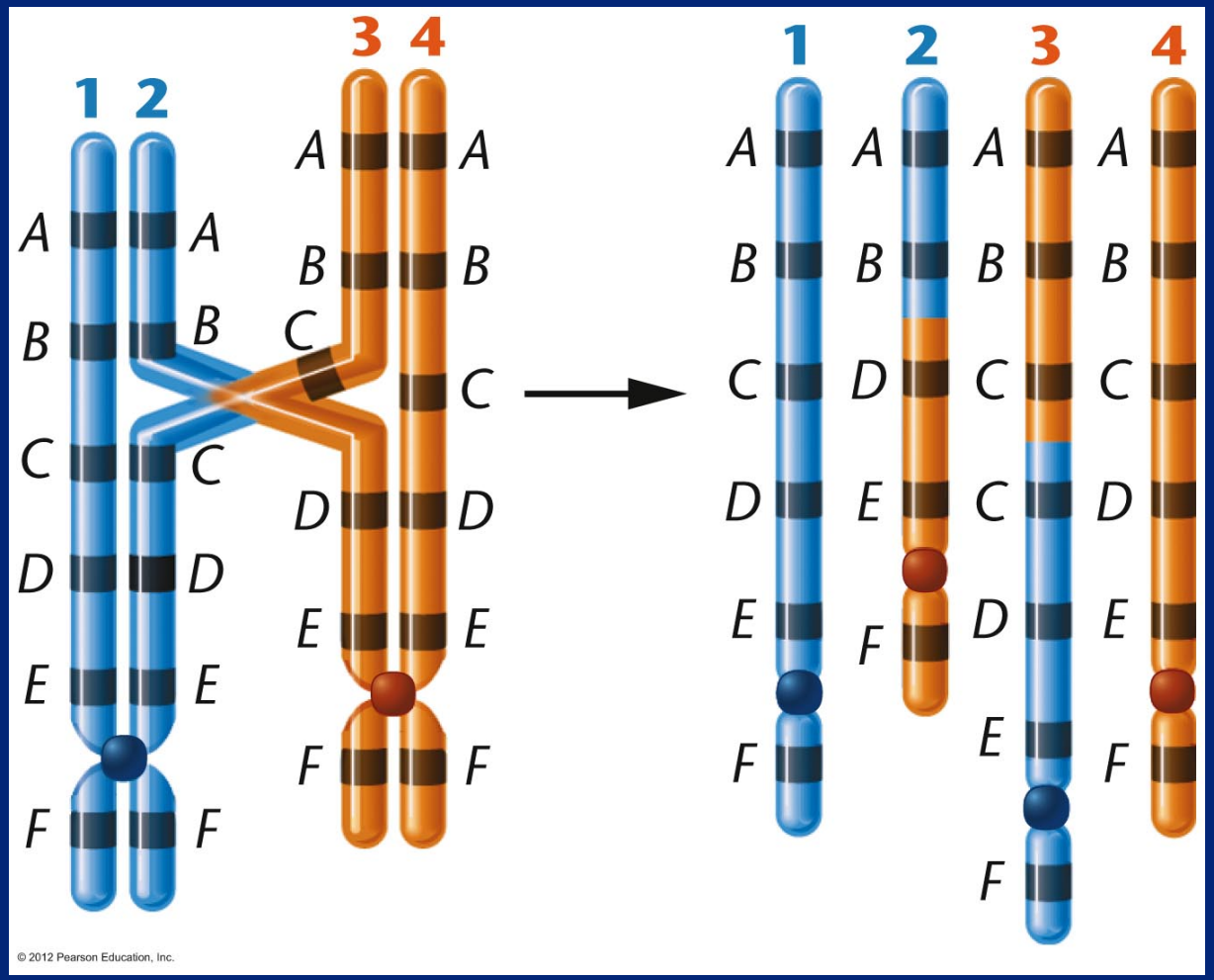


A. Indian muntjac B. Chinese muntjac
Yang et al. (1997) Chromosome Res

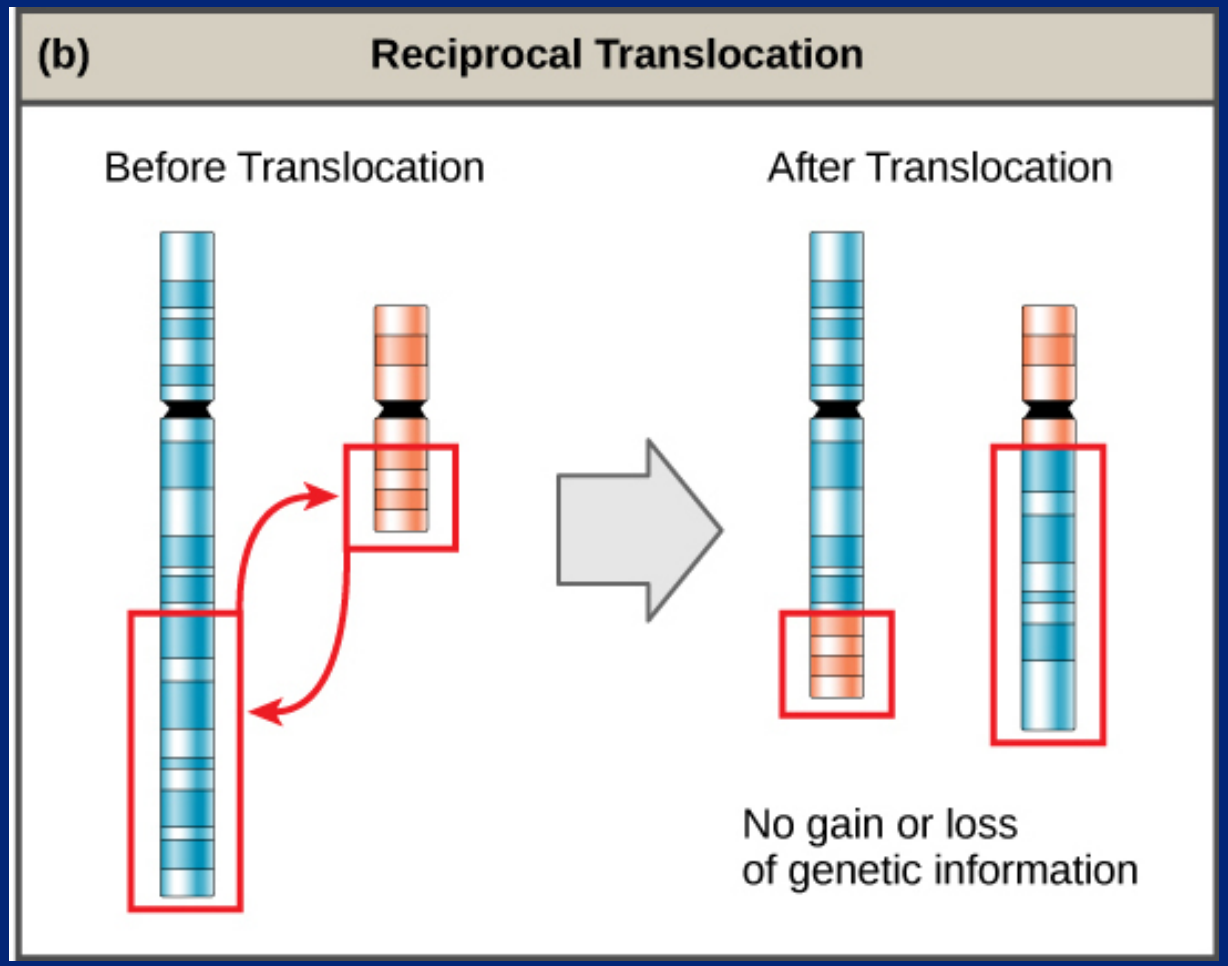
Multi-gene families

- Many examples in all taxa
- Range from 2 to 1000's of genes
- Olfactory receptor genes:
  - 400 genes in humans
  - 1000 genes in mouse
- Duplicated loci can interact, giving them novel evolutionary options

Unequal crossing over



Translocation



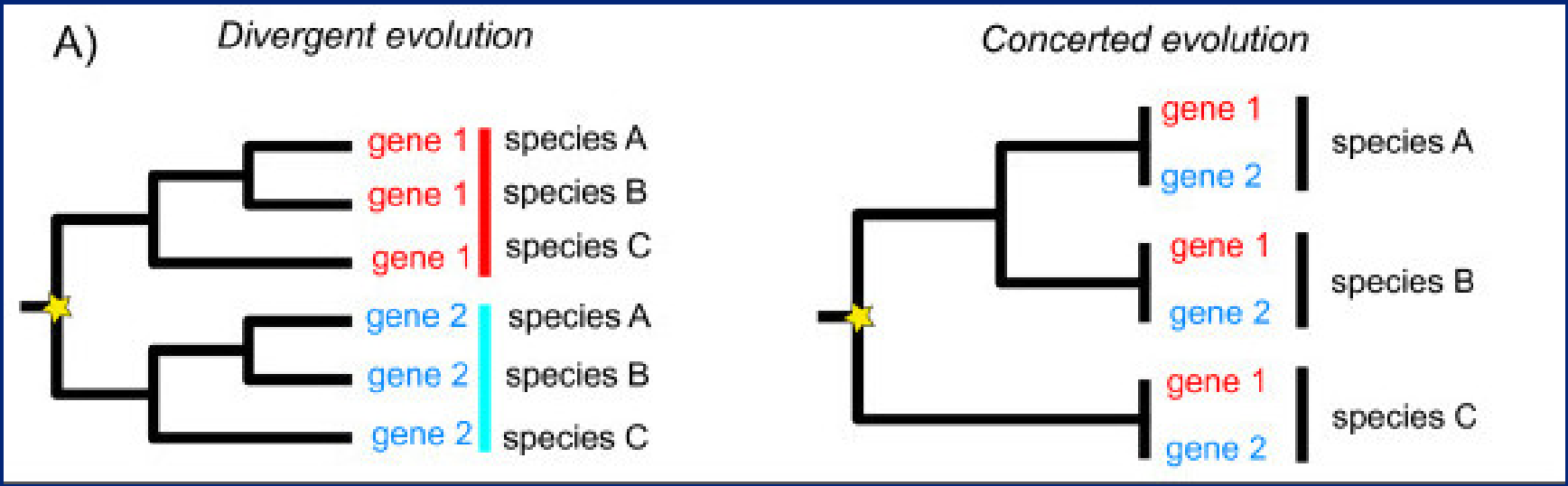
Discussion

Unequal crossing over and translocation don't change the number of gene copies (they just move them around)

Why are they described as pathways to gene duplication?

Concerted evolution

- Consider a 2-gene family:
  - If multiple species have 2 loci we assume the duplication was ancestral
  - Copies within a species therefore not closely related
- Should look like left image but often looks like right: why?

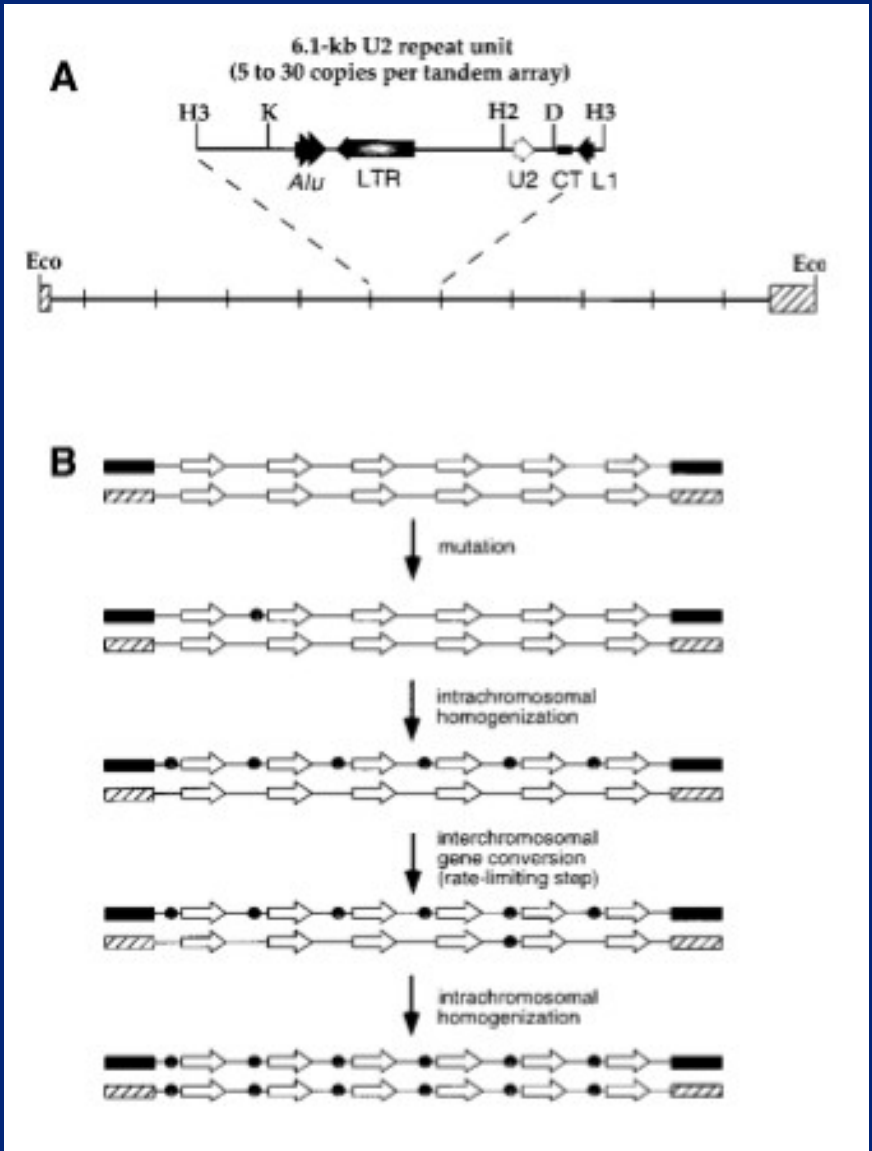


Concerted evolution–possible explanations

- Independent duplications in different lineages
- Homogenizing forces:
  - Expansion and contraction
  - Recombination
  - Gene conversion
  - Selection

Concerted evolution more common when:

- Repeats on same chromosome
- Repeats in tandem arrays rather than dispersed
- Family large
- Example:
  - RNU2 locus (encodes a functional RNA) in primates
  - 35 million years old
  - Old World monkeys have 11-kb repeat; apes and humans have 6-kb repeat
  - A chunk was deleted in apes and this spread to all copies



From Liao (1999) AJHG

Concerted evolution can be adaptive

- Ribosomal RNA genes in tandem array in majority of organisms
- Early in development, huge demand for rRNA:
  - Not protein coding so can't be amplified by translation
  - Multiple copies needed
  - Copies must interact so work best if identical
- If these genes were split up across the genome and could not evolve in concert, they might diverge, interfering with ribosome function

Concerted evolution can be maladaptive

- Red and green color vision loci in humans are a small tandem array
- Recombination and gene conversion can homogenize them

```
-------   Gene   -------   Gene   -------
                -------   Gene   -------   Gene   -------
```

A crossover can produce either of:

```
-------   Ge ne   -------
-------   Gene    -------   Ge ne   -------   Gene   -------
```

A Drosophila mystery–hybrid dysgenesis

- Lab strains were isolated from the wild about 100 years ago
- When lab female x wild male, F1 hybrids show:
  - Low fertility (F1)
  - Birth defects (F2)
  - High mutation load (F2)
  - Chromosomal rearrangements (F2)
- Lab male x wild female cross does not show dysgenesis

Drosophilia P element

- Present in wild flies only
- No transposition in somatic cells
- In wild flies:
  - Suppressor in cytoplasm prevents transposition
- In wild male x lab female:
  - High transposition in germ line cells
  - Hybrid dysgenesis

• *P*-element structure

Figure 14-16

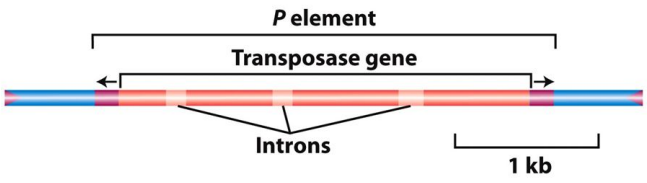


Figure 14-16
Introduction to Genetic Analysis, Ninth Edition

Two theories about P

1. Wild strains all gained P since the lab strains were collected
   - *D. melanogaster* is globally distributed
   - Would require a world-wide sweep of P
2. Lab strains used to have P but lost it
   - Separate lab strains evolved in isolation
   - Maybe something about lab life removes P?

Is P element a new invader?

- Current evidence is that P is new in wild strains
- Very similar P found in a distant relative (60 million years' separation)
- Lab strains do not have:
  - Broken copies of P
  - Supressors needed to restrain P
- P may have come in via rare cross-species mating
- It spreads because it can move around in the genome

Transposition: good or bad?

- If P truly spread across the world in 100-200 years, it's clearly good–for the transposon
- P moving at a high rate in germ cells substantially reduces fertility
- P-bearing strains experience strong selection for silencing of P
- P element can fight back by evolving immunity

Mobile elements

- Conservative transposition:
  - transposable element leaves its original position and moves to a new position
  - because of chromosome reassortment, can increase or decrease genomic copy number
  - can also increase copy number if transposition happens during DNA replication (transposon replicates, moves, and replicates again)
  - causes mutations which may cleanly revert when transposon leaves
  - often a small duplication is left at the site

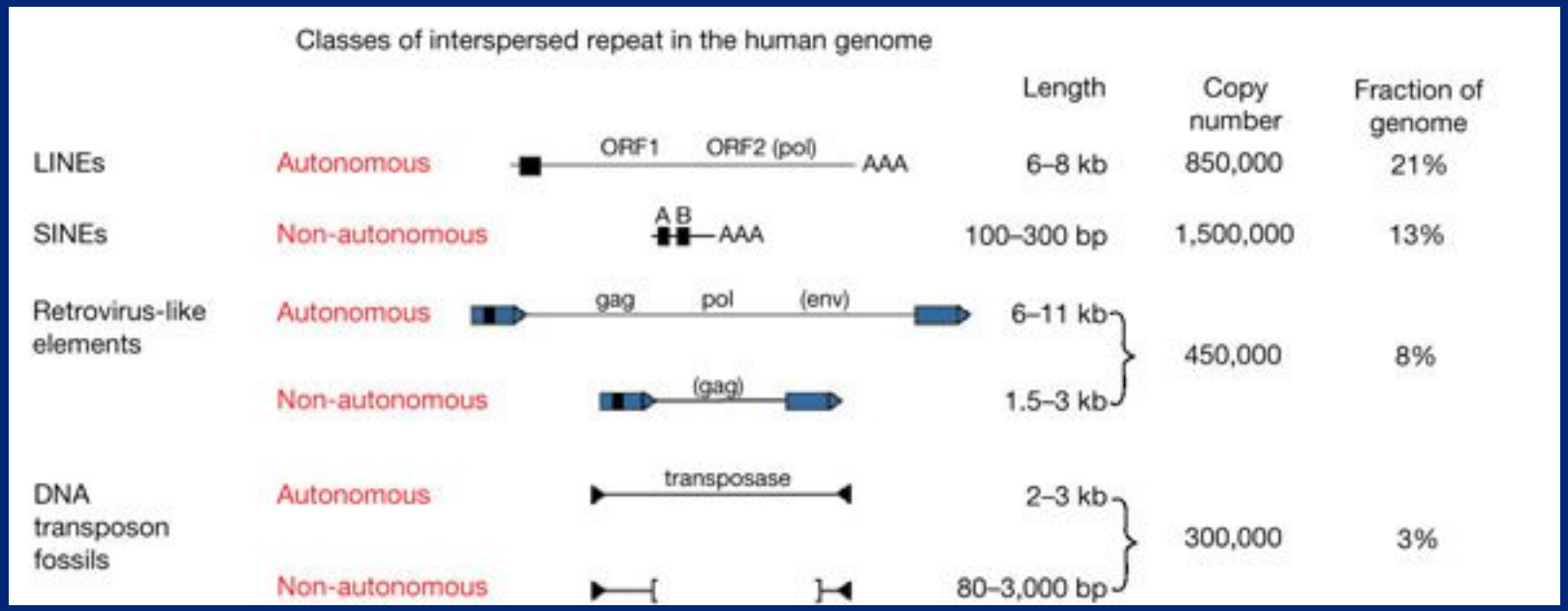
- Typical of most DNA transposons

Mobile elements

- Replicative transposition:
  - transposon stays where it is; a new copy inserts elsewhere
  - increases copy number
  - causes mutations which do not easily revert
  - this can happen via DNA copying or via DNA to RNA reverse transcription
  - also tends to cause a small duplication at the site

- RNA transposons (retrotransposons) and some DNA transposons

Consequences of a transposition



- Inactivate or truncate a gene
- Detach a gene from its promoter
- Put gene under control of the transposon promoter

Evolutionary effects of transposons–discussion

- What would be different between a species with transposons and a similar one without?

- Consider effects of:
  - Mutations
  - Similarity between different parts of the genome
  - Genome size

Thought problem

- Cross P into a lab strain and maintain a population in bottles
- Population may live or die
- Which is likely to do better, a large or small population?

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- Cross P into a lab strain and maintain a population in bottles
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- When this experiment has been done, large populations are more likely to survive

Transposons in bdelloid rotifers

- Five species of bdelloids lacked major retrotransposon families (Tc1, LINE, Gypsy)
- All other tested phyla had at least one of these, usually all three
- Bdelloids *did* have Mariner-type transposons (DNA transposon)
  - These can be transmitted horizontally
- "Retrotransposons are sexually transmitted nuclear parasites" – Arkhipova and Meselson 2000

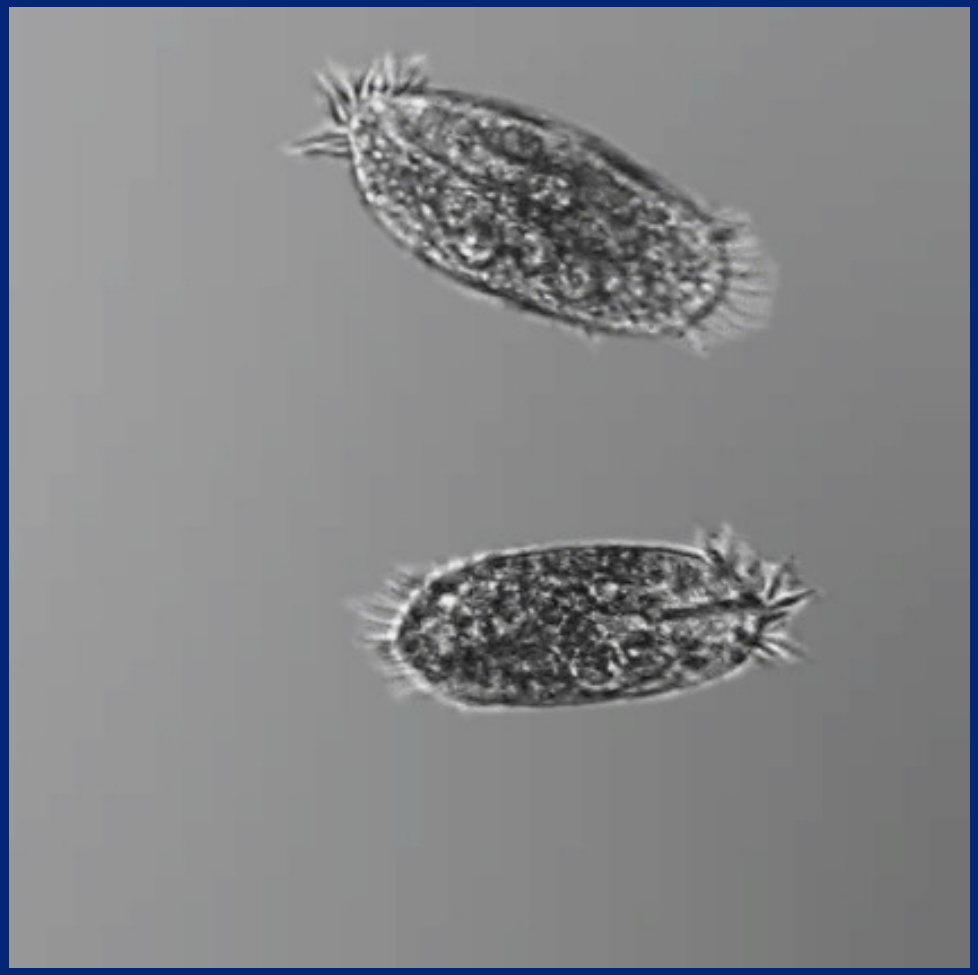
McClintock's "genome shock" hypothesis

- Transposons could allow an organism to control its mutation rate:
  - Suppress transposition when well adapted
  - Permit transposition when struggling, "hoping" for a useful mutation
- Alternative hypothesis: transposons are purely selfish
  - Suppress transposition whenever possible
  - Fail to suppress transposition when badly stressed
- Not easy to test these alternatives

One supportive observation

- *Copia* transposons in flies carry a heat-shock promoter
- Transposition is triggered when flies are stressed
- Hard to distinguish between:
  - Heat-shock regulation of transposons helps the fly
  - Heat-shock regulation of transposons helps the transposon

Finding a use for transposons

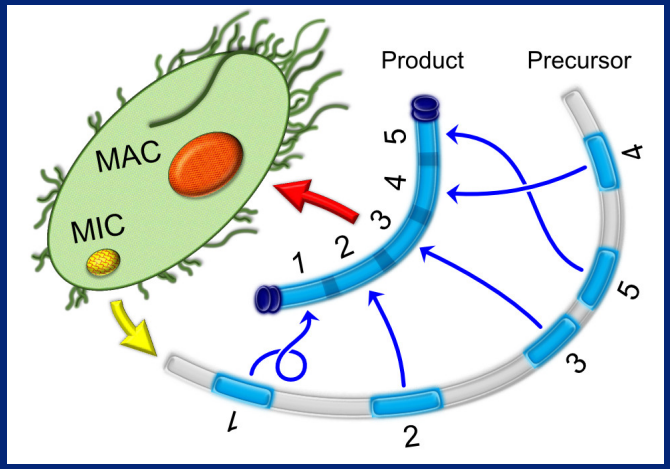


Oxytricha genome rearrangement

- Two nuclei per cell:
  - Micronucleus used for reproduction, but genes not active
  - Macronucleus expresses genes
- Macronucleus genome is highly rearranged:
  - Cut into around 16,000 tiny chromosomes
  - Usually 1 gene per chromosome
  - Genes are re-assembled from fragments
  - Some are duplicated (dosage control?)
  - 95% of germline genome is destroyed

Transposons harnessed to chew up genome

- Germline genome of *Oxytricha* full of transposons
- Macronucleus has none
- If transposases are inactivated, the macronucleus fails to develop properly
- Transposons and transposase probably central in rearrangement process



Other "tamed" genome rearrangements

- Vertebrate rearrangement of antibody genes
  - Genome contains assortment of V, D and J segments
  - Targeted rearrangement makes a final antibody gene
  - This system greatly increases antibody diversity
- Yeast sex switching
  - Genome contains inactive copies of a and α genes
  - Targeted gene conversion allows sex switching
- Evolution can "use" elements which were initially selfish

Monday

- Phylogenetic trees:
  - Intepretation and uses
  - Methodology
  - Hazards

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.