Evolutionary Considerations in Sexual Reproduction

Implications for Genomic Structure

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Problems with Sexual Reproduction

- What good are males anyway?
- If it's not broken, why try to fix it?
- sexually transmitted diseases / parasites

Observations:

- Everybody's doing it (almost anyway)
- Those that don't do it have recently stopped

Muller's Rachet

For small populations, deleterious mutations become fixed in a monotonically non-decreasing manner

Deleterious Mutation Hypothesis

For large populations, recombination is a way to skim deleterious mutations from the gene pool

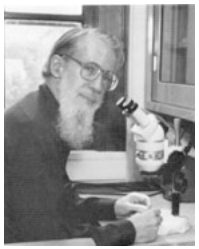
Red Queen Hypothesis

Now, here, you see, it takes all the running you can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!

- The Red Queen

“Through the Looking Glass” - Lewis Carroll

Leigh Van Valen

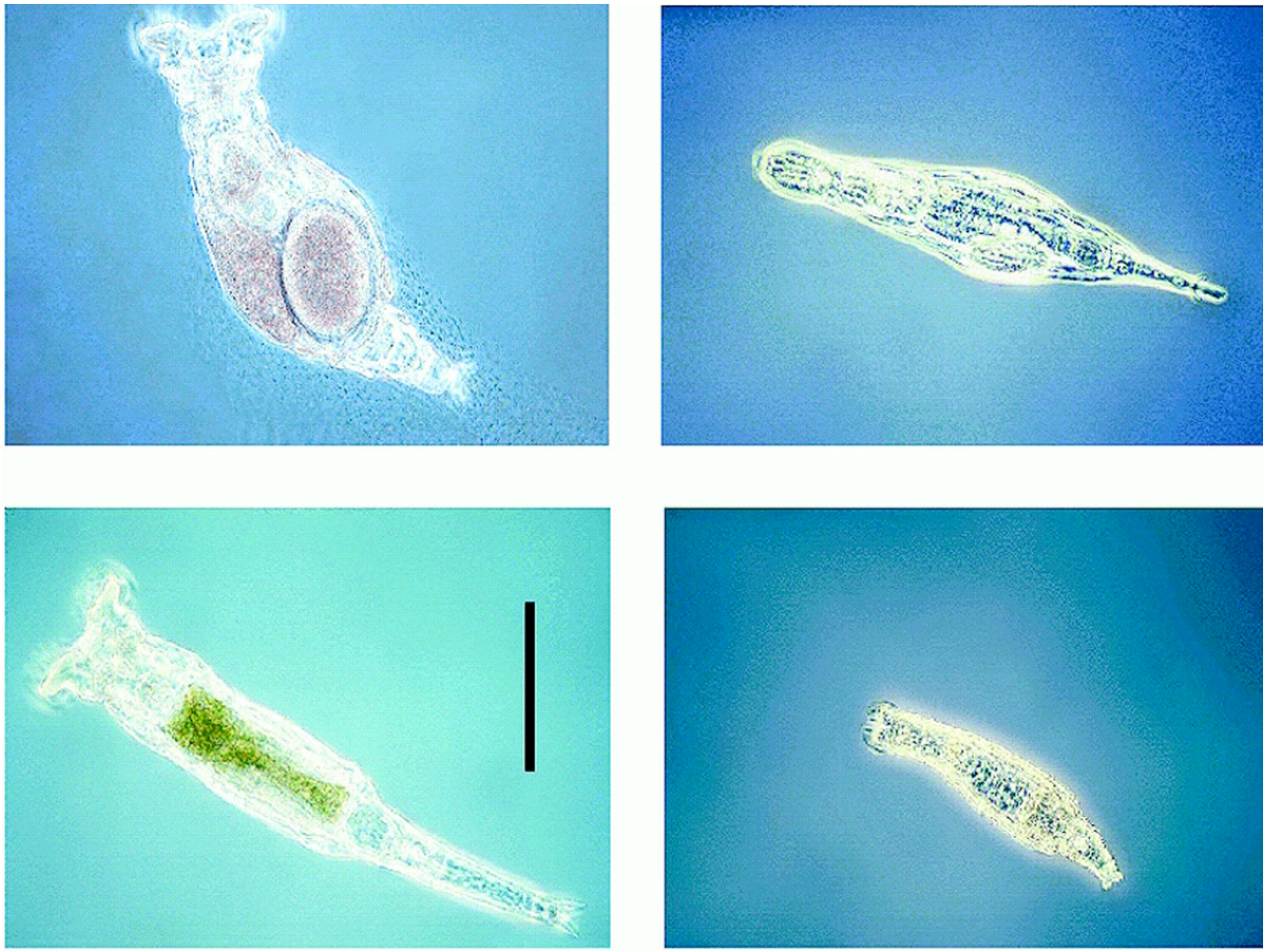


Red Queen Example?

http://www.pbs.org/wgbh/evolution/library/01/5/l_015_03.html

Bdelloid Rotifers

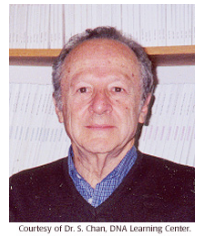
"ancient asexual scandal"



35-40 million years old

- Multicellular
- Found on every continent
- 360+ different species
- 0.1 to 1.0 mm long
- Eggs arise from two **mitotic** divisions
- No known males, hermaphrodites or meiosis
- Can survive dessication at all growth stages

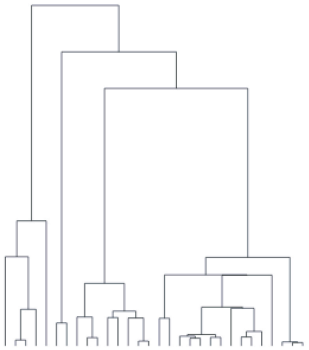
Matthew Meselson



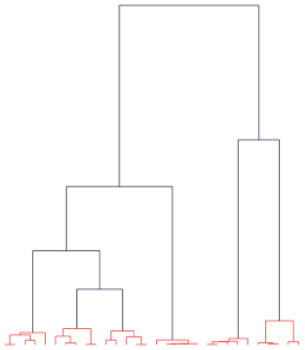
Does it make sense to speak of asexual "species"?

A Independent evolution

***H0**: Single population*
***Signature**: tree conforms to single population coalescent*



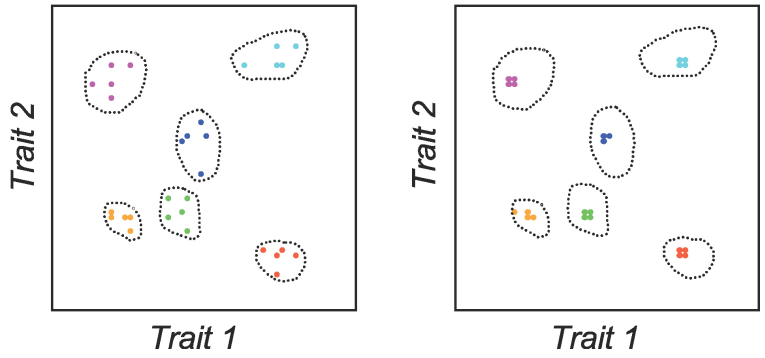
***H1**: Series of independently evolving entities*
***Signature**: genetic clusters (red) separated by longer branches (black)*



B Adaptive divergence in ecomorphological traits

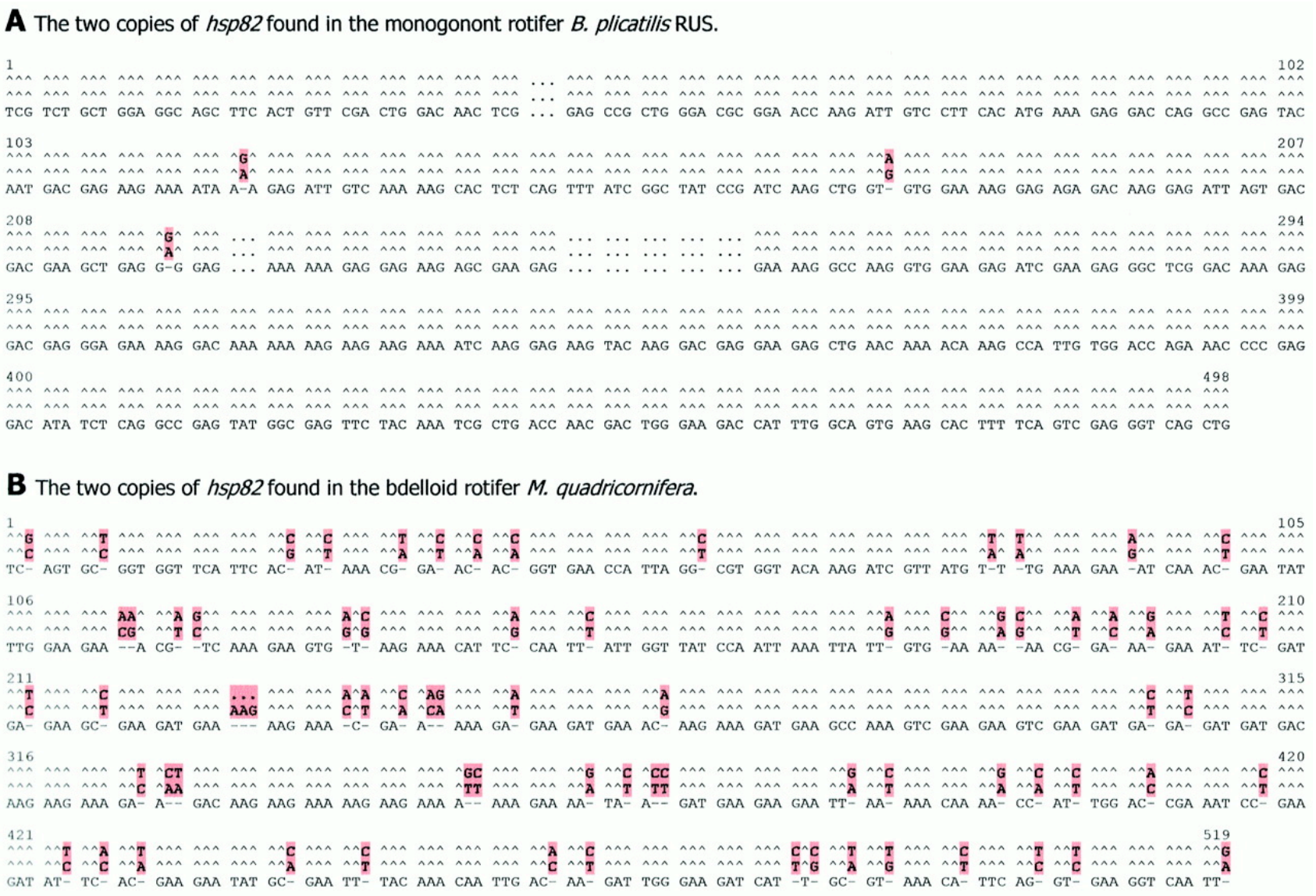
***H0**: neutral divergence*
***Signature**: trait variation (dots) proportional to neutral genetic changes (indicated by dotted lines)*

***H1**: adaptive divergence*
***Signature**: greater trait variation between clusters than within them, relative to neutral expectations*

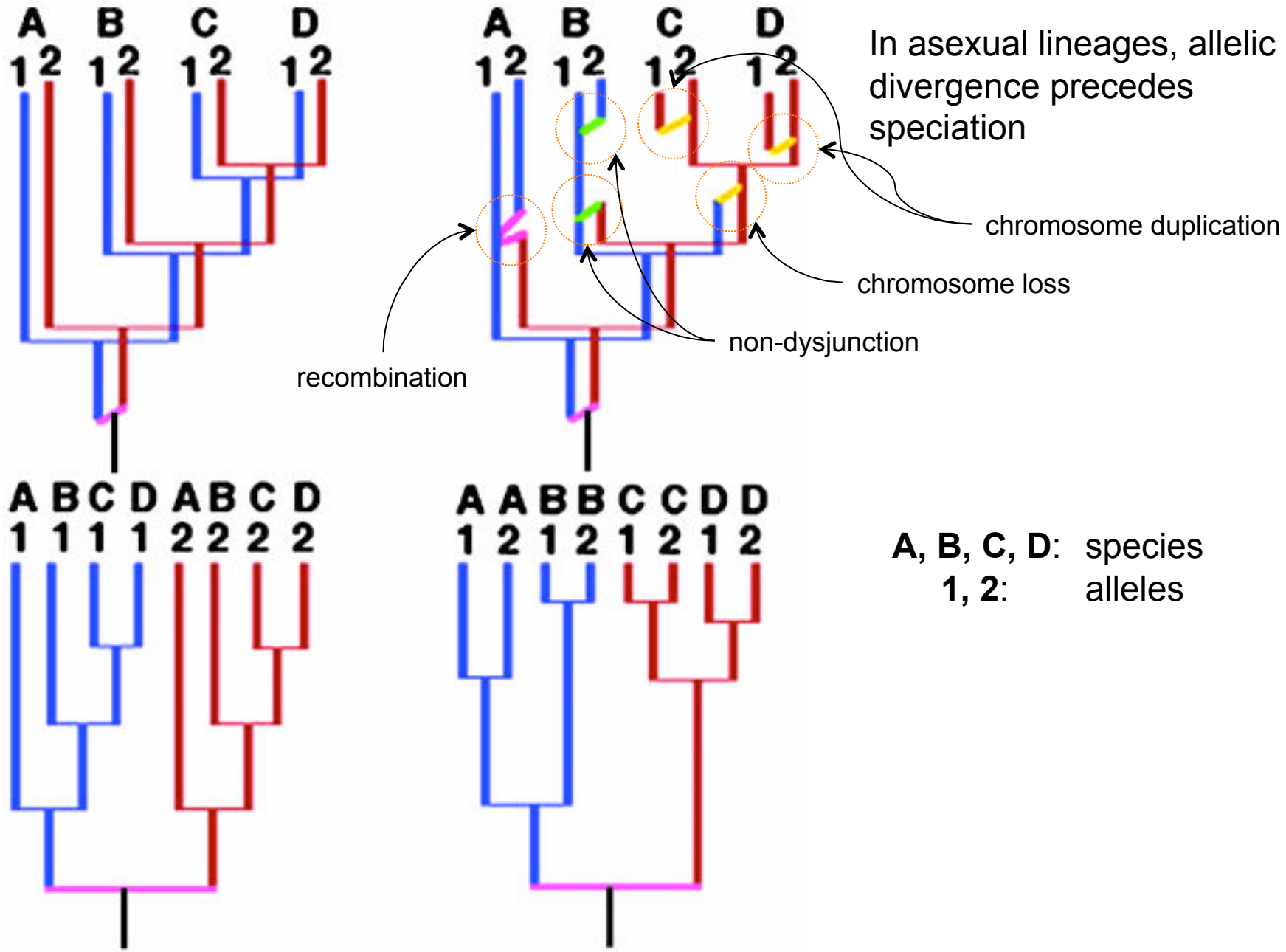


PLoS Biology. April 2007 5(4)e87 0914-0921.
Independently Evolving Species in Asexual Bdelloid Rotifers. Fontaneto D, Herniou EA, Boschetti C, Caprioli M, Melone G, Ricci C, Barraclough TG

Allelic Sequence Divergence -- The Meselson Effect



Science. 2000 May 19;288(5469):1211-5.
Evidence for the evolution of bdelloid rotifers without sexual reproduction or genetic exchange. Mark Welch D, Meselson M.

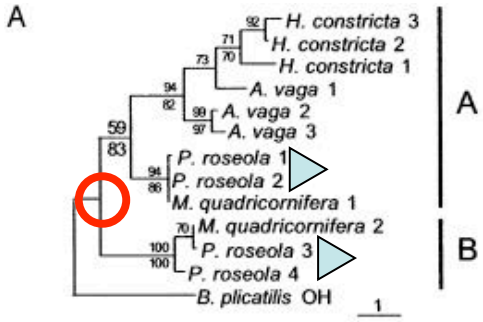


In asexual lineages, allelic divergence precedes speciation

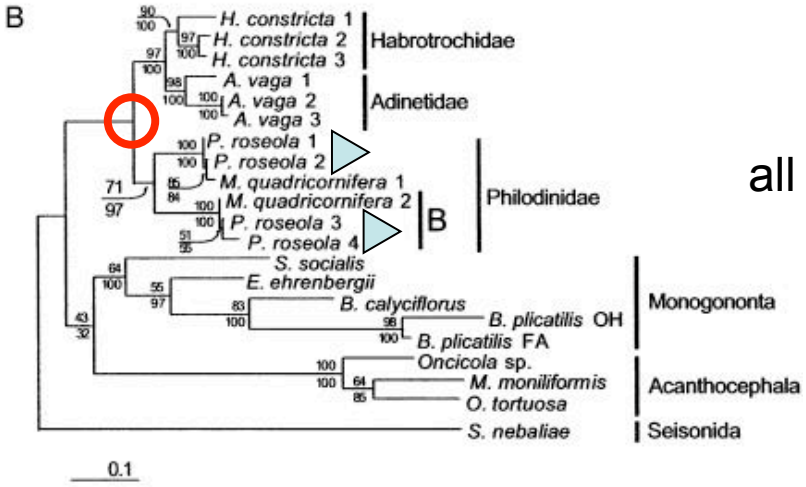
A, B, C, D: species
1, 2: alleles

Proc Natl Acad Sci U S A. 2004 March 2; 101(9): 2651–2652.
Bdelloid rotifers revisited
C. William Birky, Jr.

hsp82 allelic trees

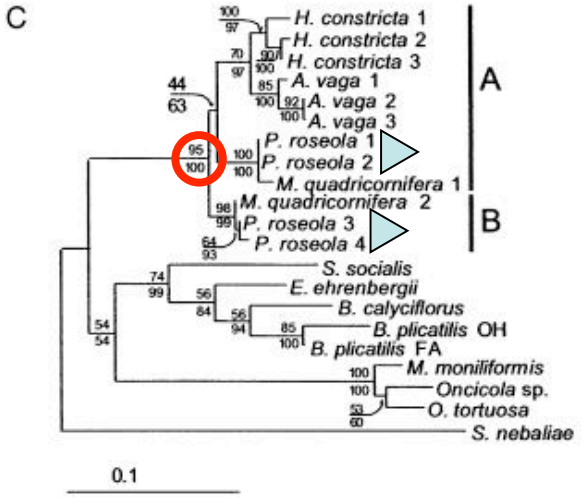


From older paper:
consistent with asexual reproduction



all codon positions

consistent with sexual reproduction



not third codon position

consistent with asexual reproduction

Proc Natl Acad Sci U S A. 2004 Feb 10;101(6):1622-5. Epub 2004 Jan 27.
Divergent gene copies in the asexual class Bdelloidea (Rotifera) separated before the bdelloid radiation or within bdelloid families.
Mark Welch DB, Cummings MP, Hillis DM, Meselson M.

Table 1. Comparison of tree alternatives for hsp82

Model	Tree	Criteria			
		BP	PP	KH	SH
Nucleotide model, all positions	B	0.732 (0.004)	0.900 (0.000)	0.729 (0.004)	0.729 (0.004)
	C	0.268 (0.004)	0.100 (0.000)	0.271 (0.004)	0.271 (0.004)
Nucleotide model, codon positions 1 and 2	B	0.408 (0.005)	0.313 (0.000)	0.362 (0.005)	0.362 (0.005)
	C	0.592 (0.005)	0.687 (0.000)	0.638 (0.005)	0.638 (0.005)
Nucleotide model, codon position 3	B	0.923 (0.003)	0.998 (0.000)	0.912 (0.003)	0.994 (0.001)
	C	0.076 (0.003)	0.002 (0.000)	0.088 (0.003)	0.168 (0.004)
Codon model, estimated frequency	B	0.021 (0.001)	5×10^{-11} (0.000)	0.016 (0.001)	0.016 (0.001)
	C	0.979 (0.001)	1.000 (0.000)	0.984 (0.001)	0.984 (0.001)
Codon model, equal frequency	B	0.362 (0.005)	0.011 (0.000)	0.349 (0.005)	0.349 (0.005)
	C	0.638 (0.005)	0.989 (0.000)	0.651 (0.005)	0.651 (0.005)

Tree B has all gene copies diverging after the separation of bdelloid families as in Fig. 1*B*; in tree C the most divergent copies separate before the bdelloid radiation as in Fig. 1*C*. Scores are shown for the bootstrap (BP), posterior probability (PP), Kishino-Hasegawa (KH), and Shimodaira-Hasegawa (SH) tests, with standard error in parentheses.

B: sexual

C: asexual

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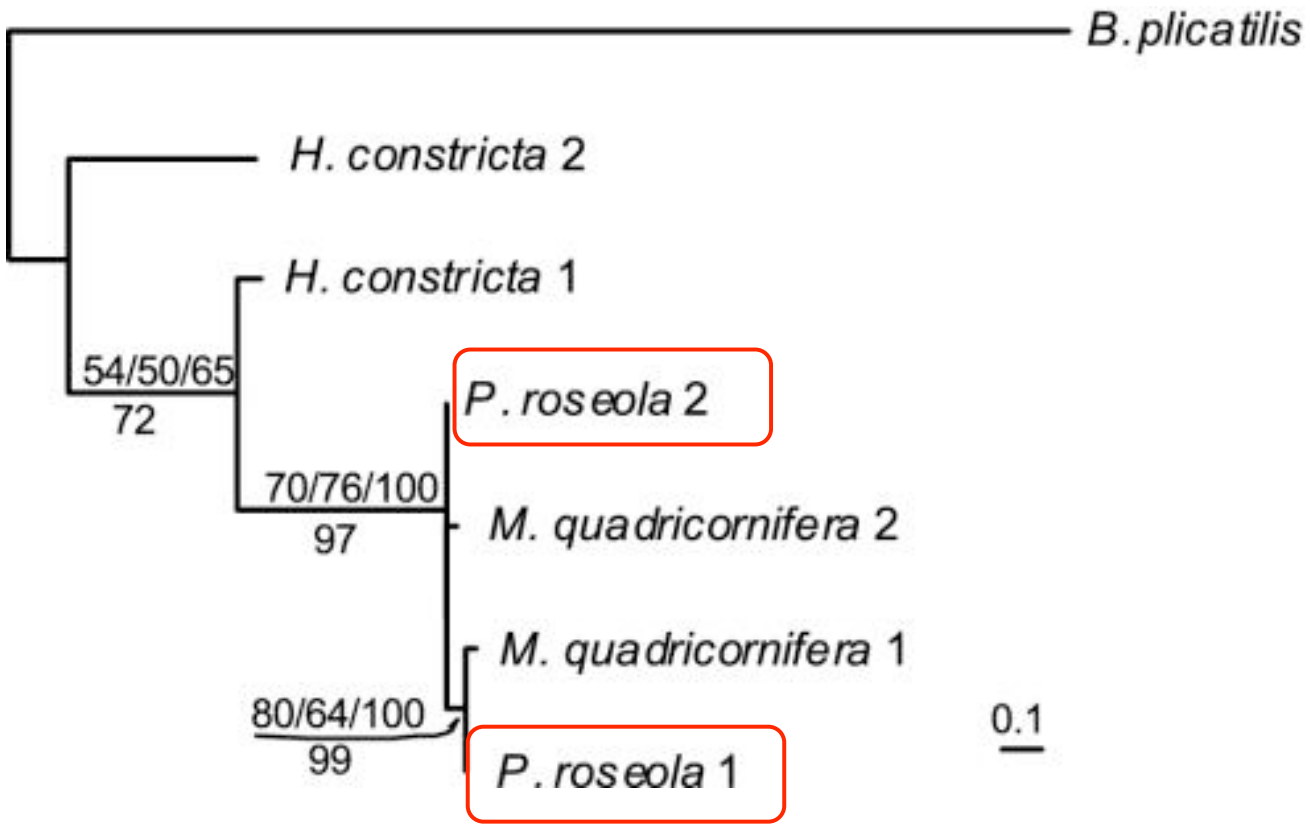
TBP allelic phylogeny



Proc Natl Acad Sci U S A. 2004 Feb 10;101(6):1622-5. Epub 2004 Jan 27.
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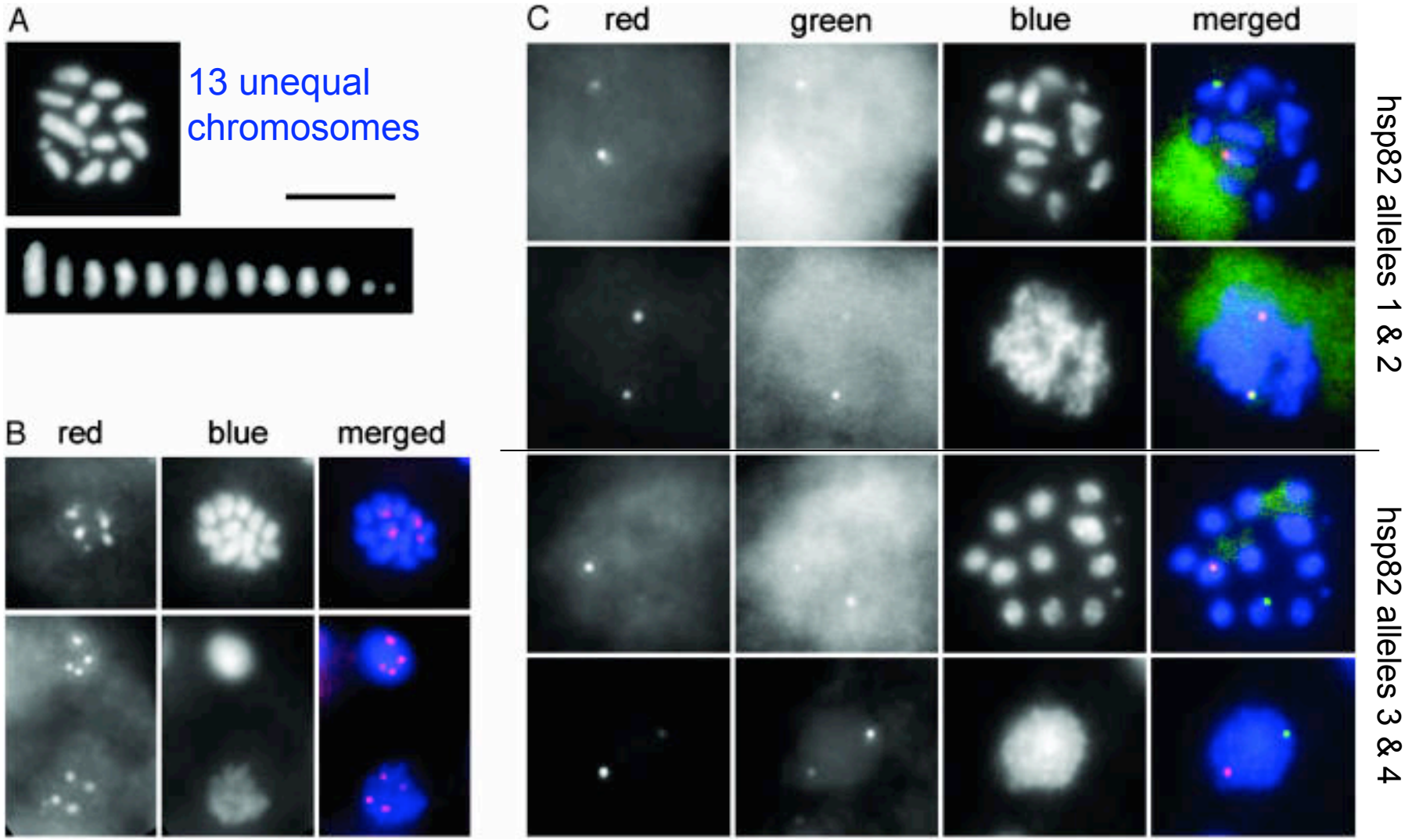
How else to explain the Rotifer data?

- rotifer genes are not alleles, but rather are identical copies
- but, limited by genome size of rotifer (2pg DNA per cell)

Looking for (and not finding) exact duplicate alleles



hsp82 FISH

different hsp82 alleles separate in space

Proc Natl Acad Sci U S A. 2004 Feb 10;101(6):1618-21. Epub 2004 Jan 27.
Cytogenetic evidence for asexual evolution of bdelloid rotifers. Mark Welch JL, Mark Welch DB, Meselson M.

How can the rotifers be so successful asexually for so long?

What happens to other animals that give up sexual reproduction?

Lack of non-telomeric retrotransposable elements

Dessication resistance and DNA repair