
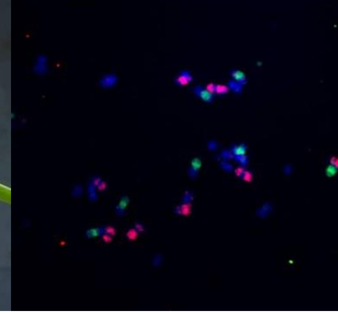
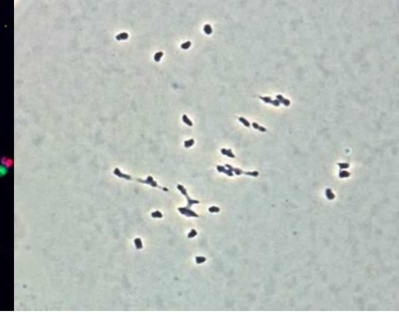


Hybrid Speciation in *Brassica*

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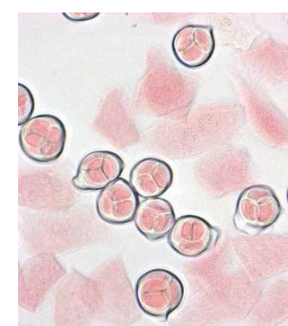
Emmy Noether Junior Group Leader

Plant Breeding Department

Justus Liebig University Giessen



World agriculture is not very diverse

- Wheat, rice and maize together comprise >50% of all plant food worldwide, while just 9 crops supply >75% of all plant food
- In many species diversity is limited, limiting possible breeding gains
- Better use of diversity in cropping systems could offer potential benefits to human nutrition, agricultural ecosystems and in building climate resilience

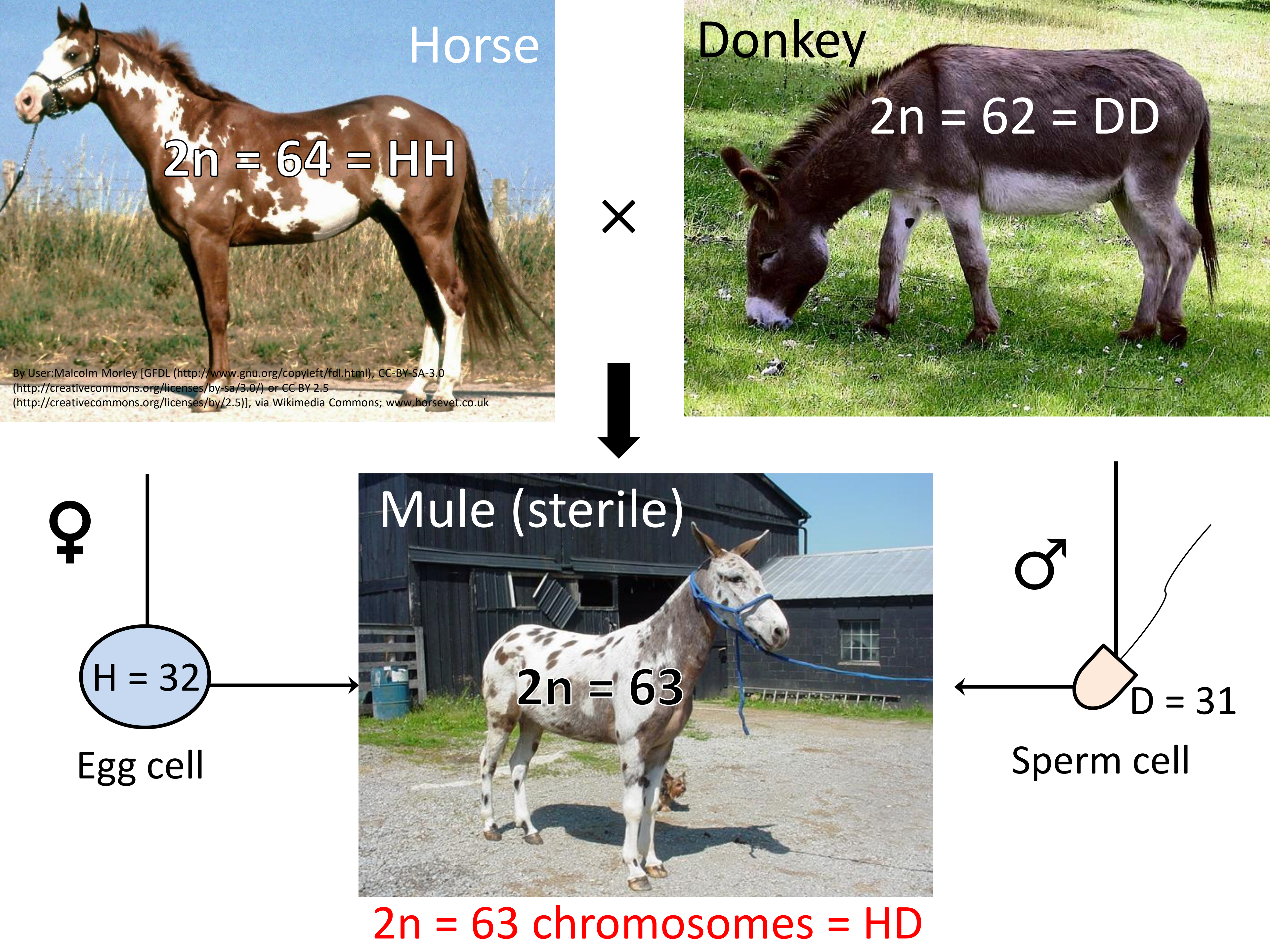




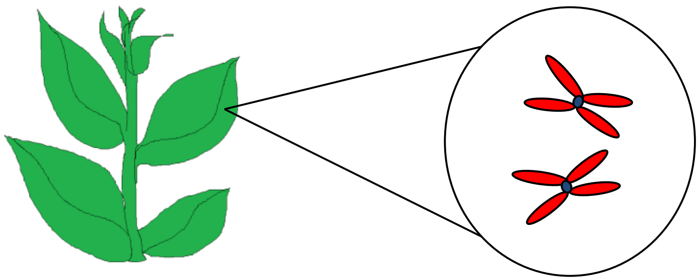
Core research theme: polyploidy and hybridisation for crop improvement






Horse
2n = 64 = HH
By User:Malcolm Morley [GFDL (http://www.gnu.org/copyleft/fdl.html), CC-BY-SA-3.0
(http://creativecommons.org/licenses/by-sa/3.0/) or CC BY 2.5
(http://creativecommons.org/licenses/by/2.5)], via Wikimedia Commons; www.horsevet.co.uk
×
Donkey
2n = 62 = DD
♀
H = 32
Egg cell
Mule (sterile)
2n = 63
♂
D = 31
Sperm cell
2n = 63 chromosomes = HD

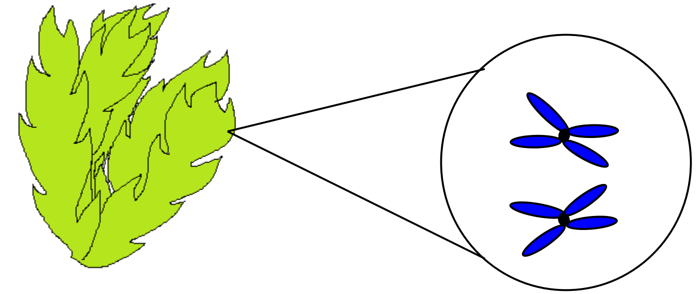
What is a hybrid species?



Species 1

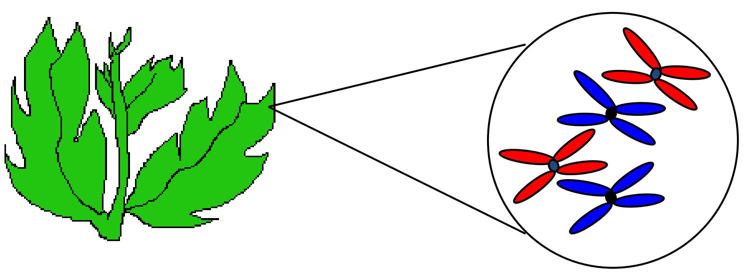
2n = 2 chromosomes = AA

×



Species 2

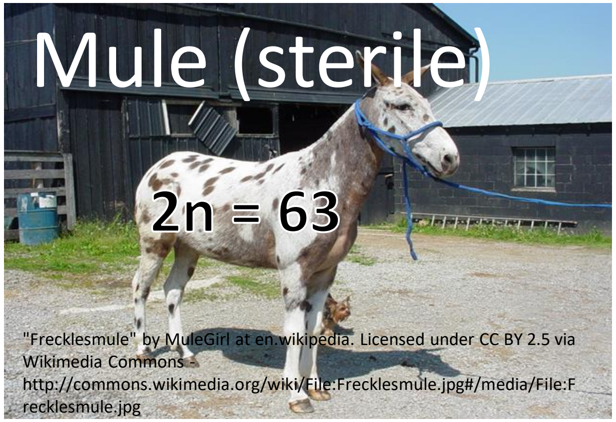
2n = 2 chromosomes = BB



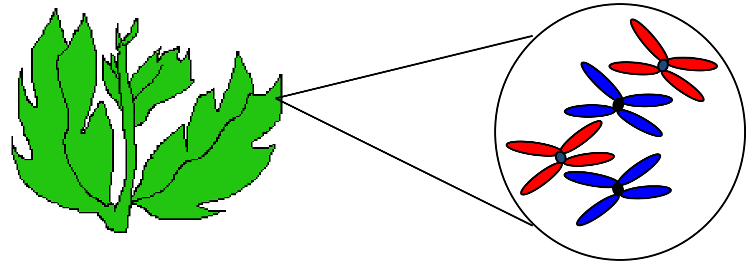
Hybrid species 3

2n = 4 chromosomes = AABB

Quick definitions



Hybrid

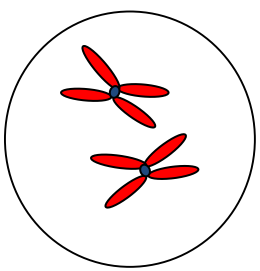


Allopolyploid

2n = AABB

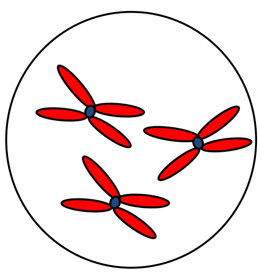
“hybrid species”

Polyploid: Greater than diploid (2x) chromosome number



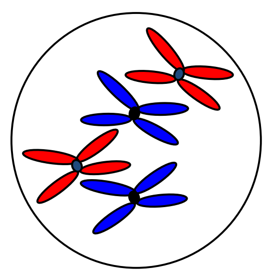
Diploid

2n = 2x = 2



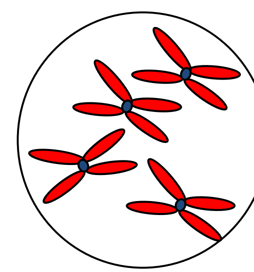
Triploid

2n = 3x = 3



Tetraploid (allo)

2n = 4x = 4



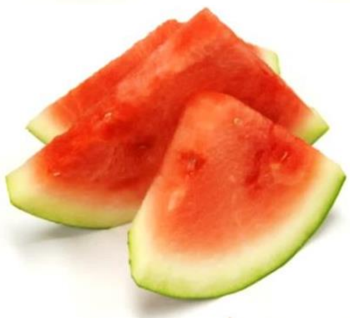
Tetraploid (auto)

2n = 4x = 4

Why should we care about hybrids and polyploids?



Hybrids between two species




Sterile triploids, three copies of each chromosome







Multiple hybridization and polyploidy events

Ancestral polyploidy in seed plants and angiosperms

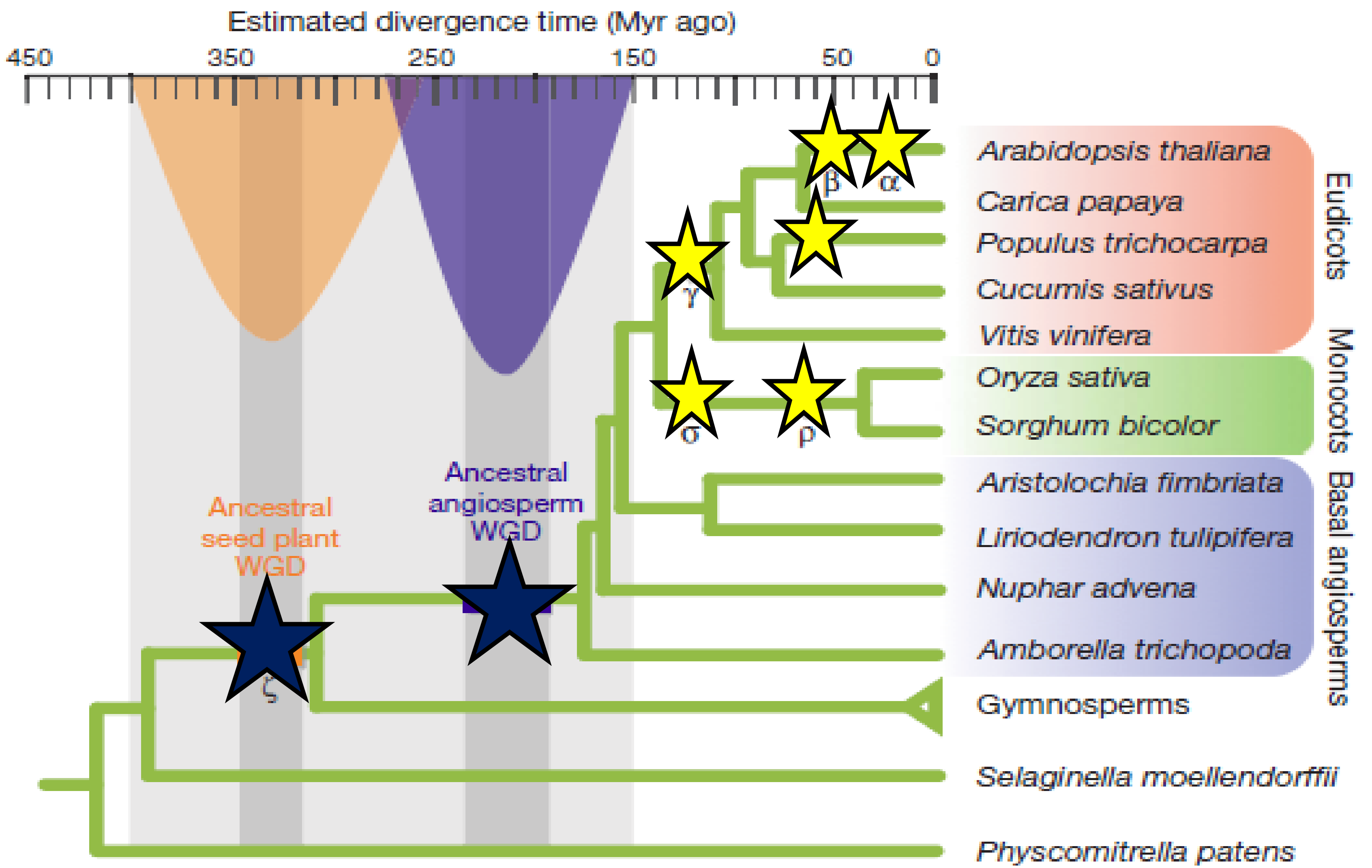


Figure from Jiao et al. 2011: *Nature* **473**, 97-100

All seed plants have at least one polyploidy event in their past!

Why are polyploids so successful?
1) hybrid vigour

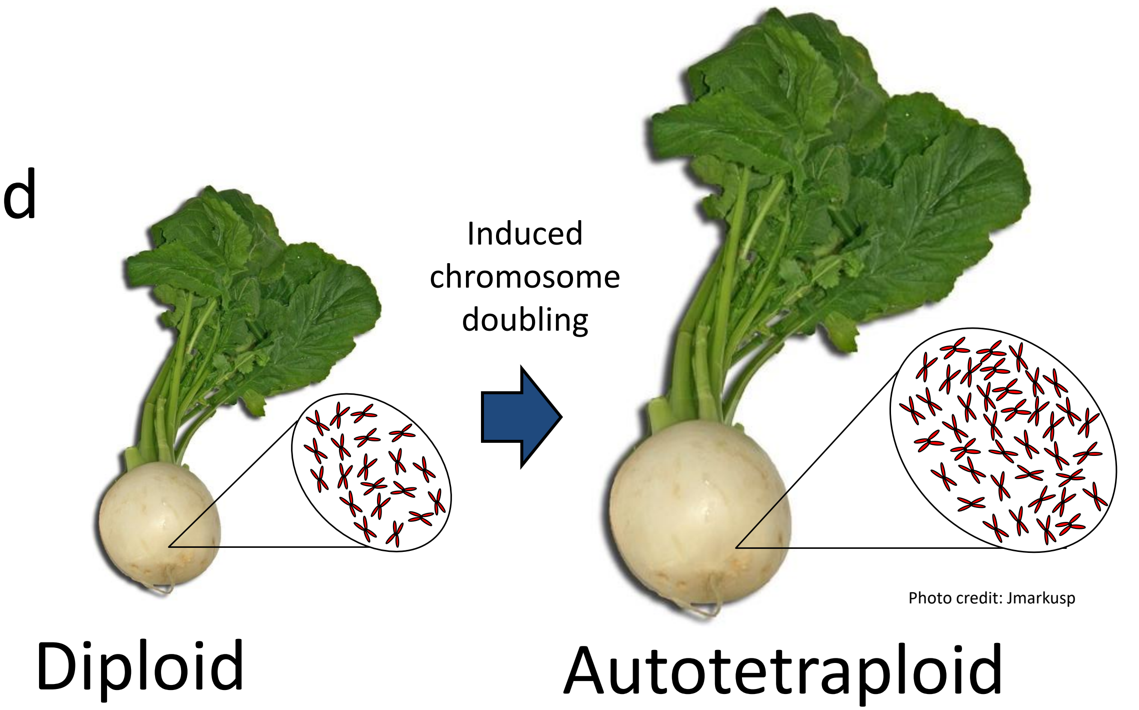
Inbred parent A | Hybrids AB BA | Inbred parent B

Birchler J A et al. Plant Cell 2003;15:2236-2239

- Hybrid breeding is one of the most important contributors to recent crop yield increases
- Polyploids have increased potential for hybrid vigour, due to the presence of additional alleles

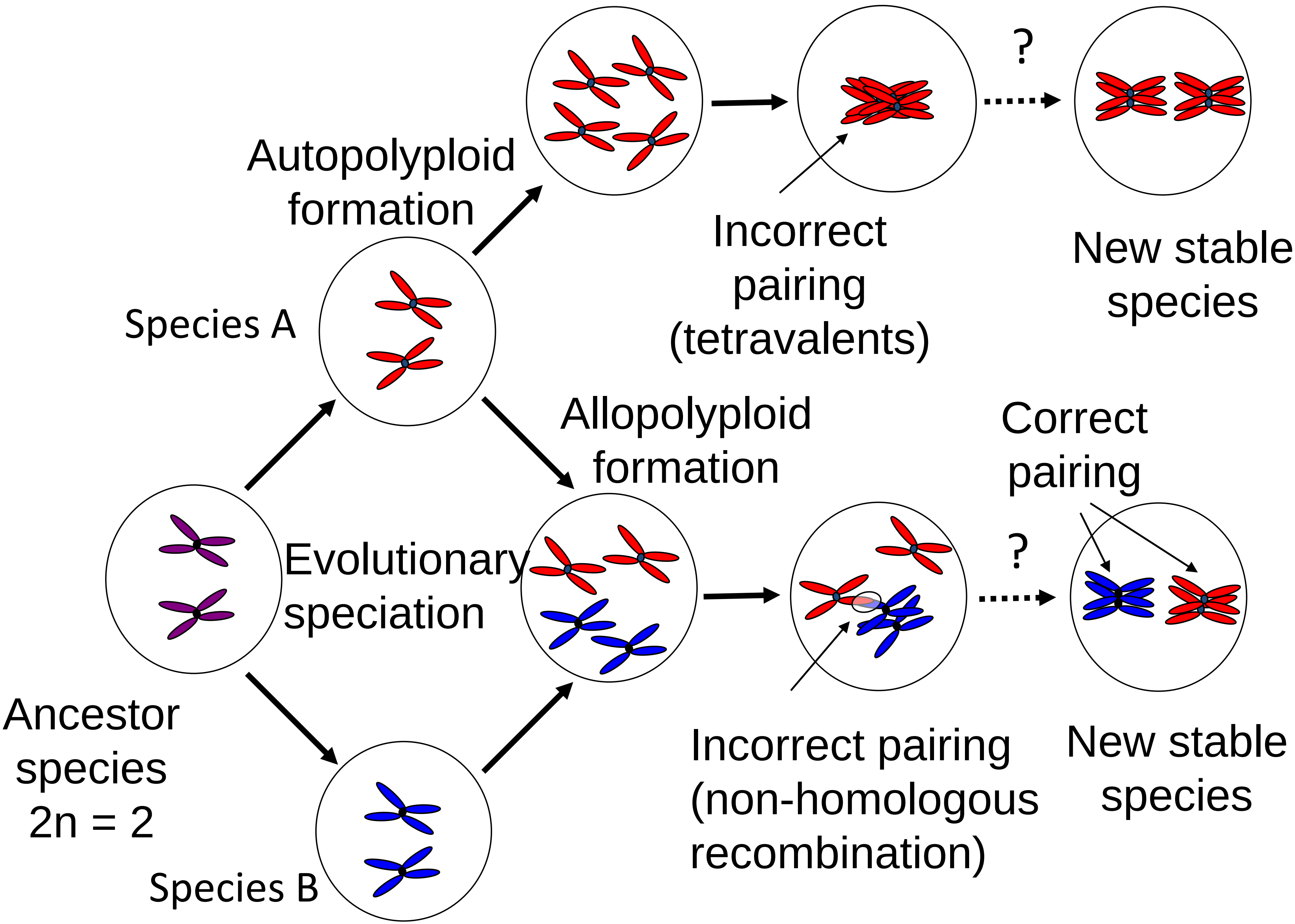
Why are polyploids so successful? Many other potential reasons:

- Increased cell and organ sizes



- Redundancy of gene copies allows for novel variation to arise without impacting gene function
- Polyploids have greater potential than diploids in terms of adaptation to environmental stress

Why aren't polyploids more common? The meiosis barrier





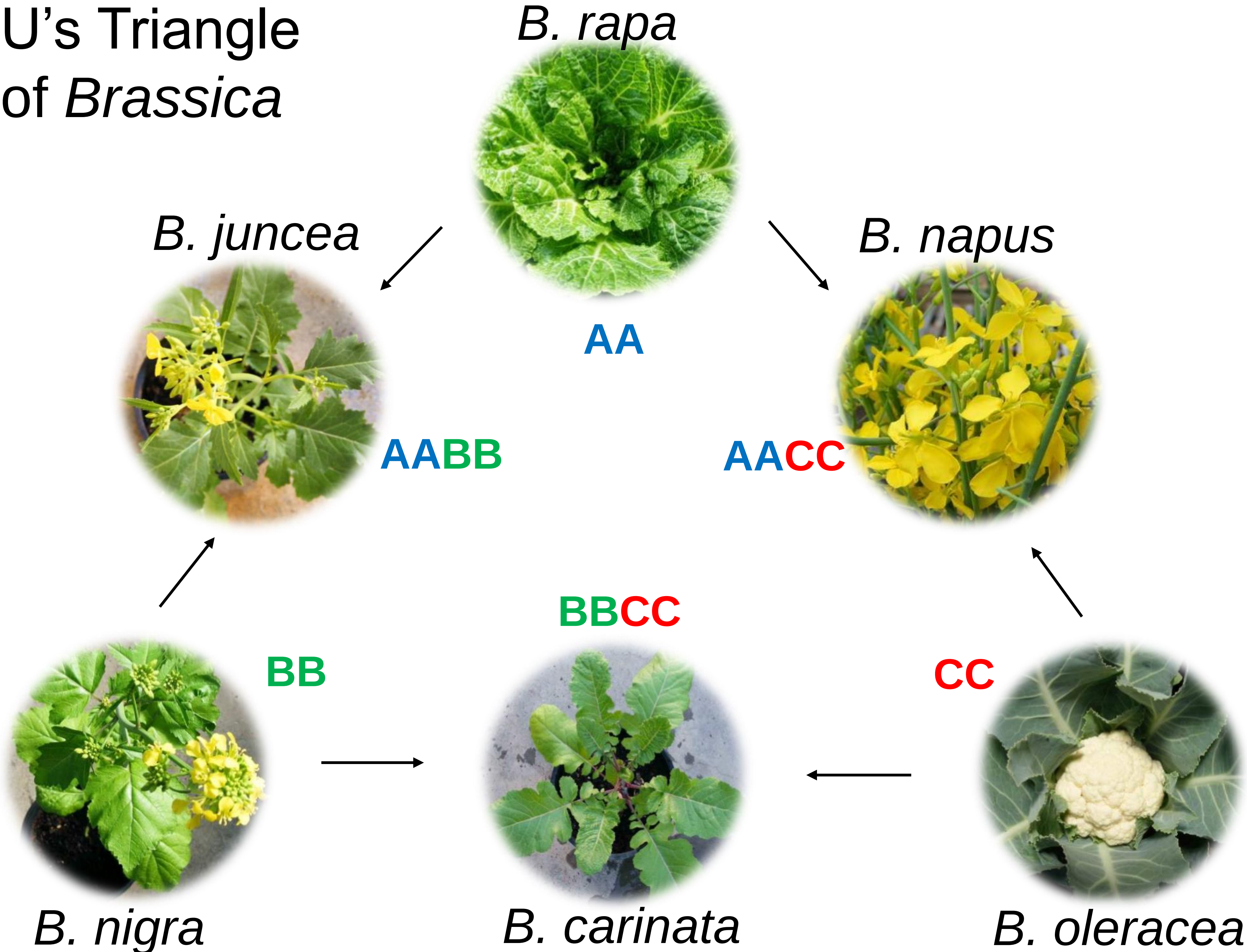


So can we synthesize new, stable polyploid and hybrid crop species for agricultural benefit?





U's Triangle of *Brassica*



Novel hybrid species by hybridisation between allopolyploids *B. juncea* and *B. carinata* followed by genome merger

B. juncea *B. carinata*

Parent species

X

$2n = AABB$ $2n = BBCC$

First generation interspecific hybrids

F_1)

$2n = BBAC$

$\otimes$

S_1) BBAC S_1

$\otimes$

Self-pollinated progeny generations

S_2) BBAC S_2

$\otimes$

$\otimes$

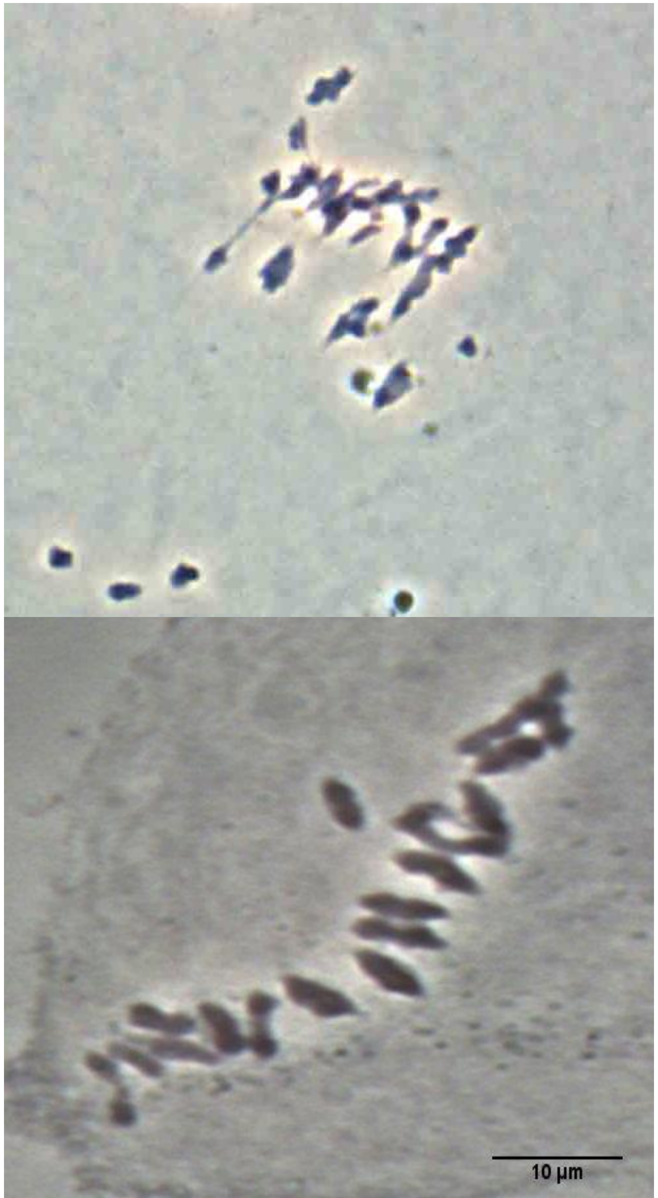
$\otimes$

S_6) BBAC S_6

Elvis Katche

Katche et al. in preparation

Regular meiosis in later generation BBAC hybrids



Generation	Average bivalent pairing
BBAC F_1	67% (highly unstable)
BBAC S_6	98% (highly stable)

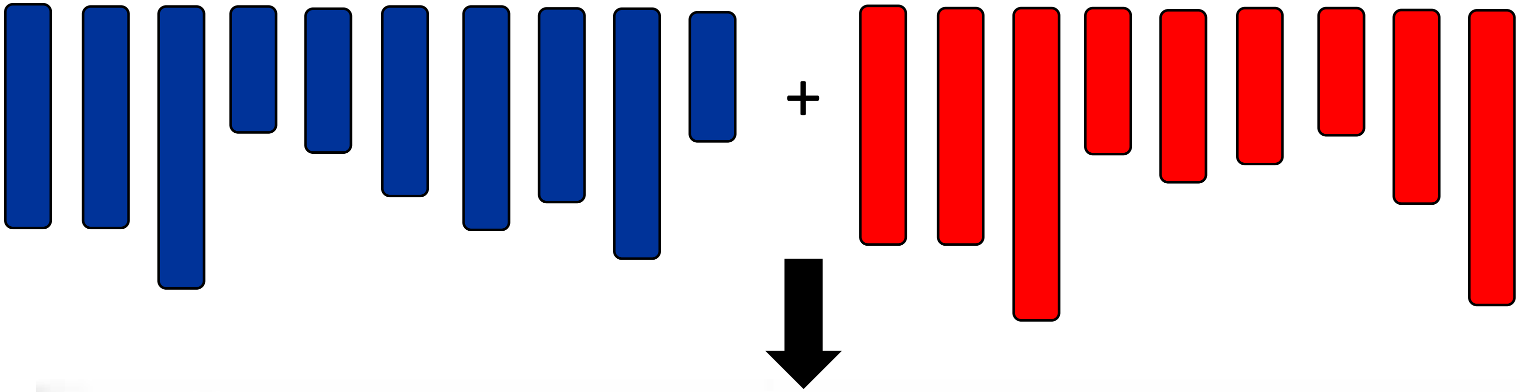
Seed fertility restored to species parent levels in many progeny sets

Mason et al. 2010 Chromosome Research; Katche et al. in preparation

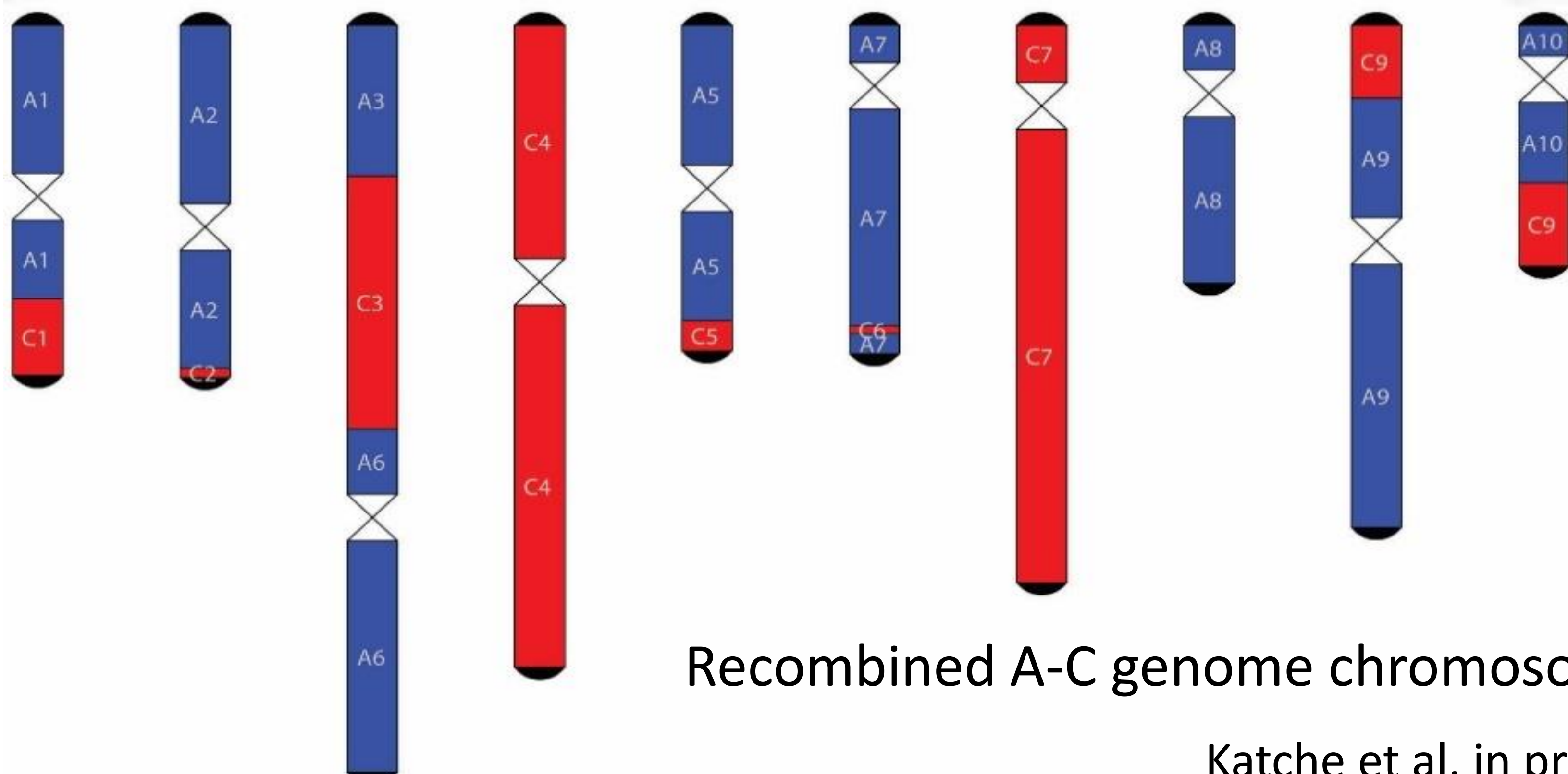
What happened to the A and C genomes?

10 A chromosomes

9 C chromosomes



Elvis Katche



Recombined A-C genome chromosomes

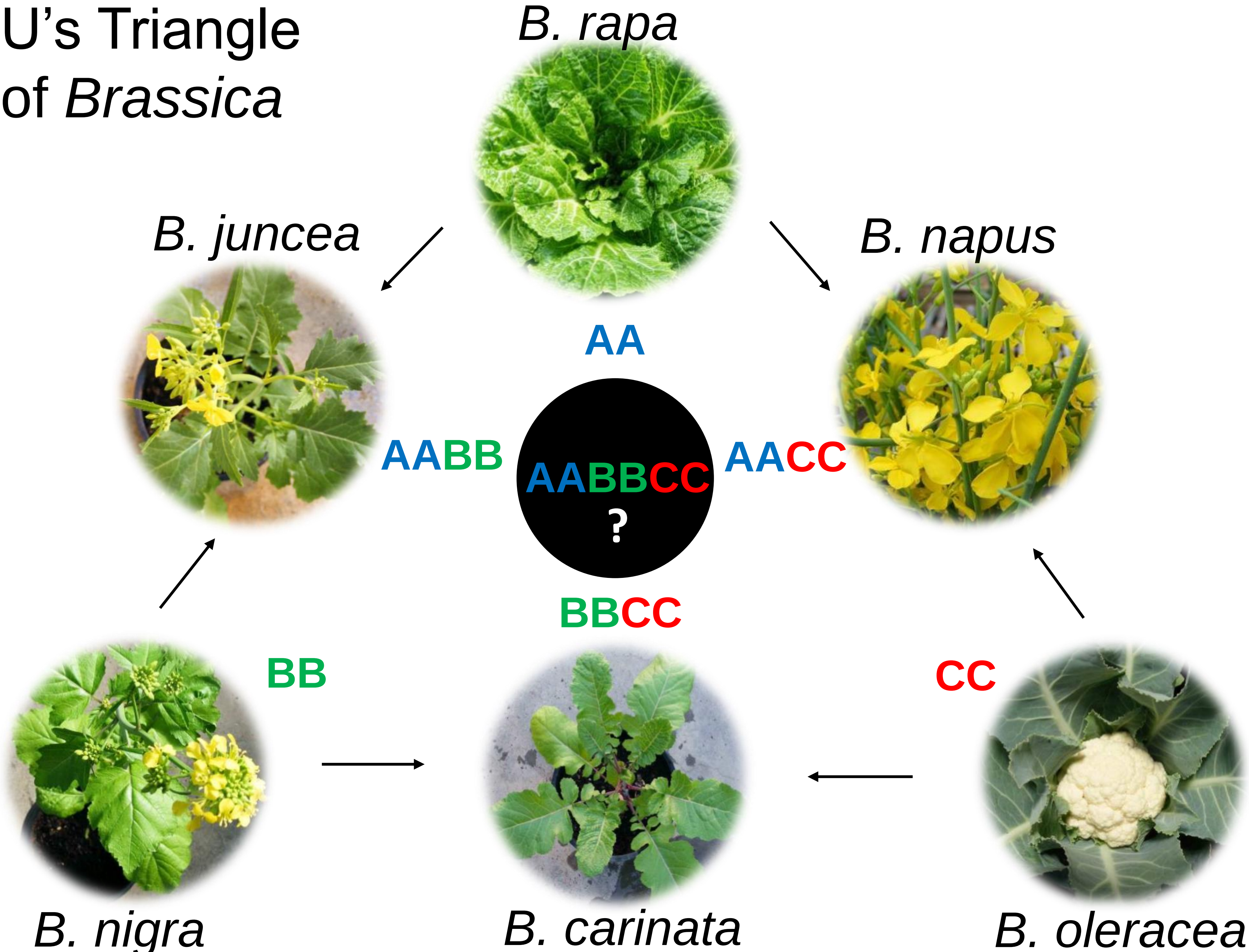
Katche et al. in preparation

Conclusions

- Selection for fertility resulted in new, stable hybrid genomes made up of recombined A-and C-genome chromosomes

- This provides the first experimental support in any genus for the formation of new genomes and species through hybridization between allopolyploids which share one of two genomes in common

U’s Triangle of *Brassica*



Types of allohexaploids produced so far

B. napus* × *B. nigra

$A^nA^nC^nC^nB^iB^i$

Gaebelein et al. and Mason 2019 *Chromosome Research*

B. carinata* × *B. rapa

$A^rA^rC^cC^cB^cB^c$

Sino-German grant collaboration with HZAU and ZJU

B. juncea* × *B. oleracea

$A^jA^jC^oC^oB^jB^j$

Mwathi et al. and Mason 2020 *PCTOC*

(*B. napus* × *B. carinata*) × *B. juncea*

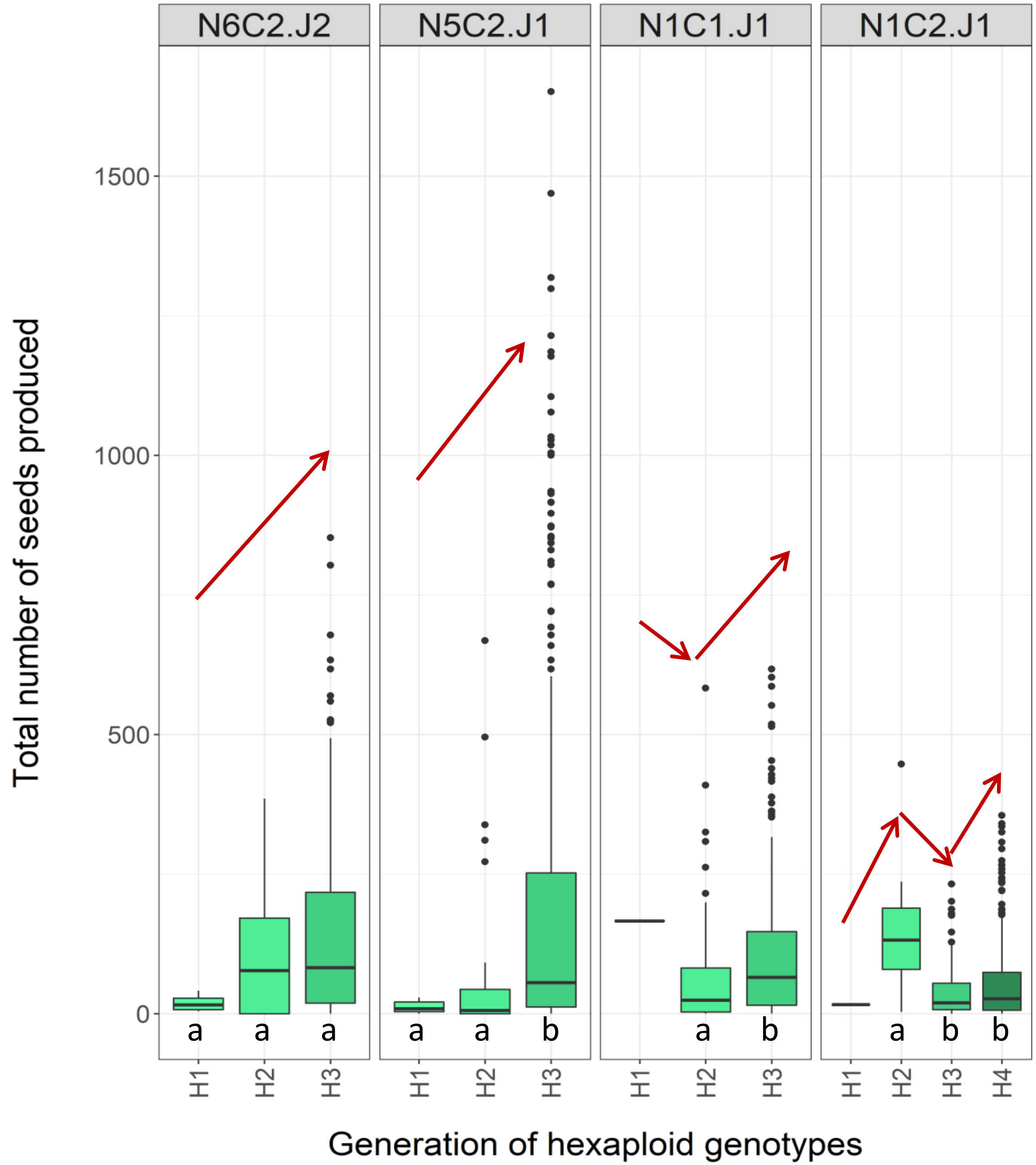
$A^{n/j}A^{n/j}C^{n/c}C^{n/c}B^{j/c}B^{j/c}$

Mason et al. 2011 *Euphytica*; Mason et al. 2014 *Genetics*, Gaebelein et al. 2019 *New Phytologist*

Major results

Fertility and genome stability improves with generational selection in *Brassica* allohexaploids

...But some genotypes also confer immediate stability: several stable combinations identified so far



Gaebelein et al. 2019 *New Phytologist* + unpublished results

We identified alleles of meiosis genes present in the parent species which could be selected for to produce immediately stable *de novo* allohexaploids

Roman Gäbelein

Dr. Sarah Schießl

- Multiple loci are involved, rather than just one major locus (unfortunately)
- Genes in each of the A, B and C genomes are implicated, and interact
- The number of functional copies of each meiosis gene plays a major role
- Validation is ongoing

Gaebelein et al. 2019 New Phytologist + unpublished results

Allohexaploids: next step

- Sino-German collaboration project: towards a viable allohexaploid crop
- Improve agronomic traits, genetic diversity and meiotic stability

- Poster P-59

Daniela Quezada Martinez

Prof. Jun Zou

HZAU

ZJU

Prof. Weijun Zhou

Overview

- In *Brassica* and many other crop species, there are opportunities to exploit polyploidy and hybridisation for crop improvement and breeding

- Better understanding of the processes involved in hybrid and polyploid species formation will facilitate innovative utilisation of genetic diversity from wild relatives and production of new crop types

Funding acknowledgements

- Hybrid Speciation in *Brassica*

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DFG

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

Giessen Plant Breeding

- Recreating genomically stable rapeseed

DFG Deutsche Forschungsgemeinschaft
German Research Foundation

- Towards new *Brassica* crops genetic improvement of *Brassica* allohexaploids

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ZHEJIANG UNIVERSITY 1897

華中農業大學
HUAZHONG AGRICULTURAL UNIVERSITY

Jun Zou Weijun Zhou

- Phoma resistance – introgression from wild species into rapeseed

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PHASE Lab

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