Wide Hybridization in Plant Breeding

Wide hybridization

- a cross of two individuals belonging to different species (also called interspecific hybridization)

- Such a cross can be (rarely) realized in nature – origin of new species

- But: it has to overcome barriers prohibiting such a cross by itself OR the development of fertile offspring

Barriers prohibiting wide hybridization

- Ecological
- Morphological
- Biochemical
- Cytological
- Genetic

Wide hybridization

-Occur in nature

- Breeders developed methods to overcome barriers and have produced various hybrids, mainly improved crops

Purpose:

Usually employed to widen the gene pool of a crop

Practically, most often used to transfer genes
for resistance to biotic/abiotic stress

Methods:

- Amphiploids
- Single Chromosome Additions/Substitutions
- Centric translocations
- Homoeologous recombination

Amphiploids (Allopolyploids)

Octoploid Triticale

Bread wheat (2n=6x=42; AABBDD) x Rye (2n=2x=14; RR)

↓

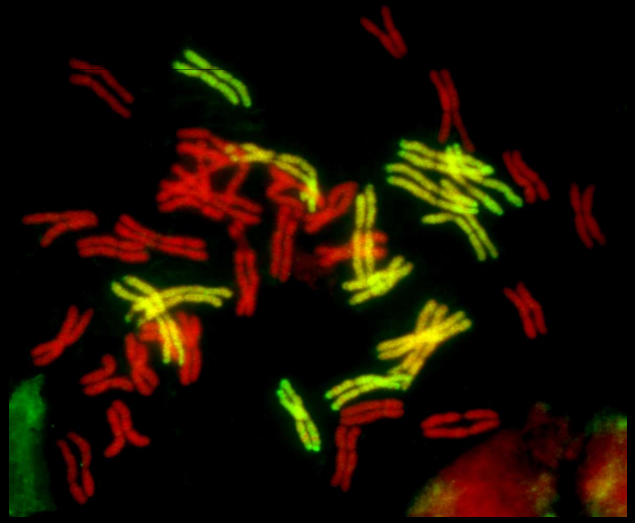
Triticale (2n=8x=56; AABBDDRR)

Hexaploid Triticale

Durum wheat (2n=4x=28; AABB) x Rye (2n=2x=14; RR)

↓

Triticale (2n=6x=42; AABBRR)



Courtesy of Adam J. Lukaszewski, UCR

Amphiploids (Allopolyploids)

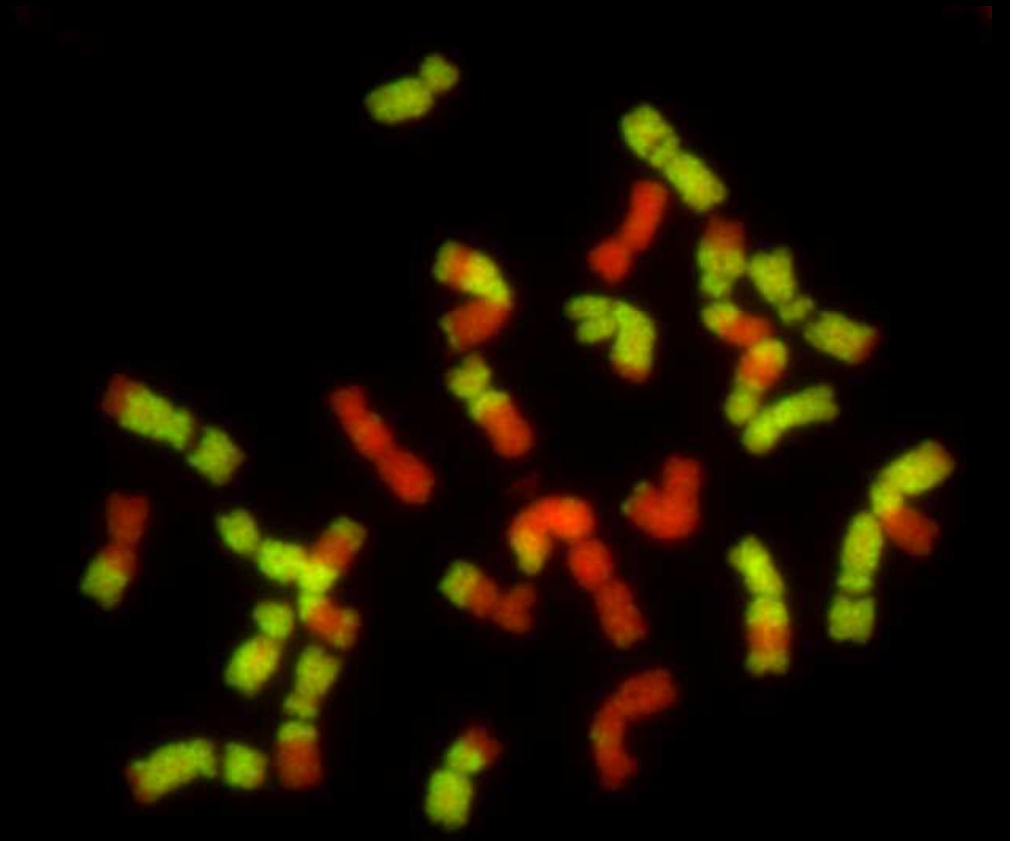
Italian ryegrass (2n=2x=14)

Meadow fescue (2n=2x=14)

Chromosome doubling

Italian ryegrass (2n=4x=28) x Meadow fescue (2n=4x=28)

Festulolium (2n=4x=28)



Polyploidy

Advantages:

- Intergenomic heterosis
- Gene redundancy*
- Loss of incompatibility
- Organism architecture

Disadvantages:

- Cell architecture (2x vs. 1.6x)
- Problems in divisions
- Epigenetic instability
- Sex determination

* Role of polyploidization in evolution

Single Chromosome Additions/Substitutions

Festuca pratensis (2n=2x=14) x *Lolium multiflorum* (2n=4x=28)

↓

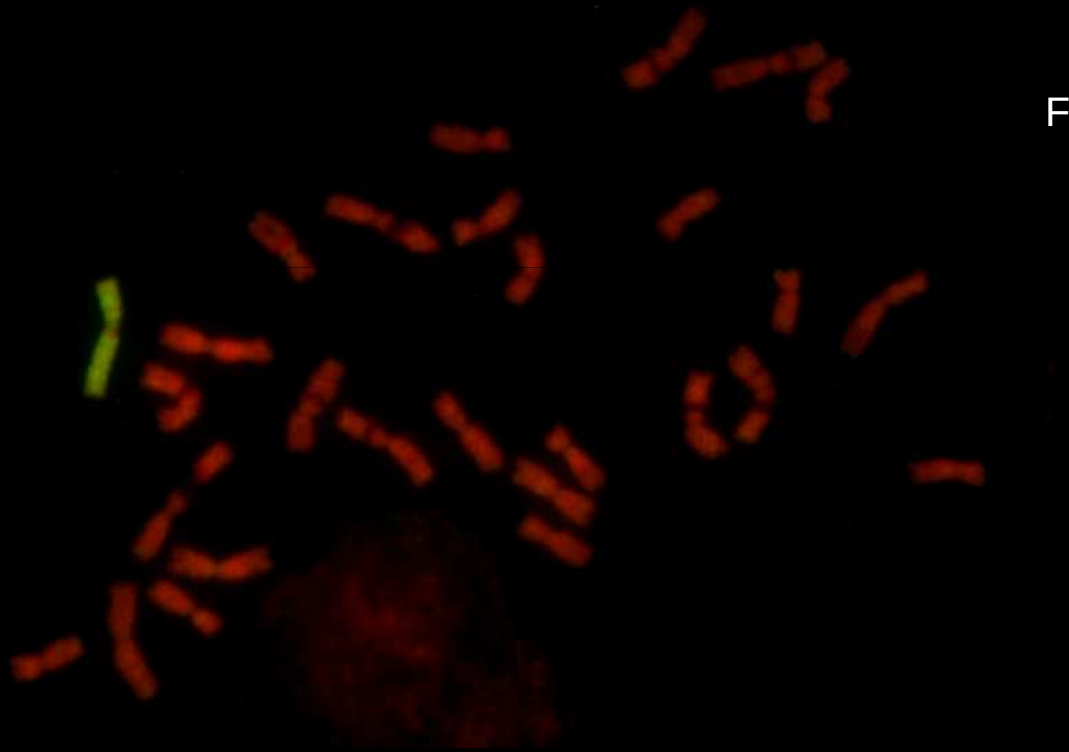
F1: (2n=3x=21, FpLmLm) x Lm (2n=4x=28)

↓

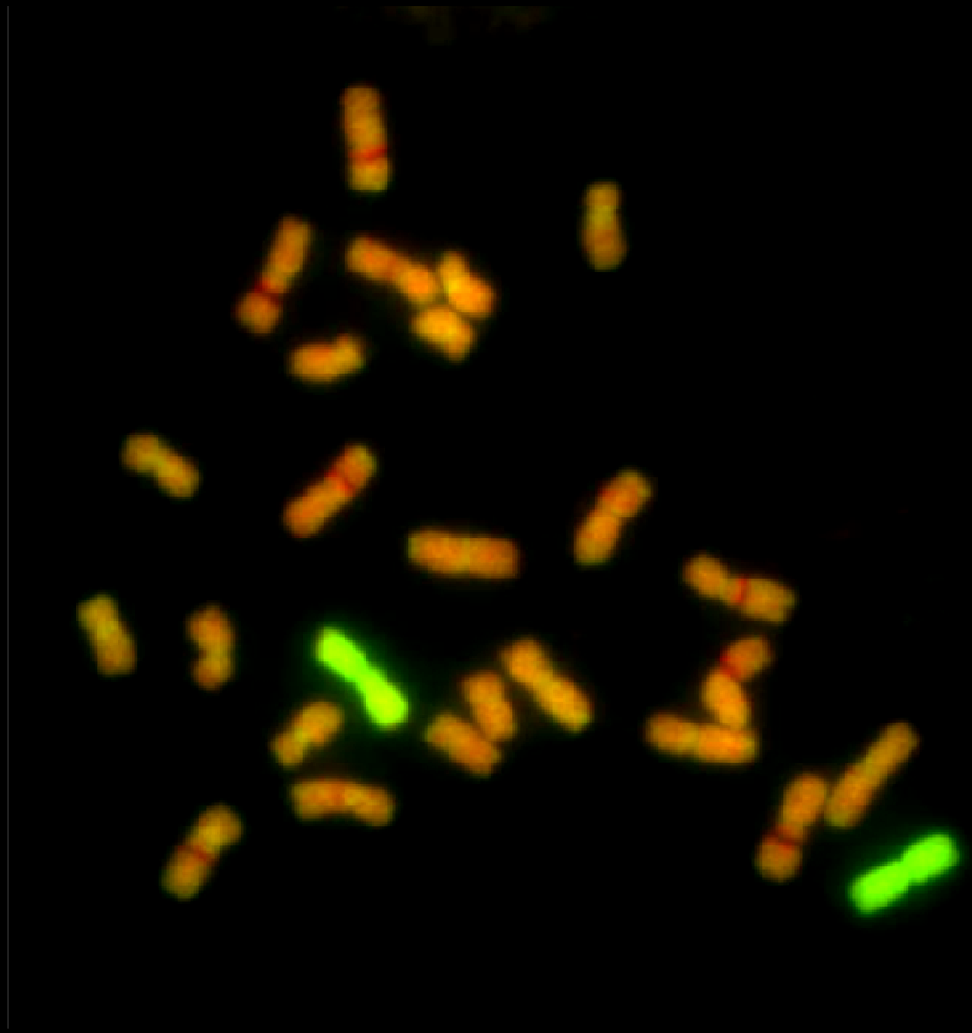
F2: (2n=4x=28, FpLmLmLm) x Lm (2n=4x=28)

↓

F3 etc. (2n=4x=28; 27Lm+1Fp)



Disomic substitution of meadow fescue in Italian ryegrass



Introgression of an entire genome (as in an amphiploid) or of a complete chromosome, in addition to the desired character, will also introduce many undesirable characteristics.

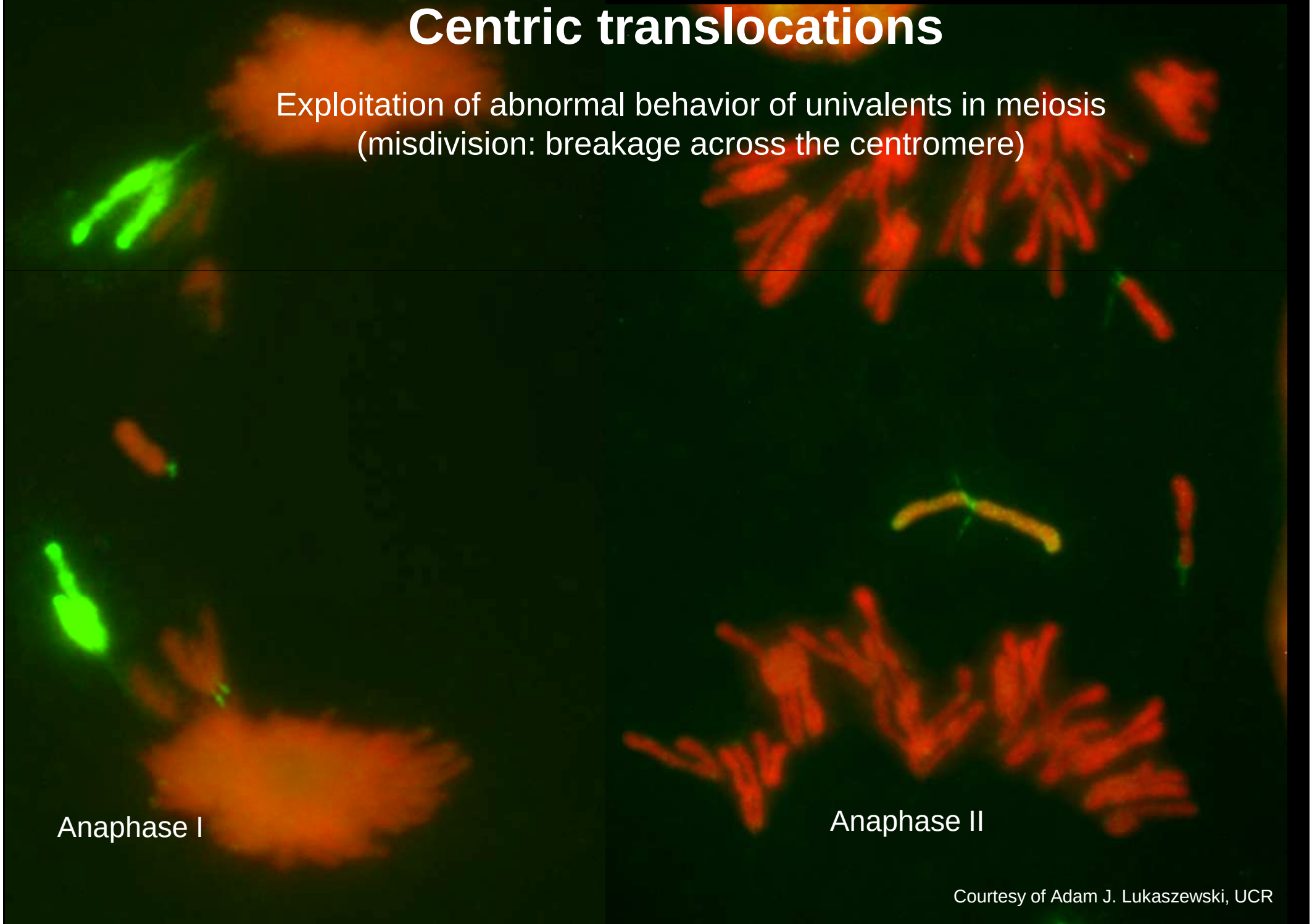
This is called linkage drag.

In most cases, the amount of alien (exotic) chromatin must be reduced, or at least, the offending locus removed.

Examples:
Triticale combines rye tolerance of stresses with wheat productivity, but has poor bread making quality.

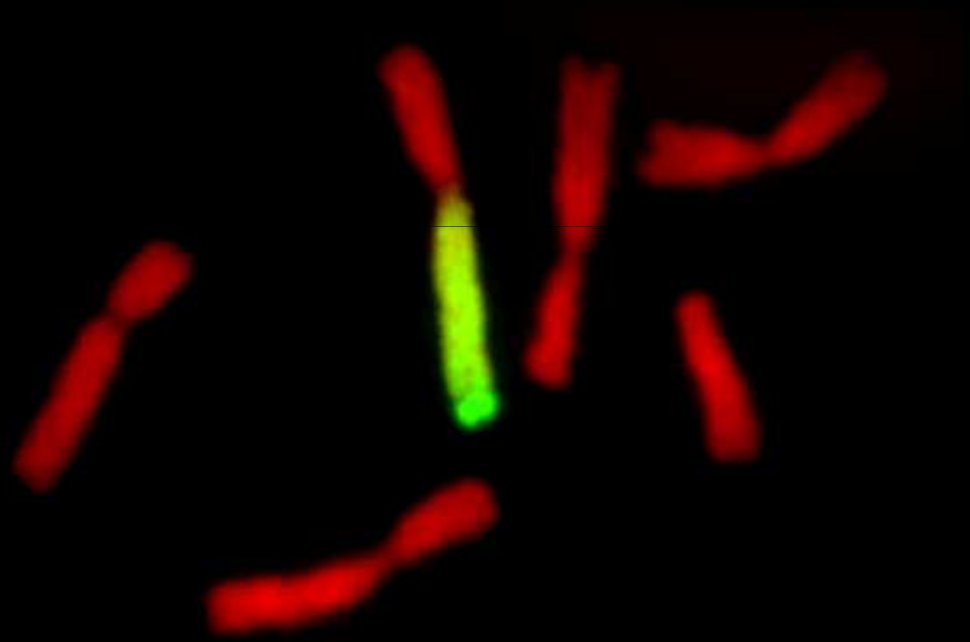
Centric translocations

Exploitation of abnormal behavior of univalents in meiosis
(misdivision: breakage across the centromere)



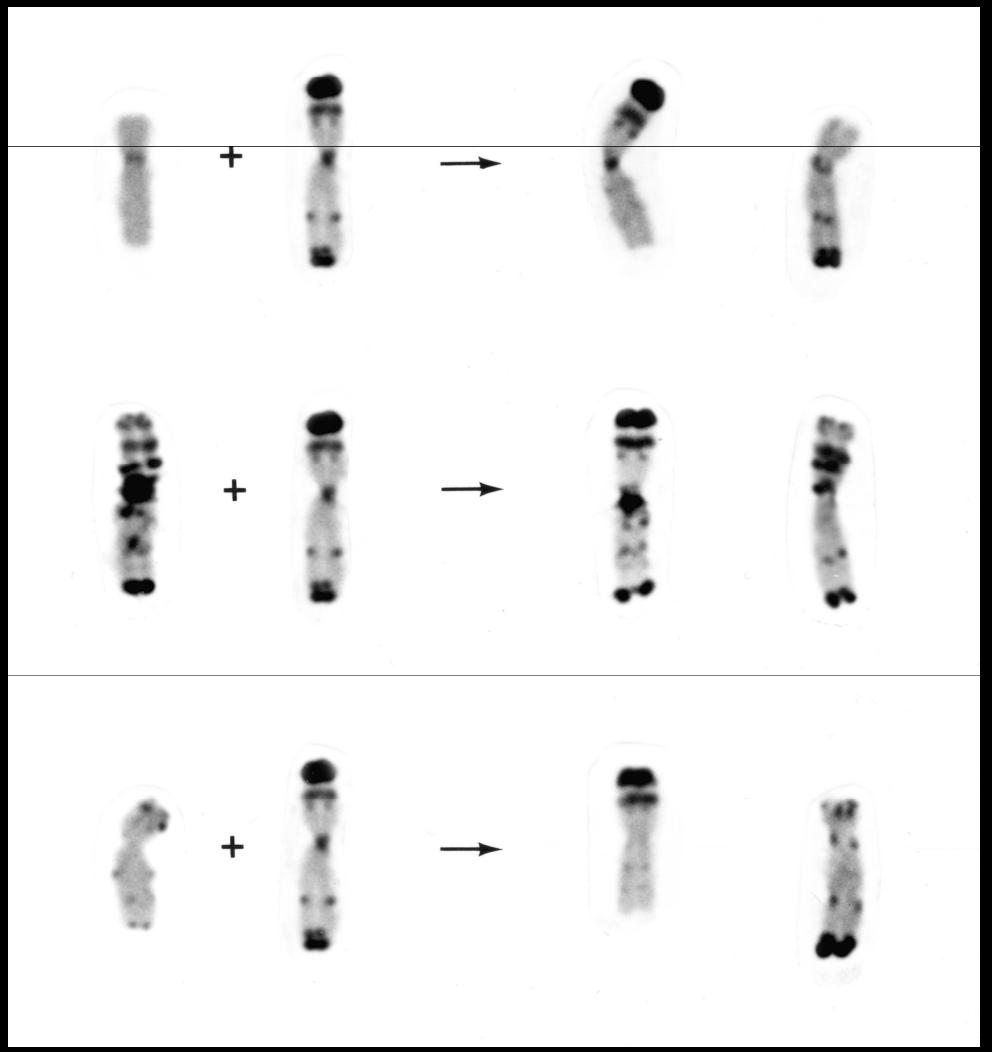
Courtesy of Adam J. Lukaszewski, UCR

If misdivision products of the two chromosomes
(in essence, one arm from each chromosome)
end up in the same cell (gamete? embryo?),
they fuse to produce a centric (whole arm) translocation.



Centric translocations:

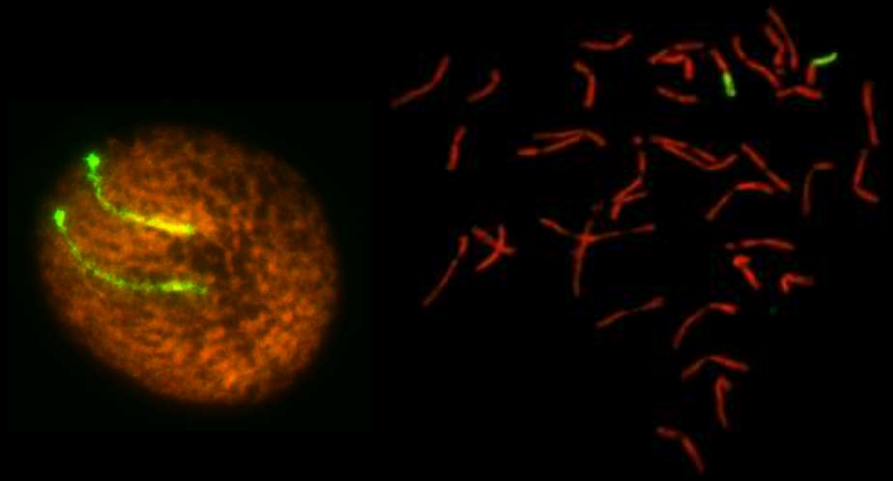
1R of rye with wheat group 1 homologues

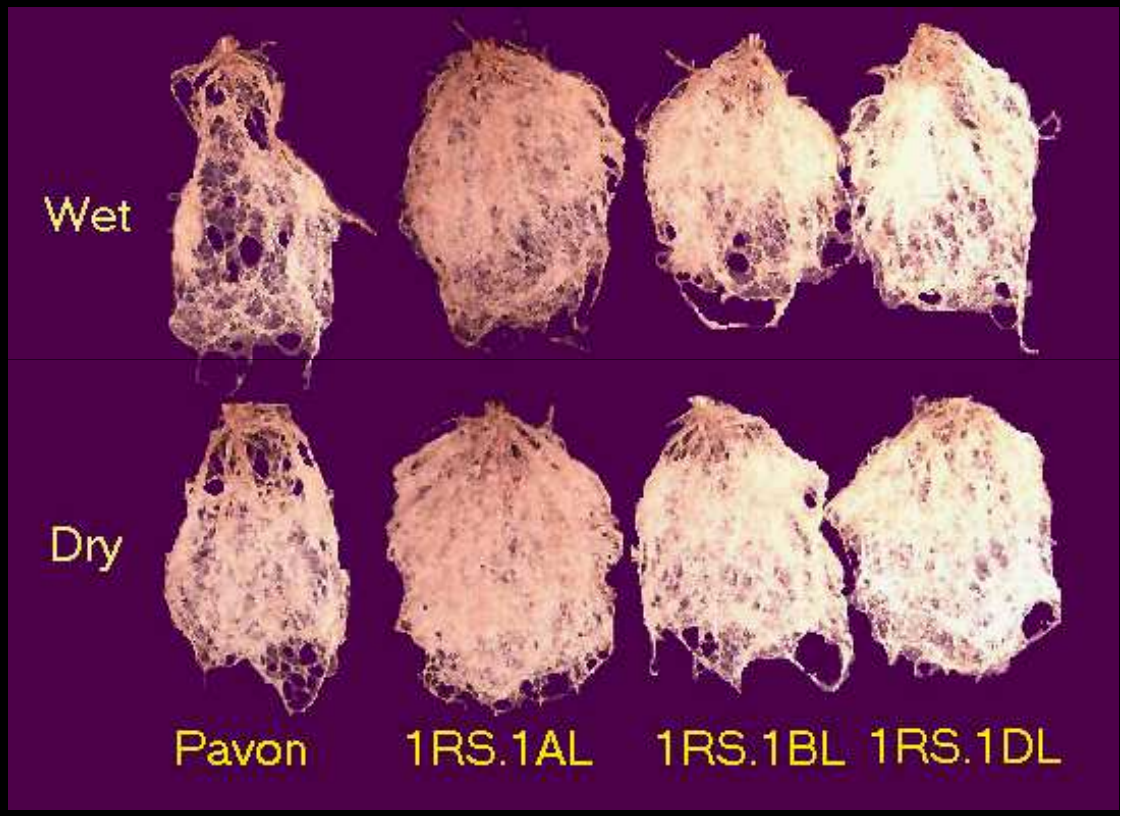


Courtesy of Adam J. Lukaszewski, UCR

Wheat-rye translocation 1RS.1BL is THE most common alien introgression in commercial wheat. It was selected for its package of disease resistance genes *Lr26, Sr31, Yr9 and Pm8,* but when these broke down, the translocation was found to increase yield, by ca. 7-8%.

This increases is related to a larger root biomass. The translocation also negatively impacts bread making quality.





Courtesy of Giles Waines, UCR

Induced homoeologous recombination

aka chromosome engineering

E.R. Sears' Approach

Invented for wheat but is applicable to all ploidy levels
and different chromosome pairing control systems

Wheat is an amphiploid (2n=6x=42; AABBDD).
Amphiploids in general benefit from stringent recombination.

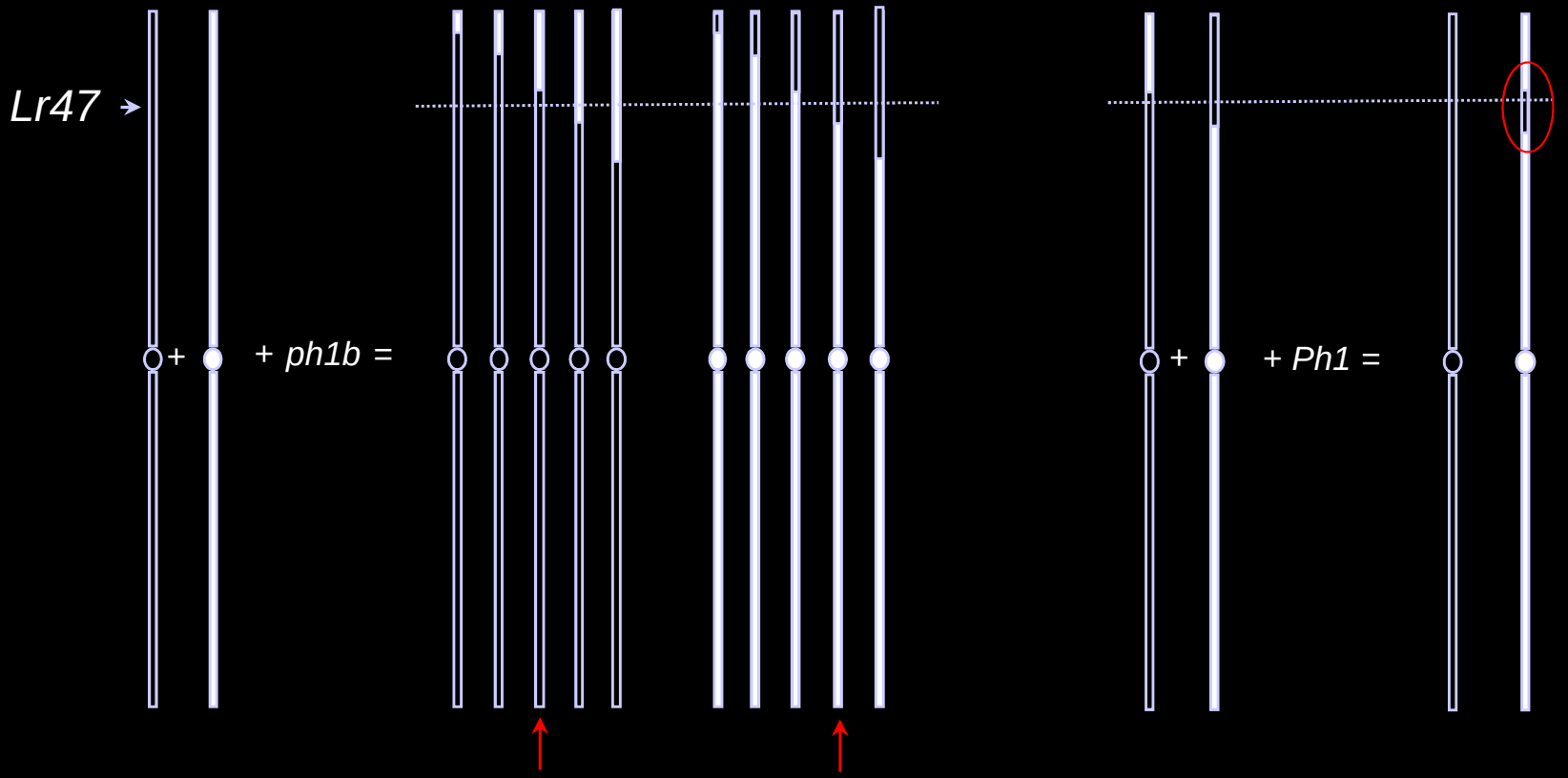
In wheat, this stringency is imposed by the *Ph1* locus.
In its presence, there is no pairing of homoeologues.

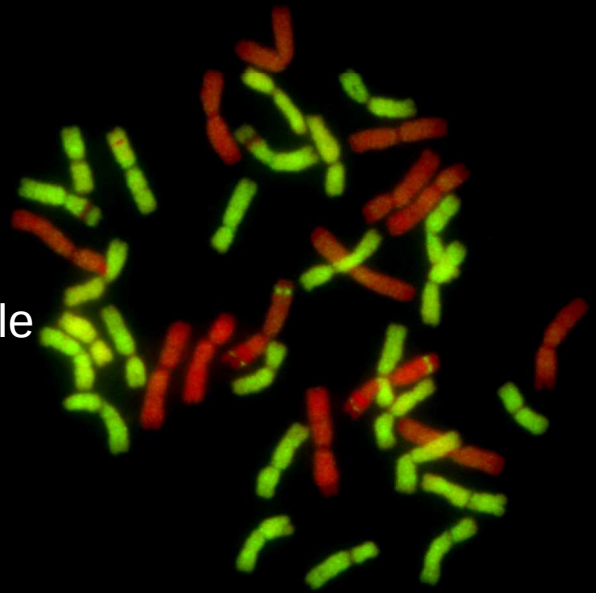
To induce pairing and recombination of homoeologues
the *Ph1* system has to be disabled.

This can be accomplished by mutation (deletion)
or substitution of chromosome 5B.
In diploids, there are no *Ph1*-like systems, so the process is simpler.

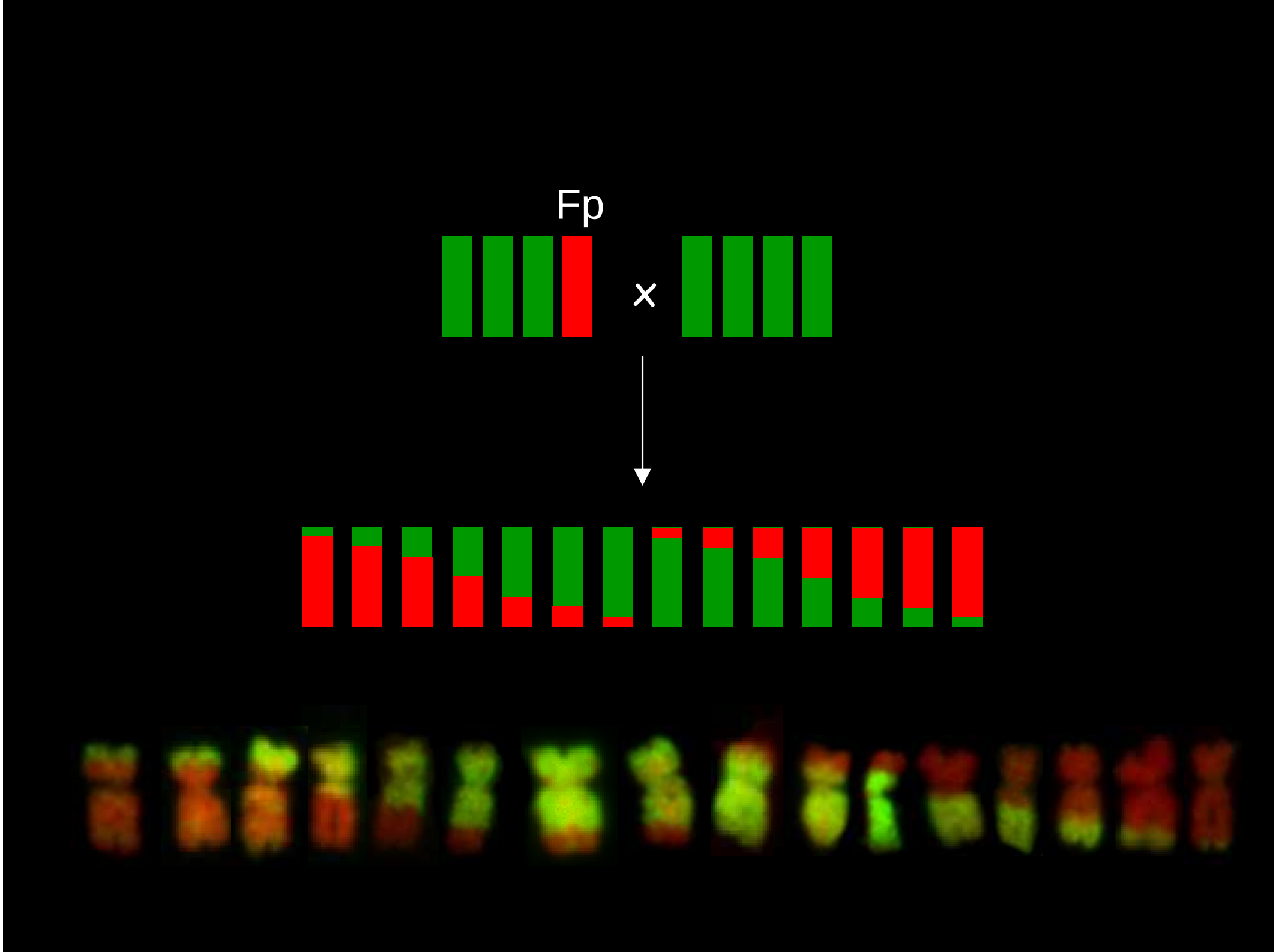
Step 1

Step 2





- Generate many primary recombinants
- Select flanking breakpoints as close to the locus of interest as possible
- recombine the two and select a small intercalary introgression


Fp
x

- induced homoeologous recombination is perhaps best
  - very small introgressions possible
  - guarantees precision
  - guarantees proper location in the genome

BUT:

  - requires patience and time
  - requires at least minimum homoeology
  - requires substantial time investment
    in the early stages

Summary

-Wide hybridization is a cross of two individuals belonging to different species

-The success (production of fertile offspring) depends on overcoming barriers

-It occurs in nature and can lead to speciation

-Breeders use it to incorporate important traits (from wild species to crops)

-The strategies:

- Amphiploids
- Single chromosome addition (substitution) lines
- Centric translocations
- Induced homoeologous recombinations

http://olomouc.ueb.cas.cz/users/kopecky
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