Wheat Chromosome Engineering and Breeding

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Chromosome Engineering

- A process to transfer favorable alleles through **inter-specific hybridization** and interchange of chromatin using **aneupolids**

Aneuploids?

- Individuals having chromosome numbers other than an exact multiple of **the basic chromosome set.**
- **A basic chromosome set** contains all chromosomes in **a genome.**
- **A genome** is defined as **the basic chromosome set** that contains all the genetic information needed to produce an organism, denoted by a x.

Review Concepts

n: gametic (haploid) chromosome number. n = 3x = 21(wheat)

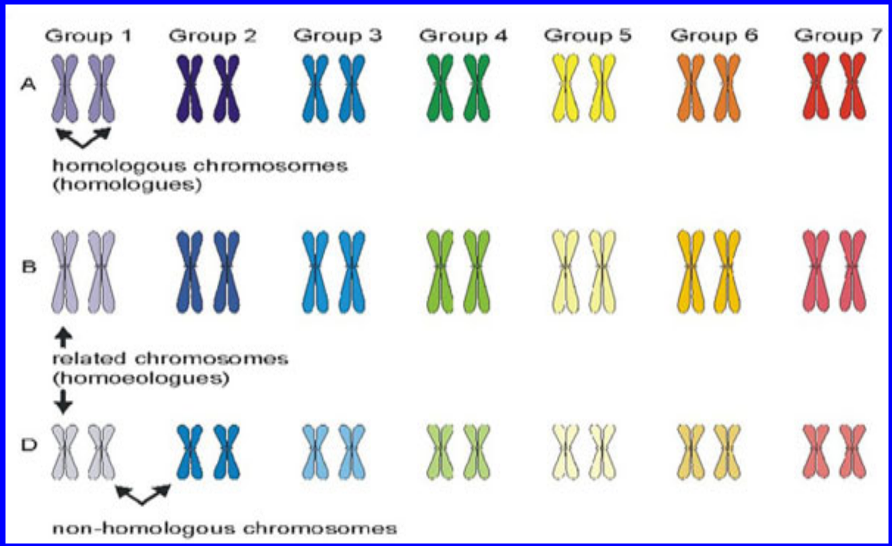
2n: disomic (somatic) chromosome number.

- wheat: 2n = 6x = 42; Barley: 2n = 2x = 14; Soybean: 2n = 2x = 20; Maize: 2n = 2x = 20

Outline of current lecture

- Types of aneuploids in common wheat
- Application of aneuploids in wheat genetic and mapping studies
- Application of aneuploids in wheat breeding

Genetic Features



- Hexaploid wheat has homoeologous genomes A, B, D derived from diploid species (AA- T. urartu, BB- Ae. Speltoides, DD- Ae. Squarrosa)
- Most of the genes have three homoeologous loci, which can functionally compensate for one another.
- The homoeologous genomes can tolerate loss or addition of chromosomes.
- Complete sets of aneuploids of Chinese Spring and other wheat varieties are available.

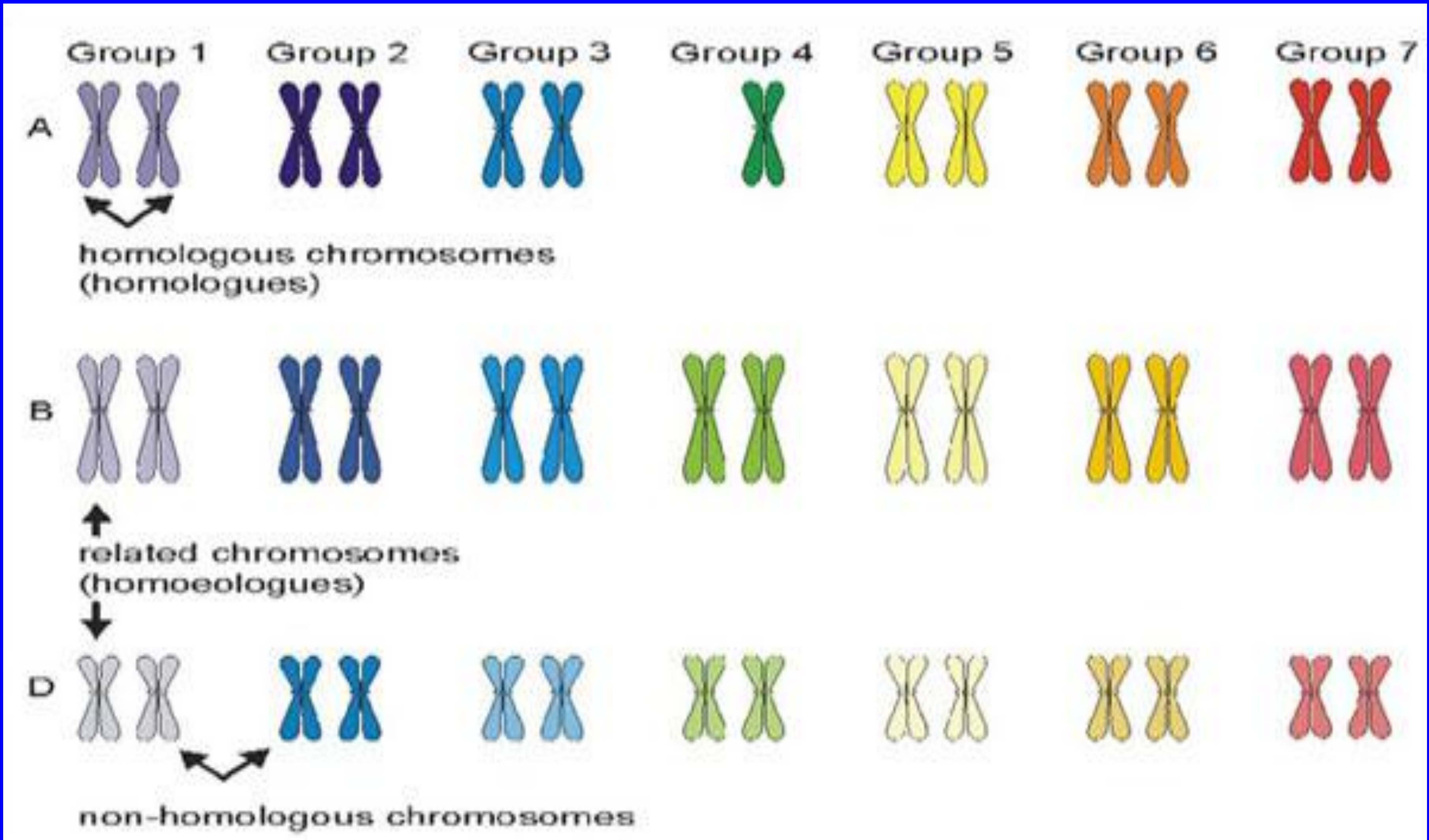
Wheat Aneuploid Series

- Monosomic lines (Sears, 1954)
- Nullisomic lines (Sears, 1954; Xue et al., 1990)
- Nulli-tetrasomic lines (Sears, 1954).
- Ditelosomic lines (Sears and Sears, 1978).
- Deletion stocks (Endo, 1978)

Monosomics (2n-1): a set of 21

- An individual lacks one of a pair of chromosomes from the normal diploid (disomic) complement (20 II +1I or 41).
- Plants look similar to the disomics and fertility is close to normal.
- Gametes are transmitted at a different rate through male and female.

Monosomy 4A (2n-1) - 4AM



Monosomic

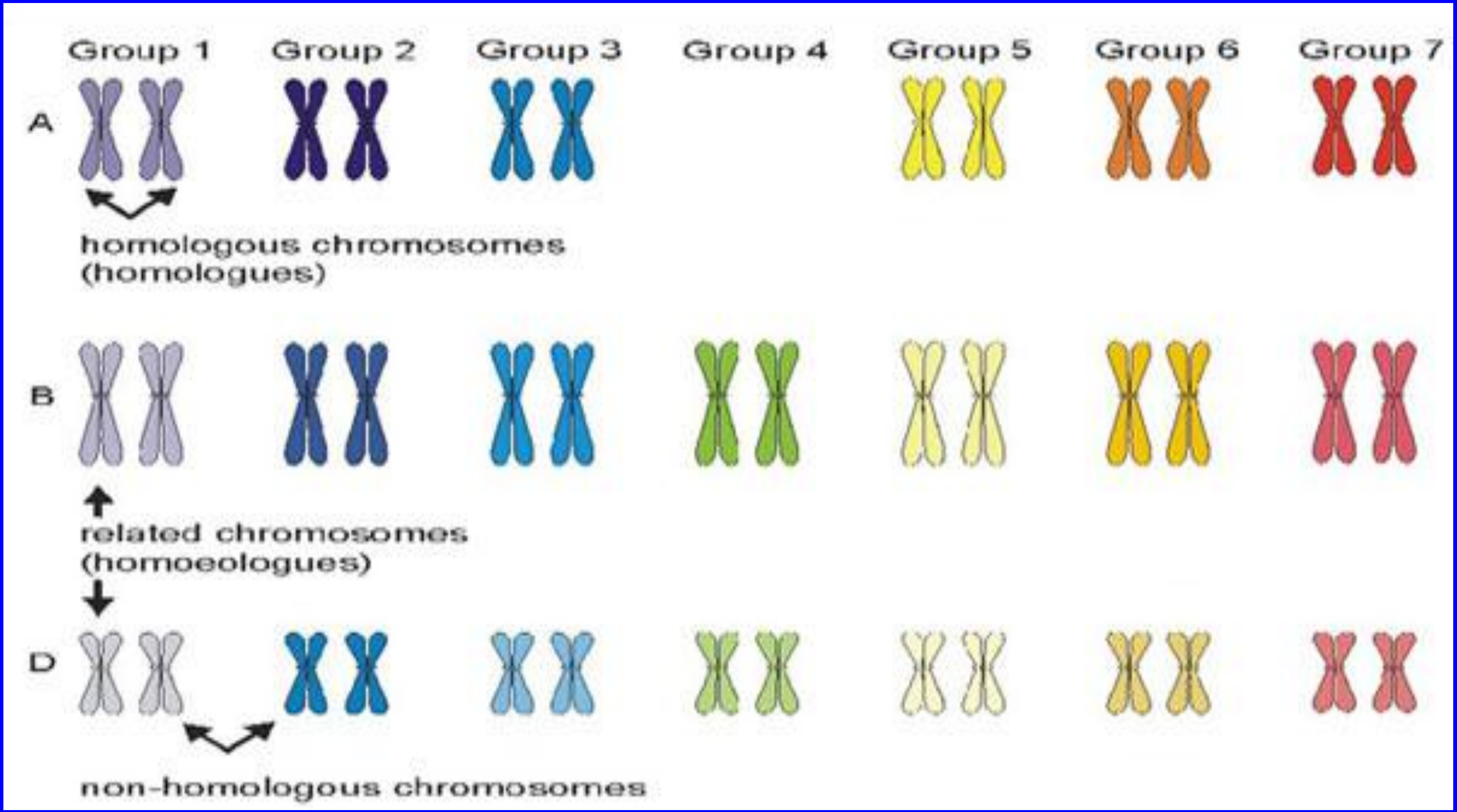
Expected transmission of the monosomics in *Triticum aestivum*

	Male Gamete	
Female Gamete	n (21) 96%	n-1 (20) 4%
n (21) 25%	Disomic 2n (42) 24%	Monosomic 2n-1 (41) 1%
n-1 (20) 75%	Monosomic 2n-1 (41) 72 %	Nullisomic 2n-2 (40) 3%

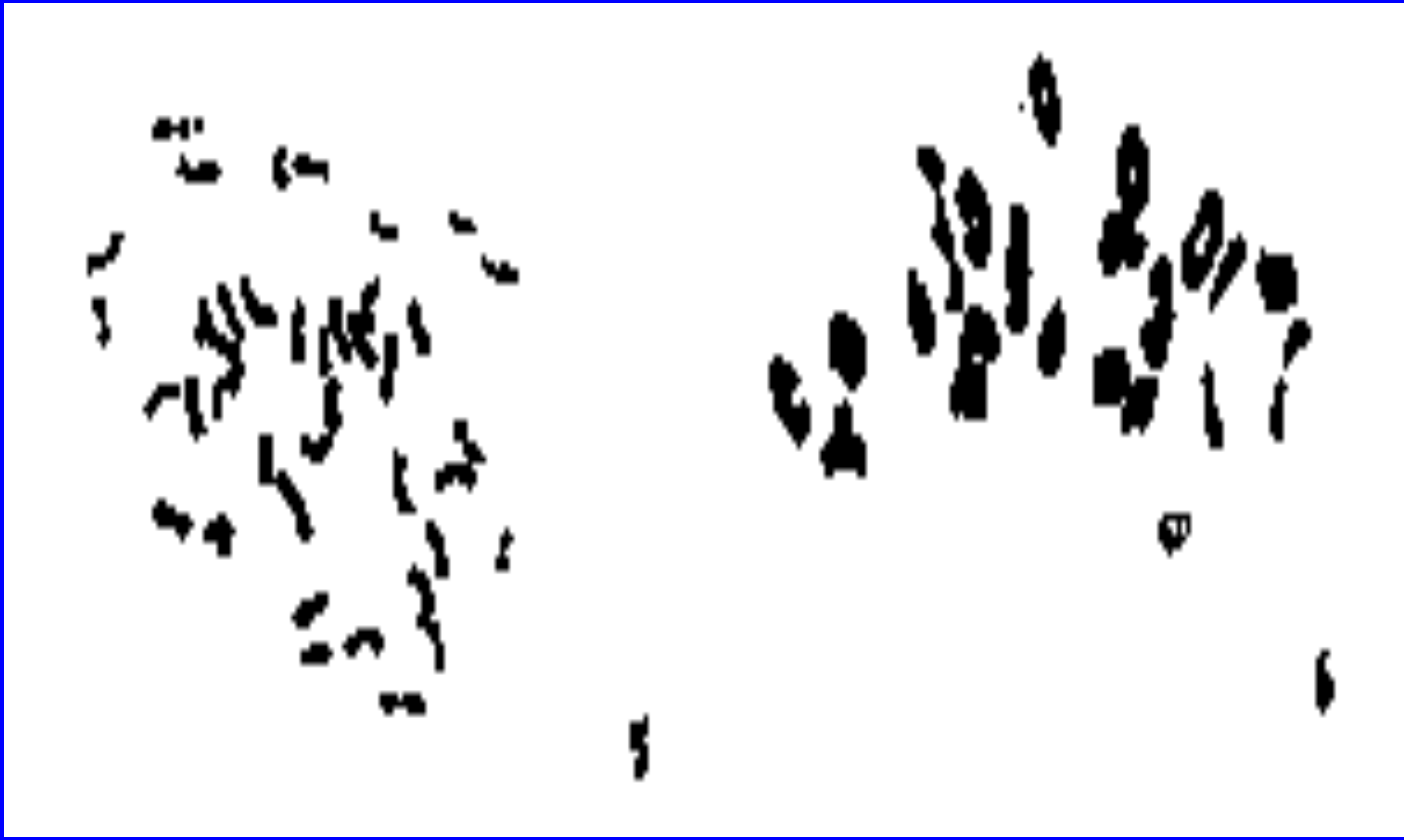
Nullisomics (2n-2): a set of 21

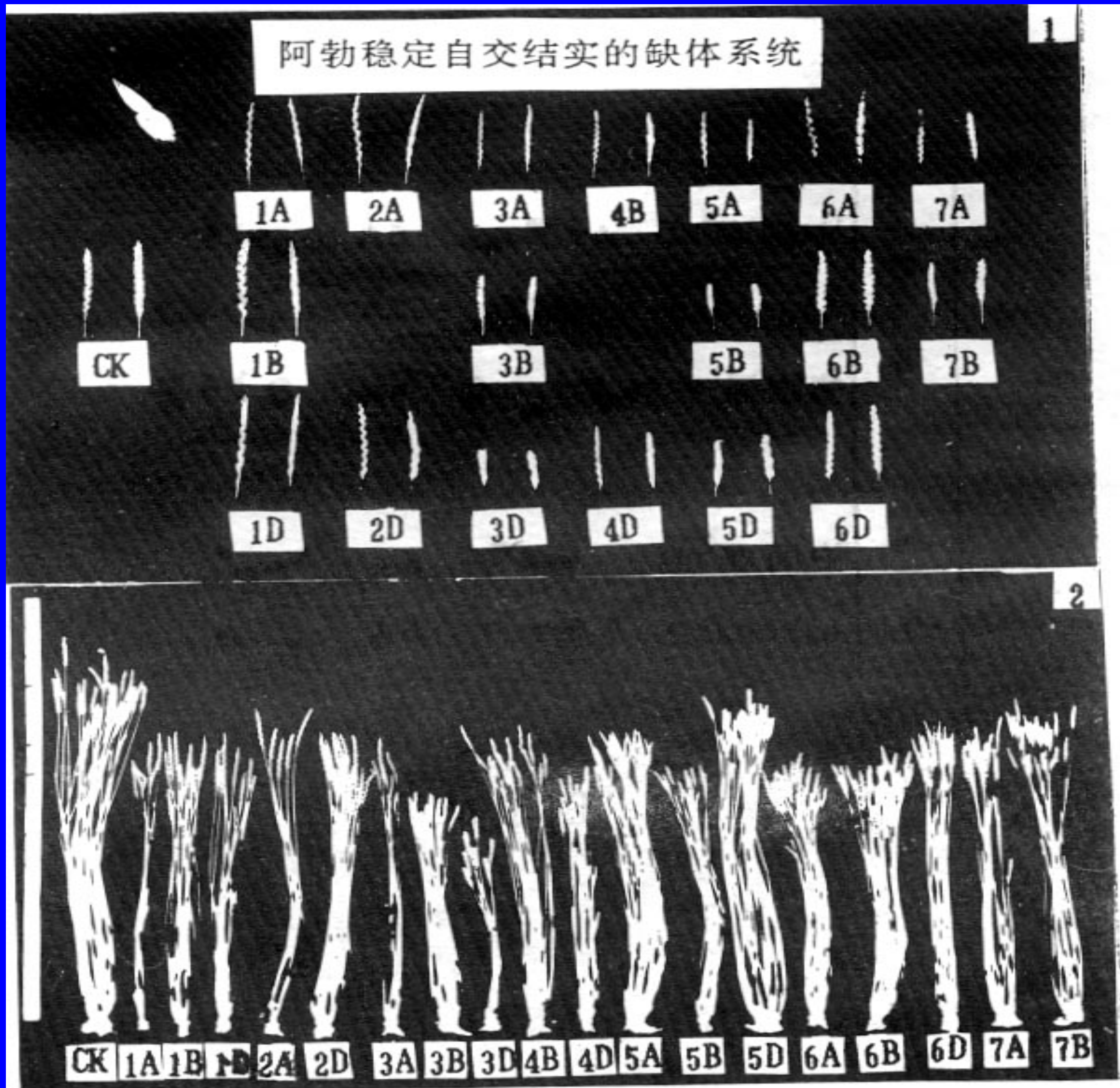
- An individual lacks of one pair of chromosomes from the normal diploid complement (20II or 40)
- Plants distinguishable by morphological features (vigor and size)
- Gametes transmitted via same rate in female and male

Nullisomy 4A (2n-2) – 4AN



Nullisomic

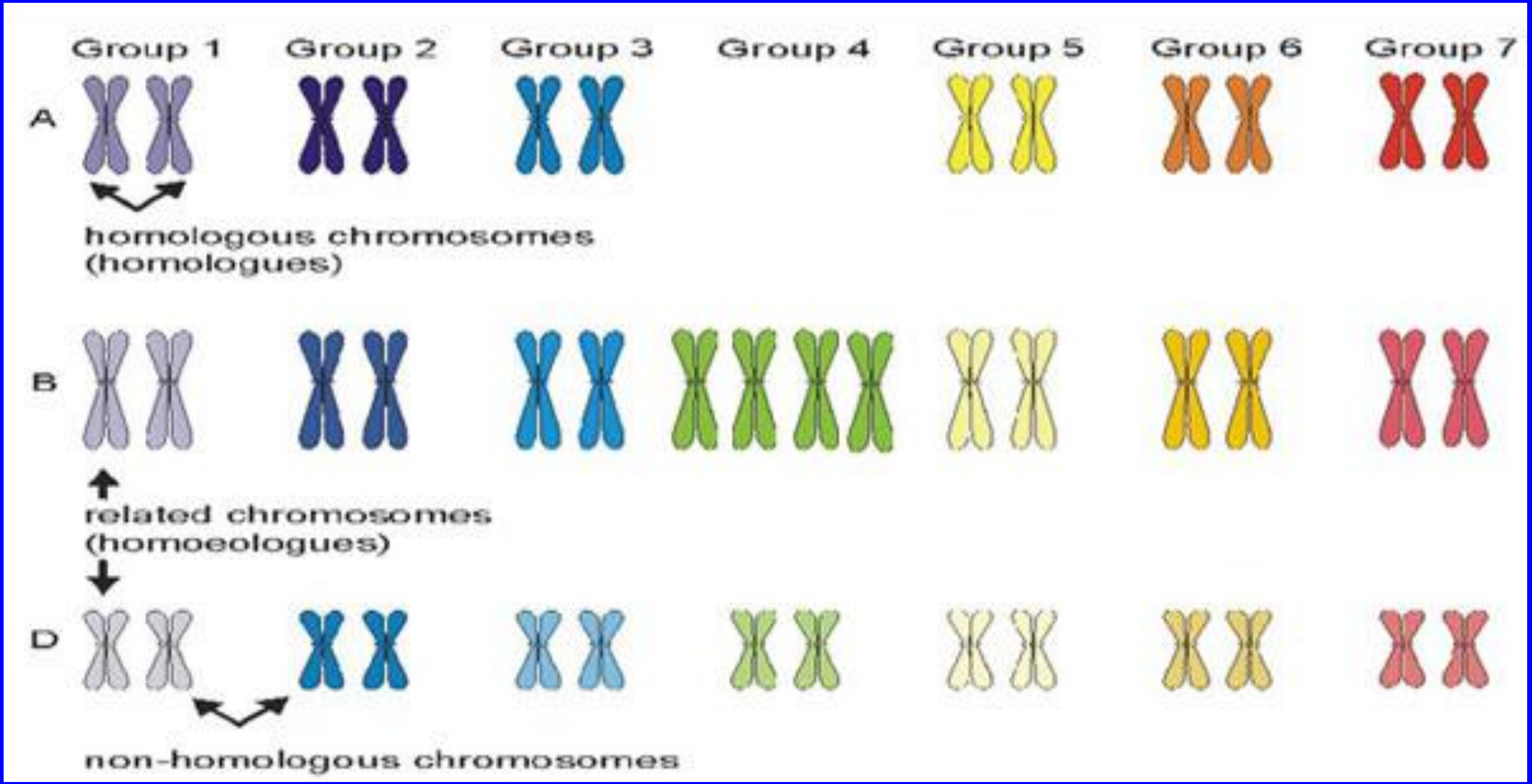



阿勃稳定自交结实的缺体系统
1
1A
2A
3A
4B
5A
6A
7A
CK
1B
3B
5B
6B
7B
1D
2D
3D
4D
5D
6D
2
CK 1A 1B 1D 2A 2D 3A 3B 3D 4B 4D 5A 5B 5D 6A 6B 6D 7A 7B

Nulli-tetrasomics: a set of 42

- An individual lacks one pair of chromosomes but have a doubled pair of chromosomes from the homoeologous group (19 II + 1IV, or 42)
- Plants look similar to disomics and fertility is close to normal
- Gametes transmitted via similar rate in female and male

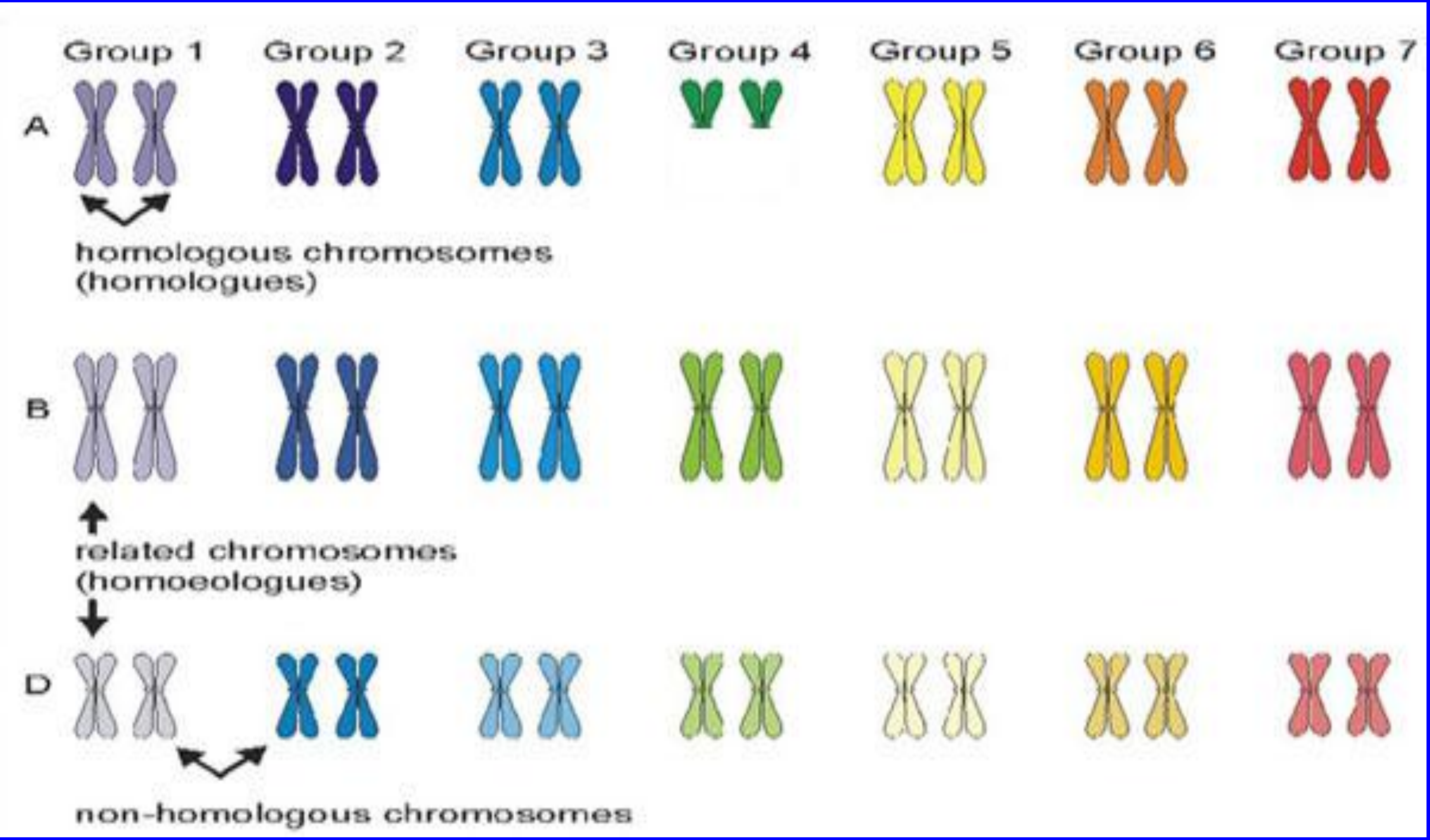
Nullisomy4ATetrasomy4B - N4AT4B



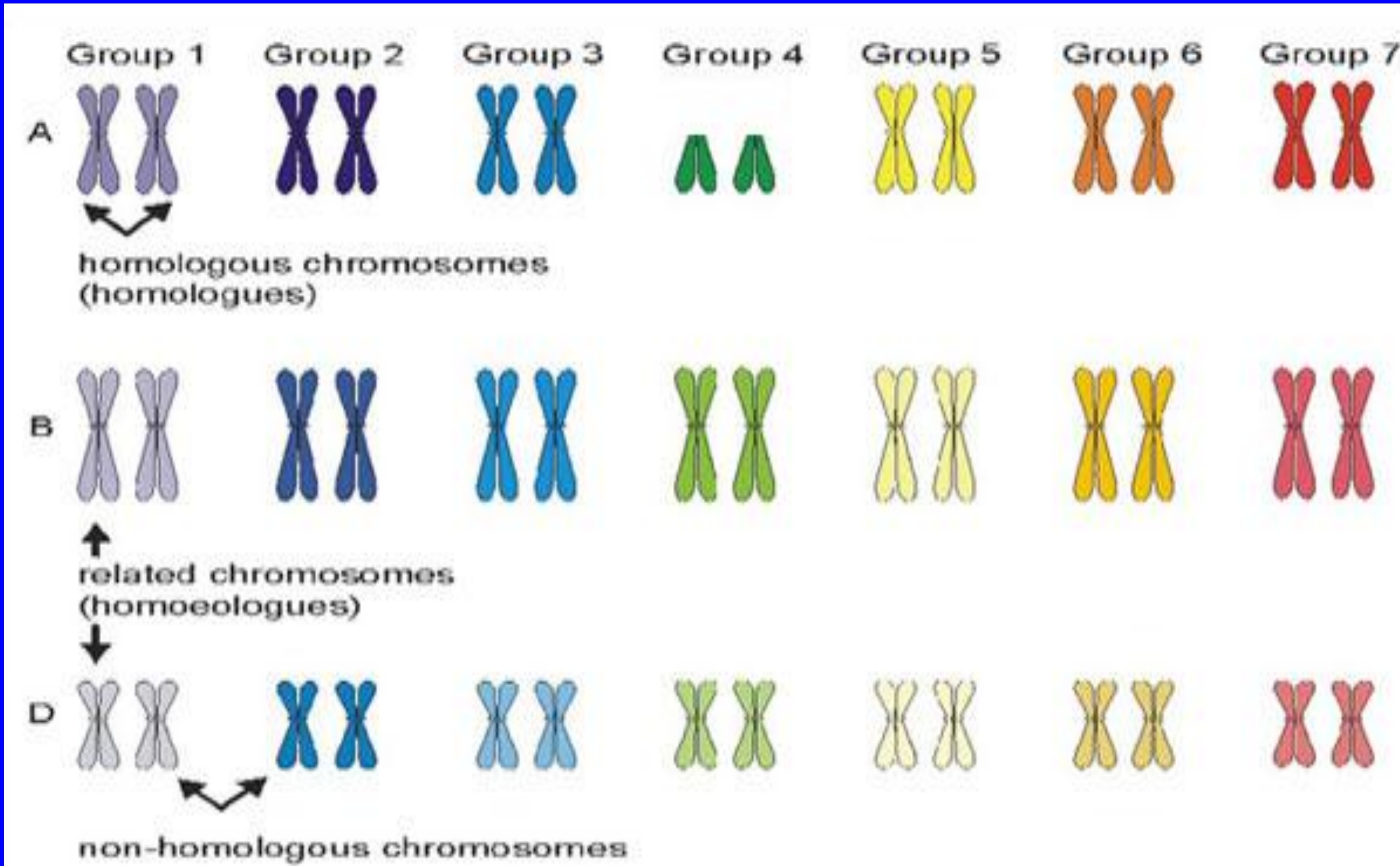
Ditelosomics: a set of 42

- An individual lacks **a pair of chromosome arms** from the normal diploid complement
- Plants look similar to disomics and fertility is close to normal
- Gametes transmitted via same rate in female and male

Ditelosomy 4AL – 4AL



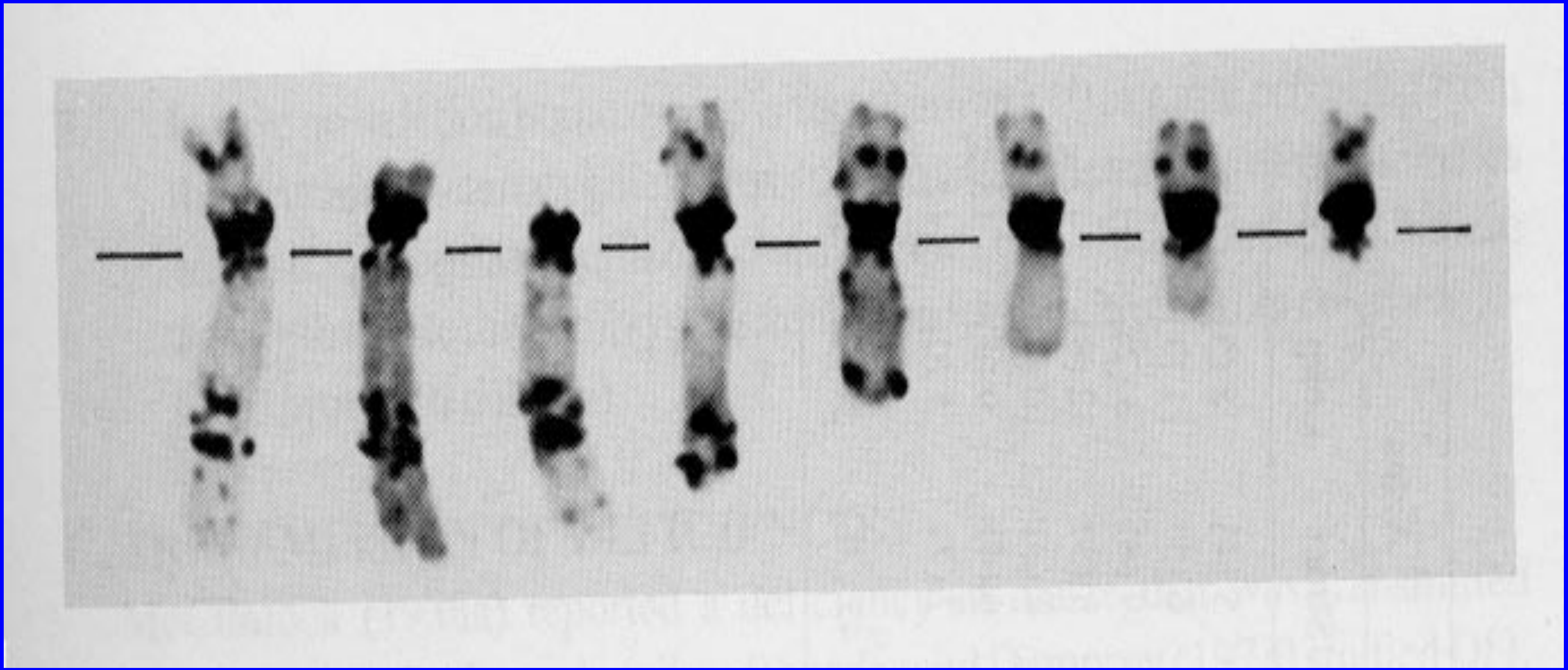
Ditelosomy 4AS – 4AS



Deletion stocks: unlimited

- An individual lacking **a segment of a chromosome** from the normal diploid complement
- Fertility is based on the location of deletions
- Mainly used in physical mapping

5B Deletion stocks



(Endo, T.R.1990. Jpn. J. Genet. 65: 135-152)

Genetic Study

Locate genes of interest:

on specific chromosome

on specific chromosome arm

on specific chromosome segment

Monosomic analysis – F1

	Male gamete
Female gamete	n (21)
n (21 chr., 25%)	Disomic (2n = 42, 25%)
n-1 (20 chr., 75%)	Monosomic (2n-1 = 41, 75%)

Expected transmission of the monosomics - F2

	Male Gamete	
Female Gamete	n (21) 96%	n-1 (20) 4%
n (21) 25%	Disomic 2n (42) 24%	Monosomic 2n-1 (41) 1%
n-1 (20) 75%	Monosomic 2n-1 (41) 72 %	Nullisomic 2n-2 (40) 3%

Locating Recessive Genes (1A is gene carrier)

Female	Male
(Awnless)	(Awn)

$20II + 1I_{1A}$ X $20\ II + 1II_{1aa}$

↓

F_1 75% $20\ II + 1I_{1a}$

25% $20\ II + 1II_{1Aa}$

3(Awn and monosomic)

1(Awnless and disomic)

Female	Male
(Awnless)	(Awn)

$19II + 1II_{1AA} + 1I_{1b}$ X $20\ II + II_{1aa}$

↓

F_1 75% $19II + 1II_{1Aa} + 1I_{1b}$

25% $19II + 1II_{1Aa} + 1II_{1bb}$

All plants are awnless

Locating Dominant Genes

(Monosomic Analysis)

Female		Male	Female		Male
(S)		(R)	(S)		(R)
$20II + 1I_{1a}$	X	$20\ II + 1II_{1AA}$	$19II + 1II_{1aa} + 1I_{1b}$	X	$19\ II + 1II_{1AA} + 1II_{1bb}$

F_1 25% $20\ II + 1II_{1Aa}$

75% $20\ II + 1I_{1A}$

F_2 4% S -- nullisomic

73% R –monosomic

24% R -- disomic

F_1 25% $19II + 1II_{1Aa} + 1II_{1bb}$

75% $19II + 1II_{1Aa} + 1I_{1b}$

F_2 75% R to 25% S

Locating Dominant Genes

(Nullisomic Analysis)

Female (S) × Male (R)

20II X 20 II + $1II_{1AA}$

↓

F_1 **20 II + $1I_{1A}$**

↓

F_2 4% S -- nullisomic

73% R –monosomi

24% R -- disomic

Female (S) × Male (R)

19II + $1II_{1aa}$ X 19II + $1II_{1AA}$ + $1II_{1B}$

↓

F_1 **19II + $1II_{1Aa}$ + $1I_{1B}$**

↓

F_2 75% R to 25% S

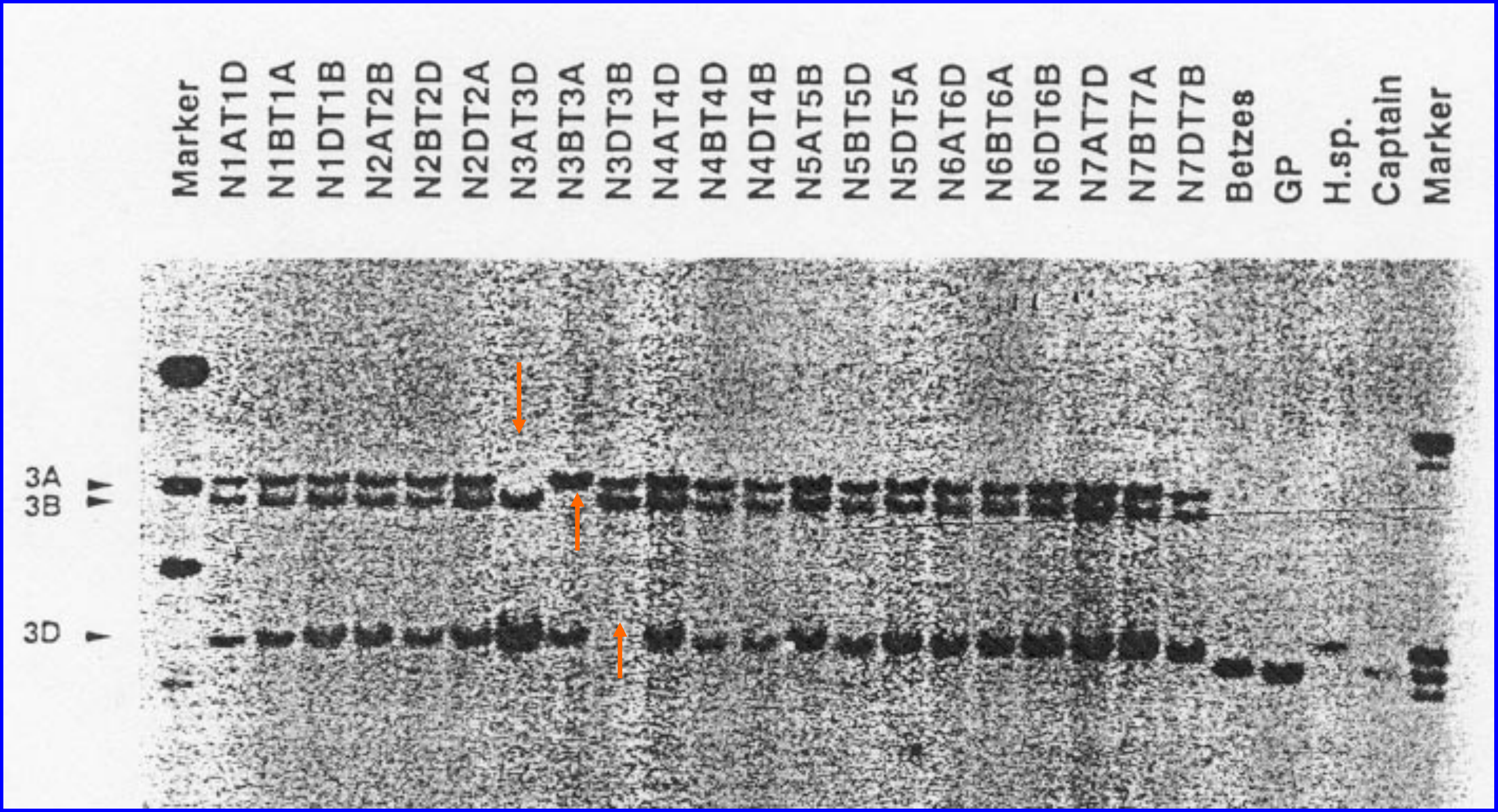
No cytogenetic work in F_1 !

Genome Mapping

Locate genes of interest or gene tightly linked markers

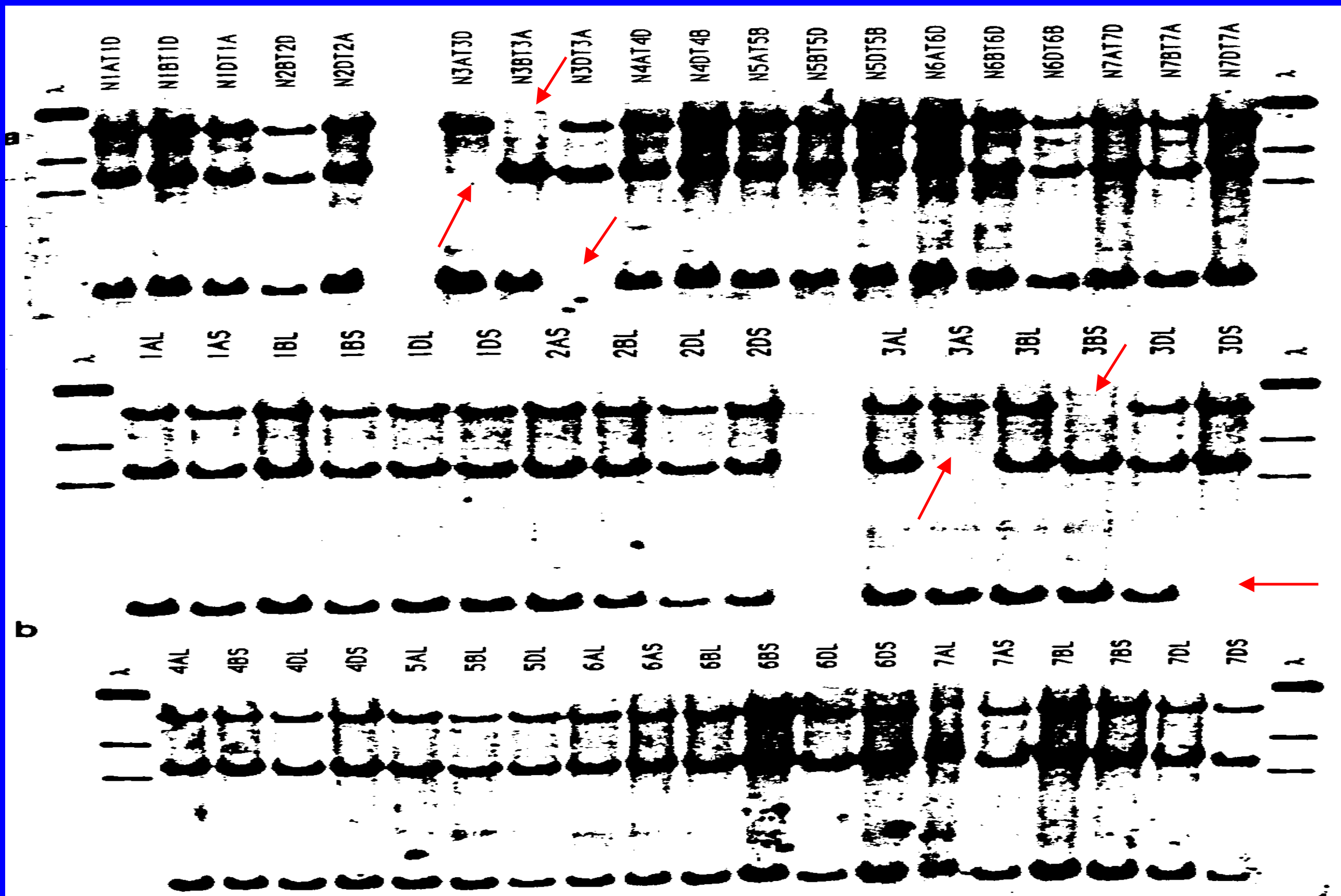
- on specific chromosome
- on specific chromosome arm
- on specific chromosome segment

Nulli-tetrasomic analysis - RFLP



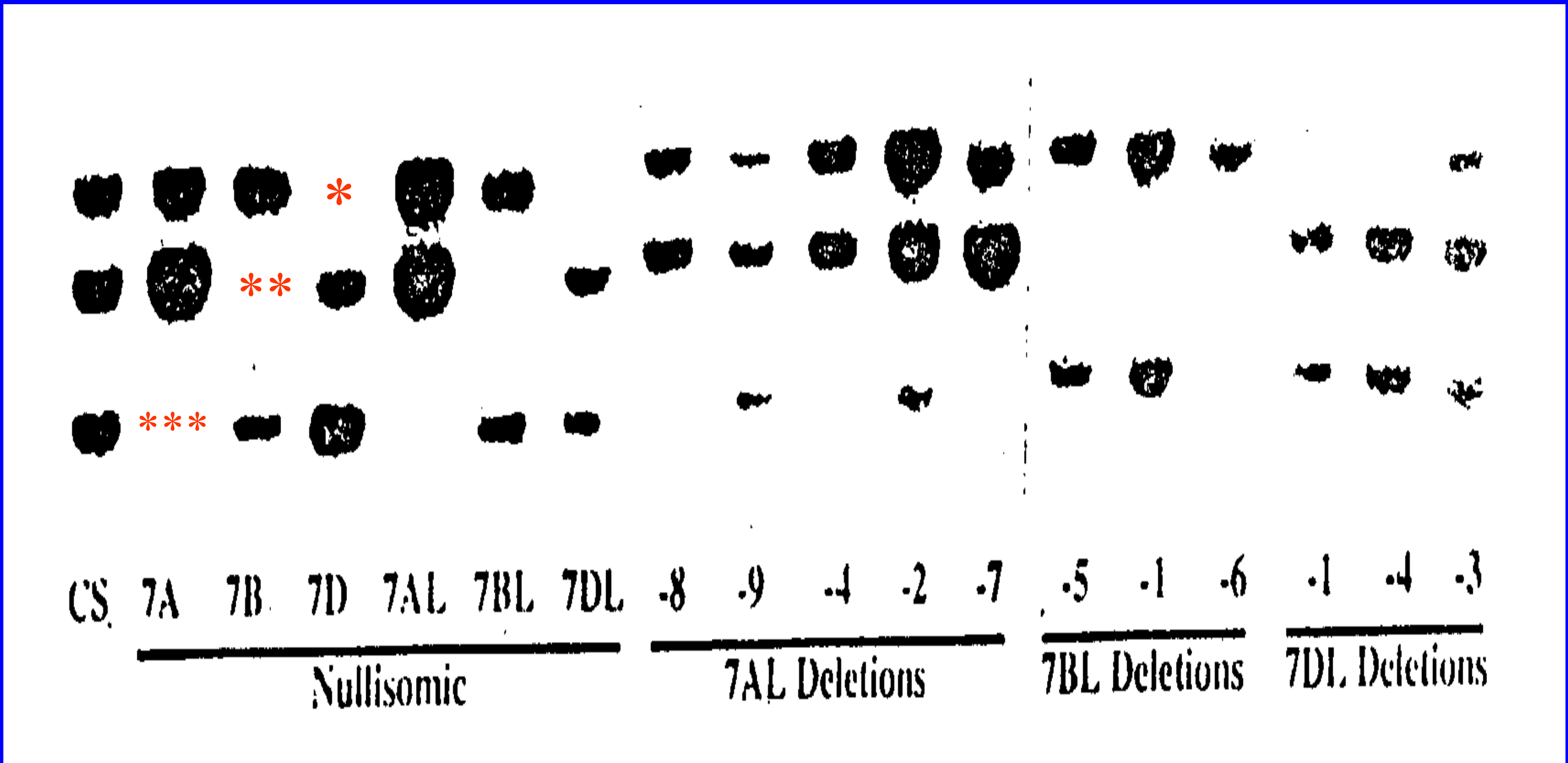
(Devos KM and Gale MD. 1993. Theme:93-99)

Nulli-tetrasomic and ditelosomic analysis - RFLP



(J.A. Anderson et al. 1992. TAG 83:1035 - 1043)

Deletion analysis – locate markers on chromosome segment



Variety Improvement: interspecific hybridization

- Introgression of useful traits from alien species to common wheat
- Issues on interspecific crosses
  - sterile or partially sterile in F_1
  - effective way to tag introduced chromosome or chromosome segments
  - Chromosome banding, genomic in situ hybridization, and molecular marker assisted selection

Procedures for transferring useful genes

- Screening of donor populations
- Producing hybrids
- Chromosome doubling/backcrossing
- Production and identification of alien addition/substitution lines
- Induction of recombination
- Screening/stabilizing recombinants/translocations
- Gene tagging/Newer technologies

Useful agronomic traits in alien species

Disease resistance

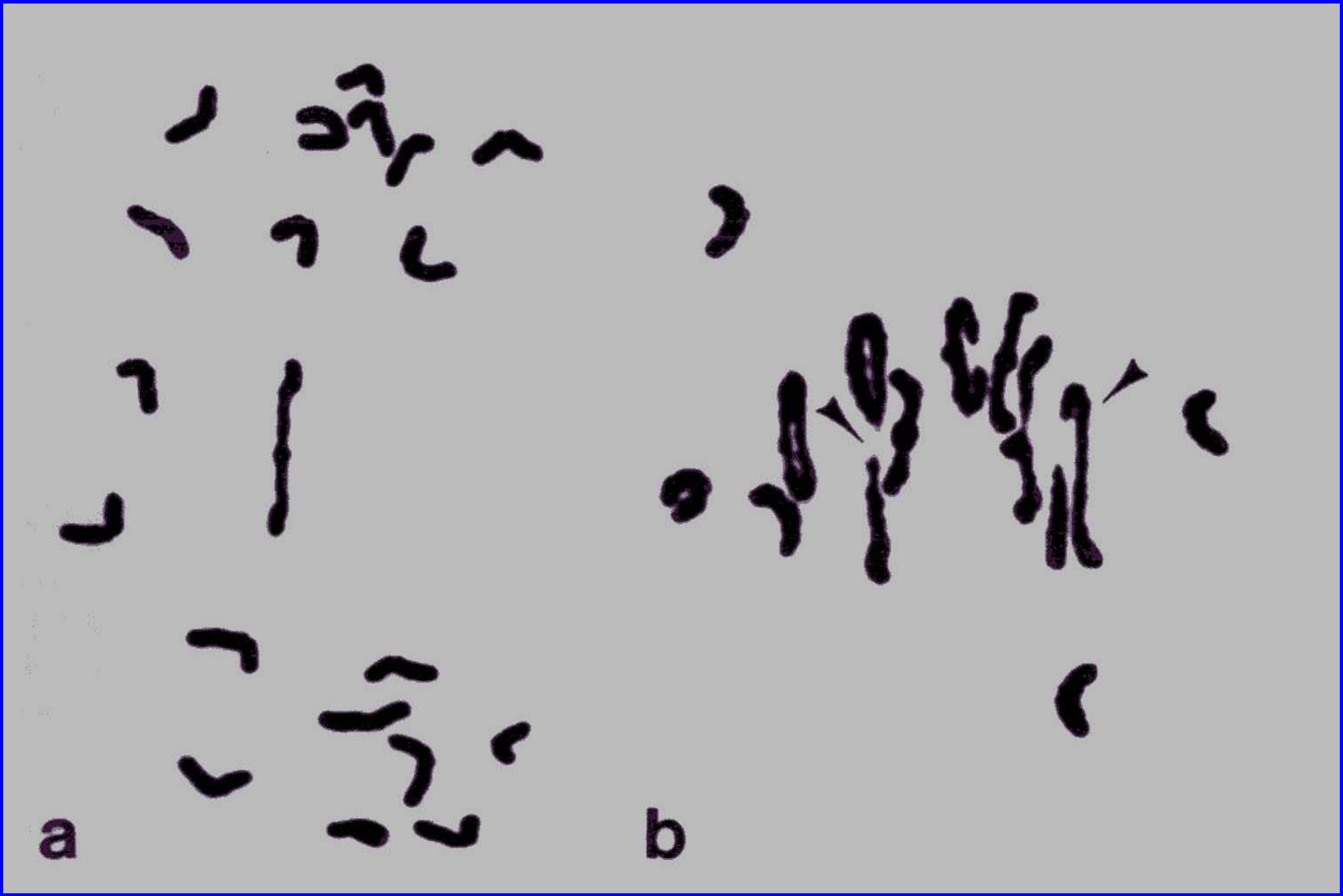
- **Powdery mildew –** ***Ae. Markgrafii, Ae. Comosa, D. villosum, T. spelta, T. dicoccoides, T. macha, Ae. kotschii***
- **Leaf rust –** ***Ae. Caudata, T. monococcum, T. tauschii, Th. Distinchum***
- **Stem rust –** ***T. diccoides, T. tauschii***
- **Yellow rust –** ***T. spelta, synthetic hexaploids***
- **Karnal bunt –** ***triticale (4R, 6R), T. monococcum***

Method of Translocation Induction

- Tissue culture (BYDV) (Bank et al., 1995)
- Radiation (Lukaszewski, 1995)
- **The 5B system – induction of homeoelogous paring (Sears, 1977)**

The 5-B system in wheat

- The 5B system, a Ph gene (homoeologous pairing suppressor) is a genetic control which restricts chromosome paring to homologs.
- When Ph is removed, or its activity is suppressed, not only do homoeologous chromosome pair but they also pair with the chromosome of related species and genera, making alien gene transfer possible (Sears, 1975, 1976).

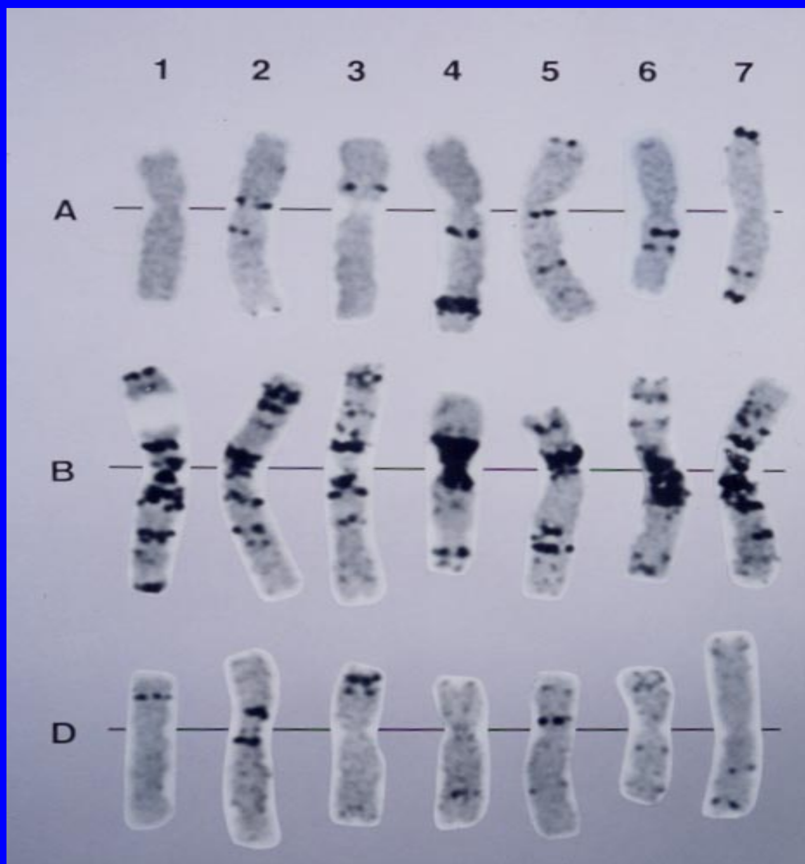


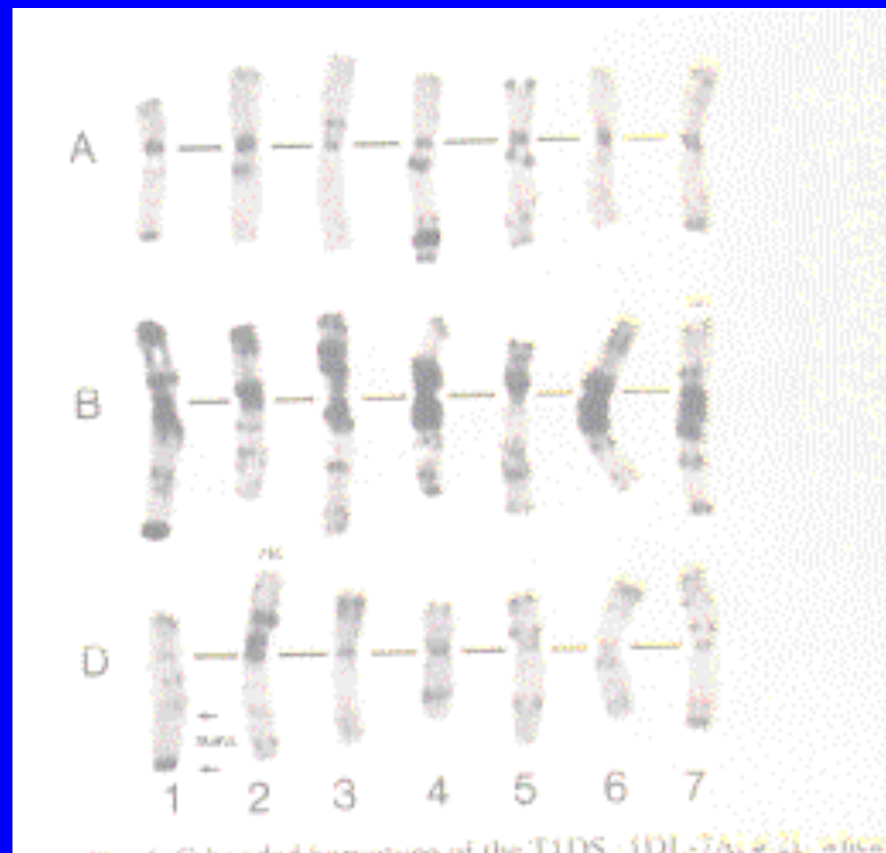
Chromosome paring in polyhaploids of bread wheat (2n = 21) with (a) and without (b) ***Ph gene (from Jauhar et al., 1991)***

Procedures for inducing homoeologous pairing

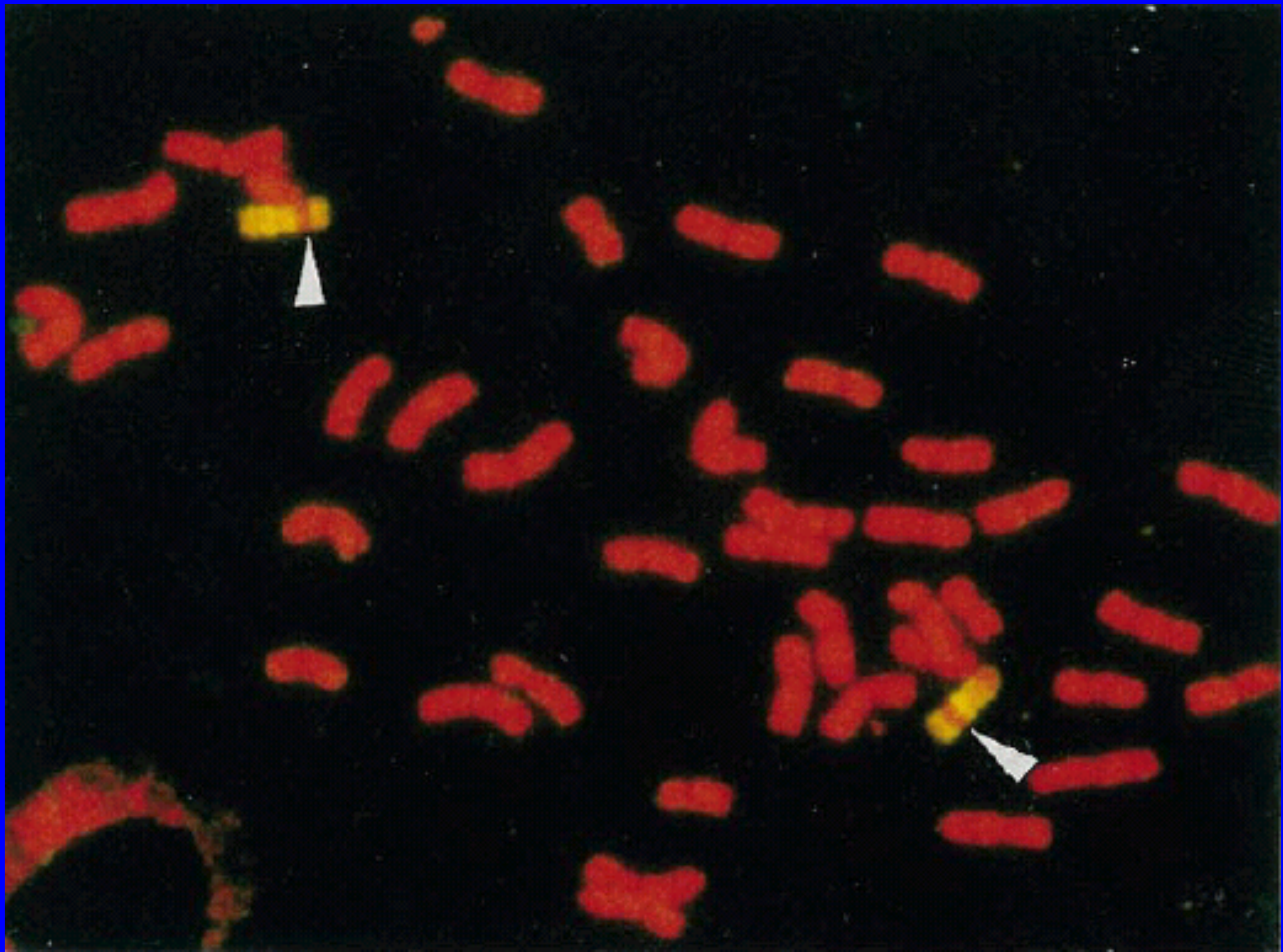
1. Monosomic or Nullisomic 5B x Alien species, F_1 x adapted lines or variety;
2. Monosomic or Nullisomic 5B x Alien addition or substitution lines, F_1 x adapted lines or variety.

Identification wheat-alien translocation lines

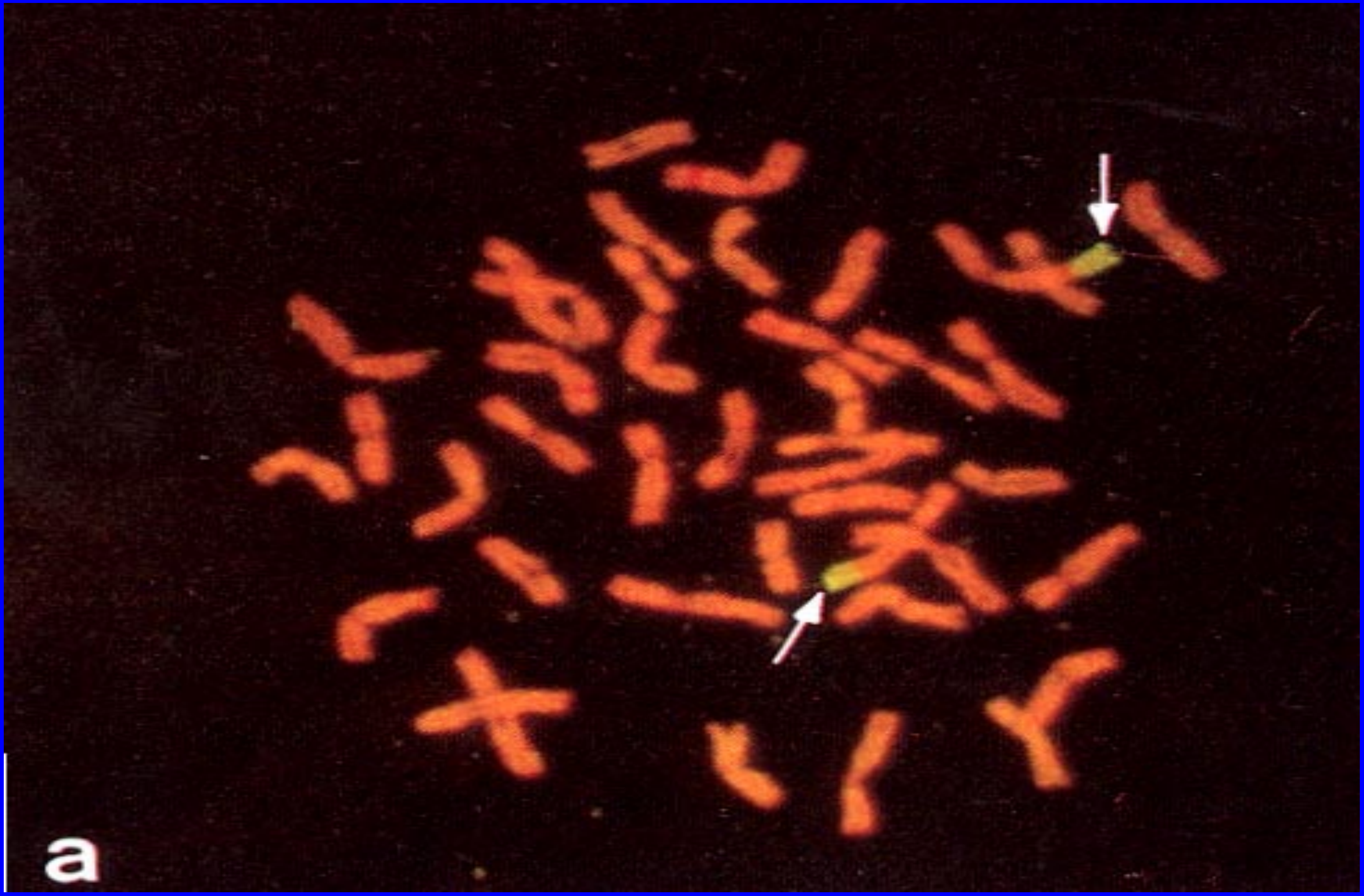




Identification wheat-alien substitution lines



Identification wheat-alien translocation lines



Identification wheat-alien addition lines

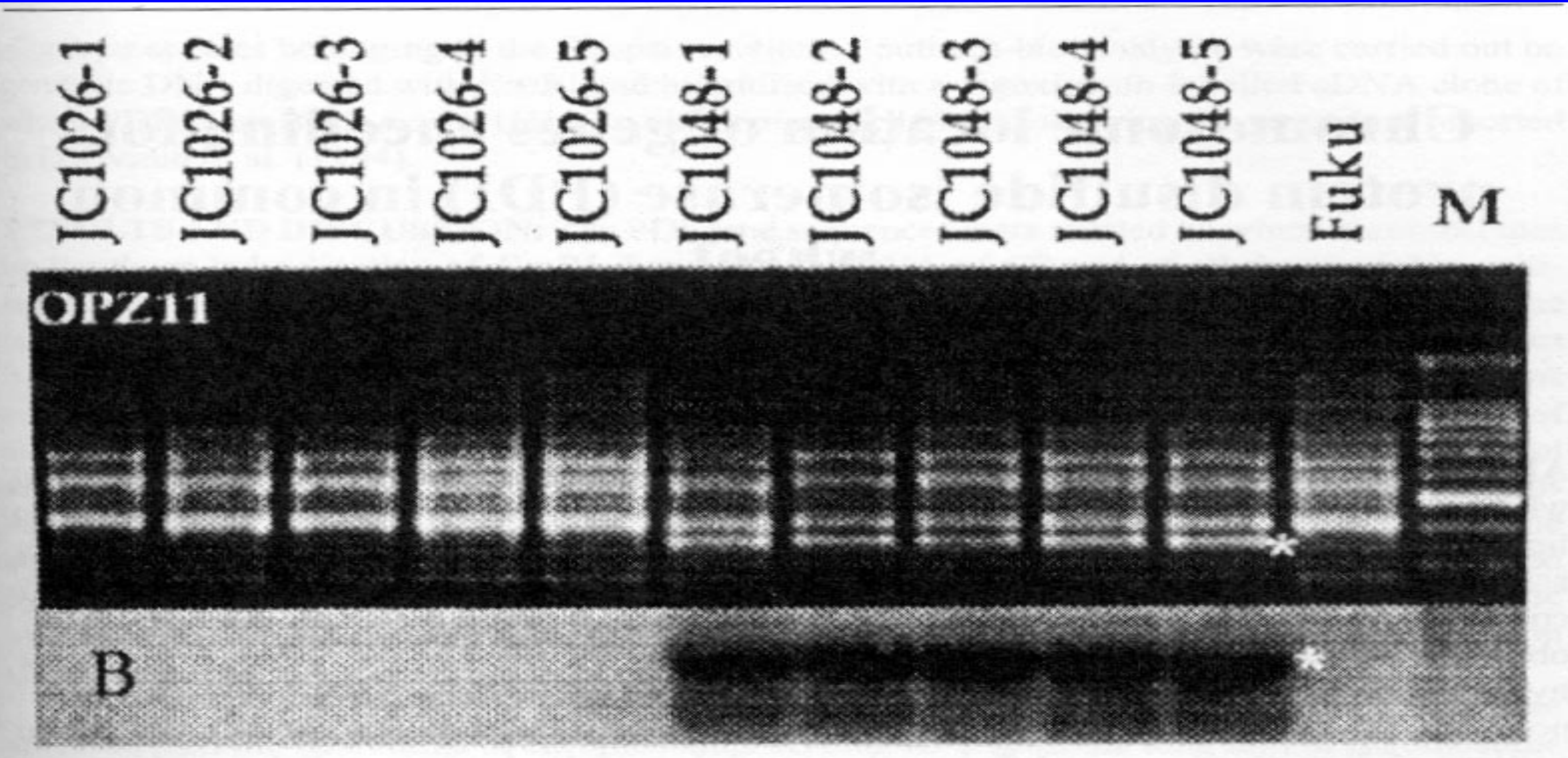


Figure 3 RAPD analysis in 10 individuals of two addition lines from JC1050. RAPD was performed by primer OPZ11(C), and the product was hybridized with OPZ11-350 (C1).

Conclusion

- Aneuploids are unique in hexaploid wheat.
- Genome analysis in wheat has served as a model in other plant systems, and has made tremendous advances.
- Chromosome engineering will continue to make contributions to wheat improvement as new techniques become available.

Aneuploid Analysis

Practical considerations

- Availability of aneuploid stocks in your crop species
- Nature of genes: qualitative or quantitative; dominant or recessive