Chromosome reconfigurations

Deficiencies

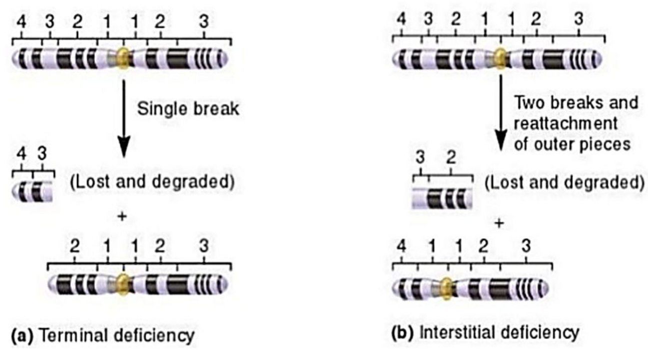


Figure 1, https://www.slideshare.net/Samchuchoo/chromosomal-aberration

McClintock, 1931

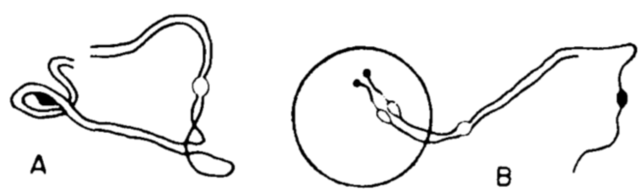
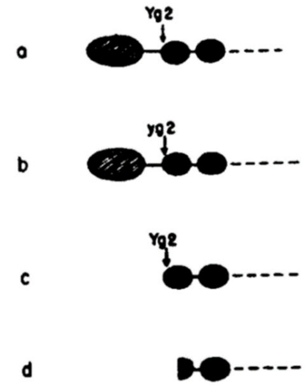


Figure 2. A: Interstitial deficiency of chromosome 7. B: Terminal deficiency of chromosome 6 (McClintock, 1931)

McClintock, 1944



5A deficiencies in wheat and oat

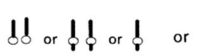
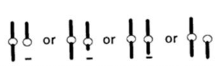
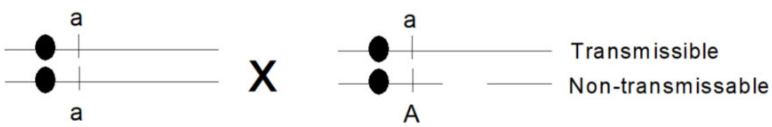
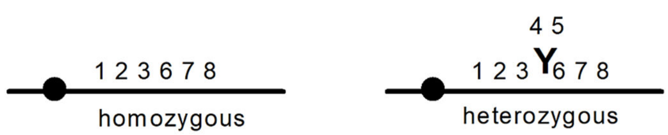
Oat	Wheat	
Fatoid	Speltoid	
	Het speltoid	
	Subnormal	
Steriloid	Subcompactoid	
	Compactoid	

Figure 3. Speltoid, normal, subcompactoid, and compactoid heads of wheat

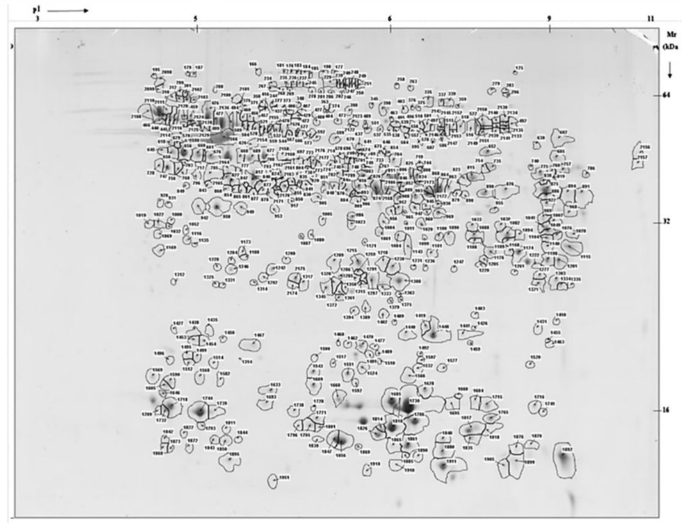
Mapping deficiencies



Effect of deficiencies on linkage maps

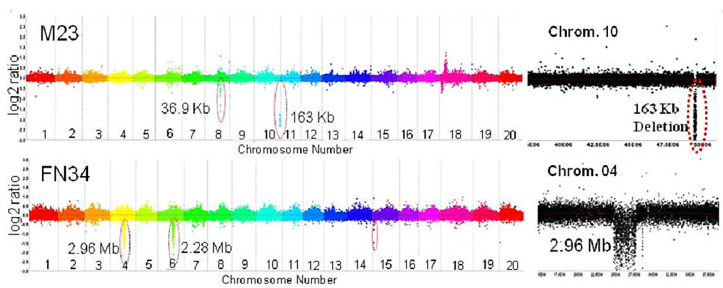


Uses of deficiencies



Merlino et al., 2012

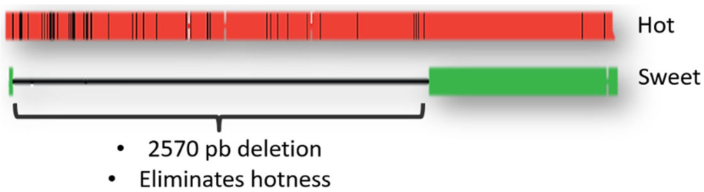
Dectection



Structural variants: Indels

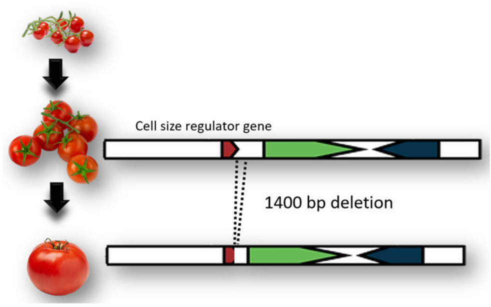
Non-pungent chili peppers

Stewart et al., 2005; Hulse-Kemp et al., 2018



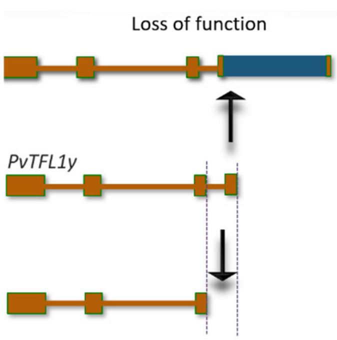
Tomato fruit size

Mu et al., 2017

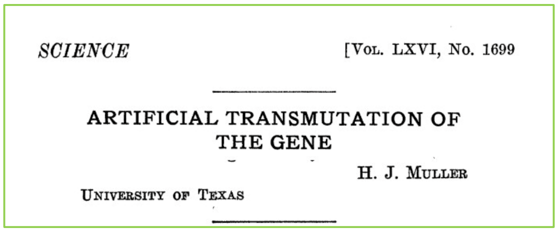


Determinancy in bean

Kwak et al., 2012



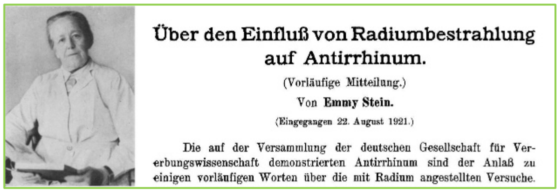
Ionizing radiation creates deficiencies


SCIENCE [VOL. LXVI, No. 1699

ARTIFICIAL TRANSMUTATION OF THE GENE

H. J. MULLER

UNIVERSITY OF TEXAS

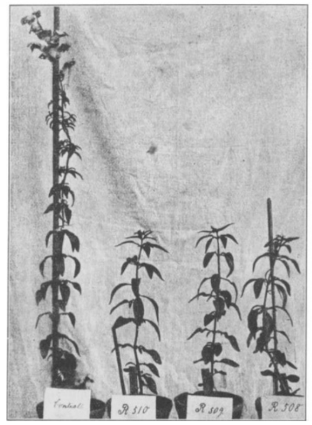

Über den Einfluß von Radiumbestrahlung auf Antirrhinum.

(Vorläufige Mitteilung.)

Von Emmy Stein.

(Eingegangen 22. August 1921.)

Die auf der Versammlung der deutschen Gesellschaft für Vererbungswissenschaft demonstrierten Antirrhinum sind der Anlaß zu einigen vorläufigen Worten über die mit Radium angestellten Versuche.



Structural variants: Mutation breeding

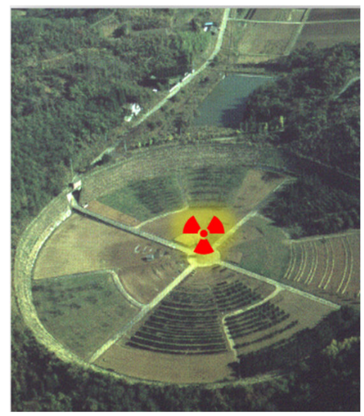
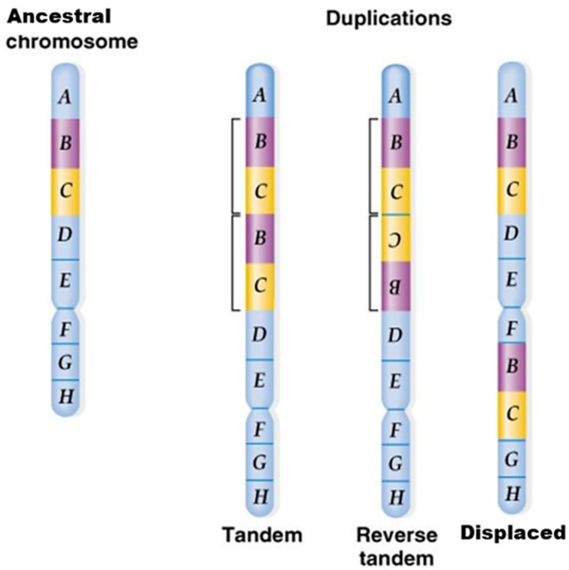
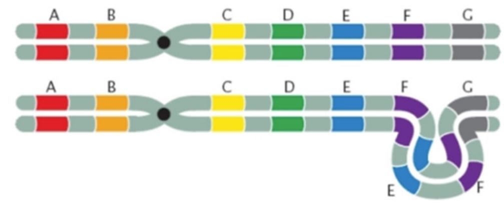


Figure 4. Institute of Radiation Breeding, Ibaraki-ken, JAPAN

Duplications



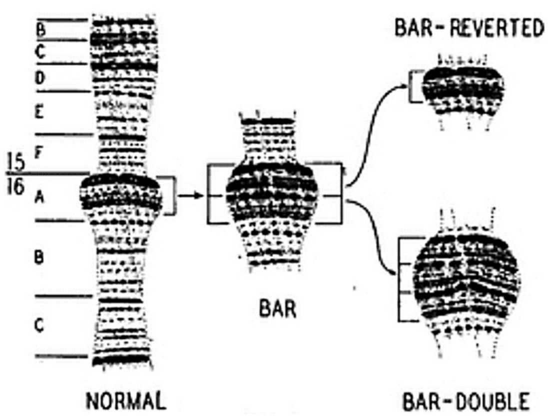
Modified from Randall, PJ. iGenetics, Pearson Education Inc, published as Benjamin Cummings



Nature Education Adapted from Pierce, Benjamin. Genetics: A Conceptual Approach, 2nd ed

Behavior of duplications

Bridges 1936



Duplications prone to unequal crossover

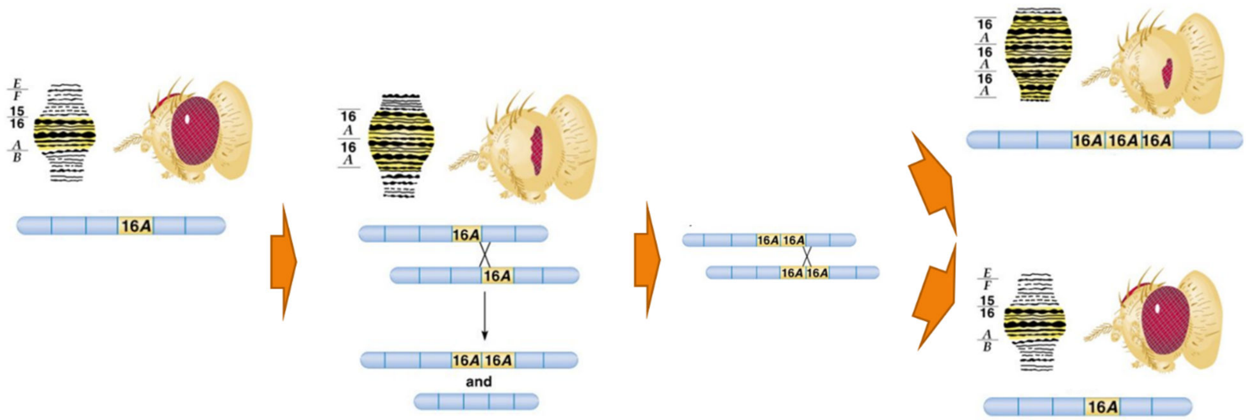


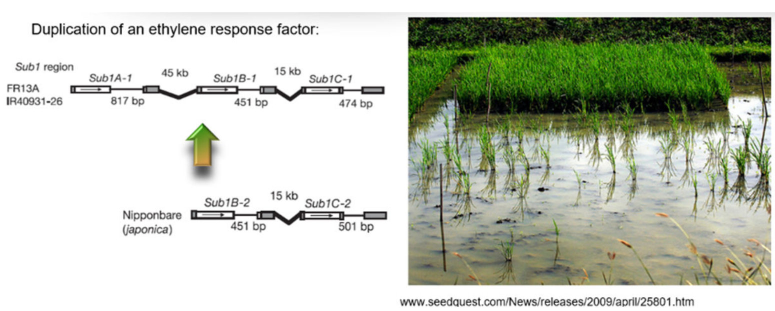
Figure 5. Modified from https://slideplayer.com/slide/10755099/

Uses

Structural variants: Duplications

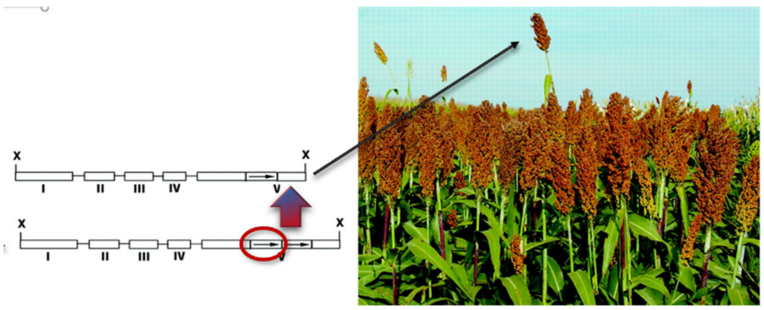
Sub1 rice

Xu et al., 2006



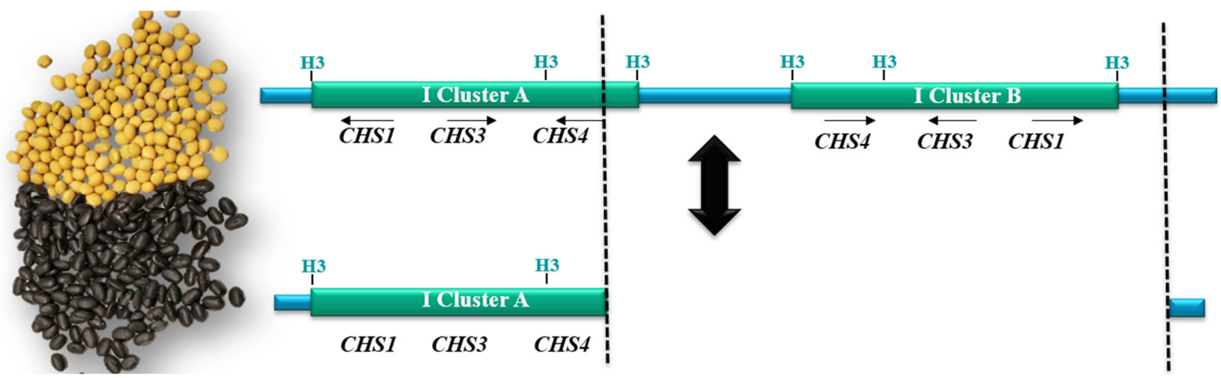
Sorghum dwarfism

Multani et al., 2003



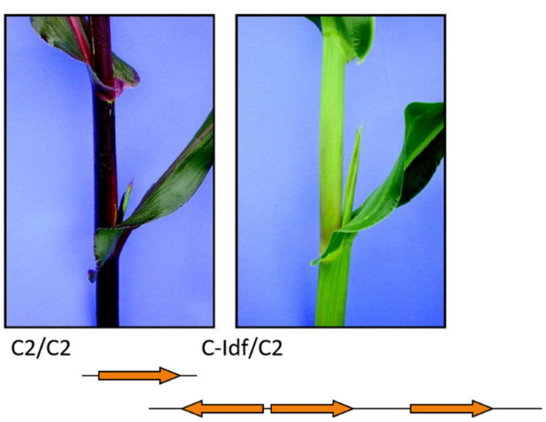
Seed coat color in soybean

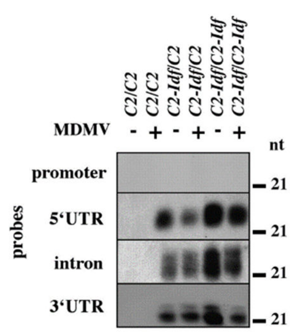
Tuteja et al, 2004



C-Idf green stalks in corn

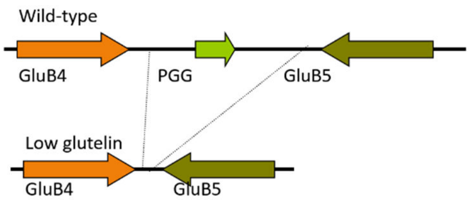
Della Vedova et al., 2005

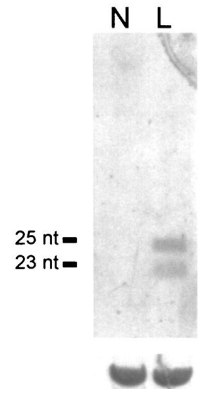




Low glutelin rice

Kusaba et al., 2003



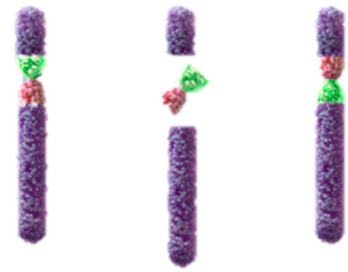


Inversions

A paracentric inversion

A pericentric inversion

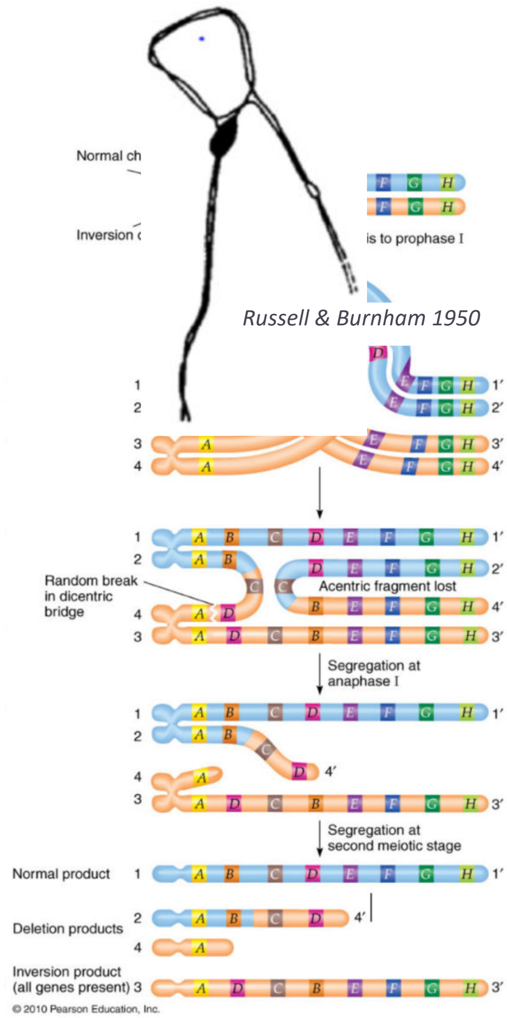
Figure 6. From US National Library of Medicine



Paracentric inversions

Crossover suppression

McClintock, 1931; 1933

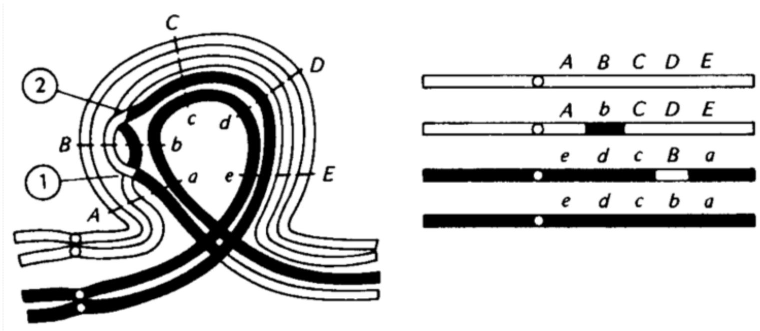


Russell & Burnham 1950

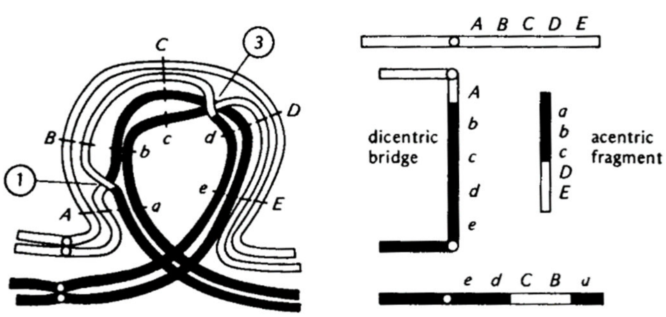
Double Crossovers in the Inversion Loops

graphics from **Strickberger, 1976**

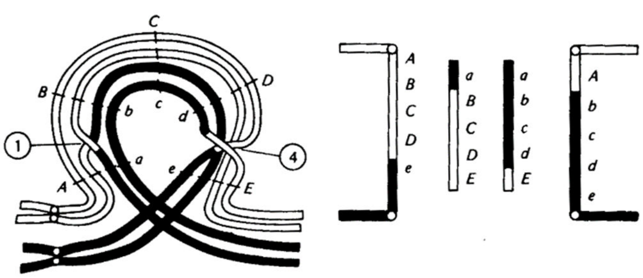
1) 2-strand double crossover



2) 3-strand double crossover

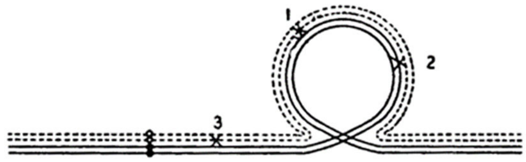


3) 4-strand double crossover



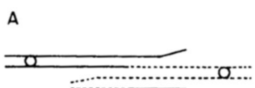
If one of the double crossovers occurs outside of the loop

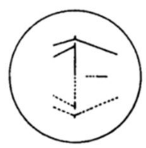
Modified from **McClintock, 1938**

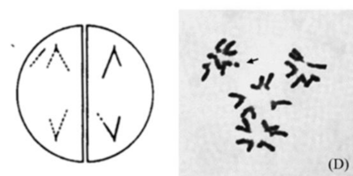


From **Burnham, 1962**, after **McClintock, 1938**
Ana I from Stevens & Bougourd. 1991. Heredity 66: 391-401
Ana II from Wang & Zhang. 2007. Plant Sci 172: 380-392

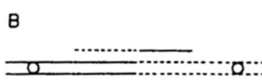
ANA I **ANA II**

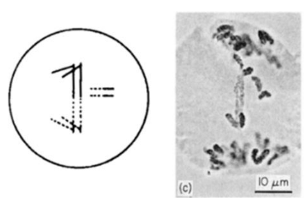




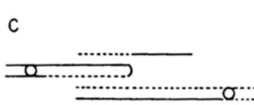


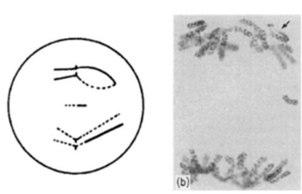
Single Crossover @ 1 or 2 → bridge & fragment at anaphase I

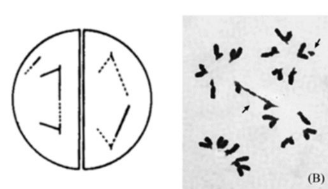




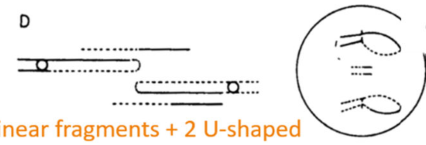
CO @ 1 & 2 → 4 strand double crossover → 2 bridges and two fragments







3-strand DCO @ 1 or 2 & 3 → linear & U-shaped fragments @ anaphase I + a bridge @ anaphase II



4-strand TCO @ 1 & 2 & 3 → 2 linear fragments + 2 U-shaped fragments at anaphase I and 2 bridges at anaphase II

Pericentric inversions

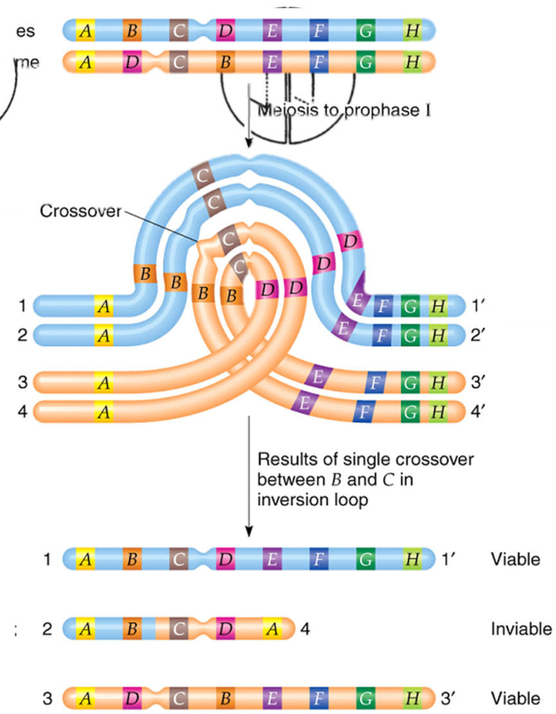
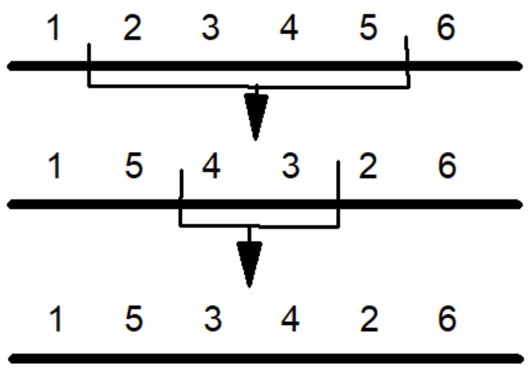
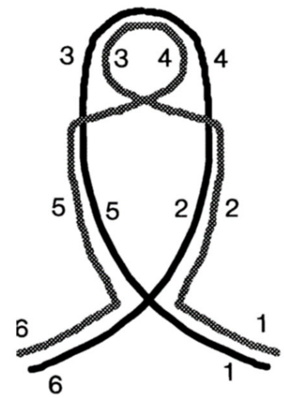


Figure 7. McClintock, 1931

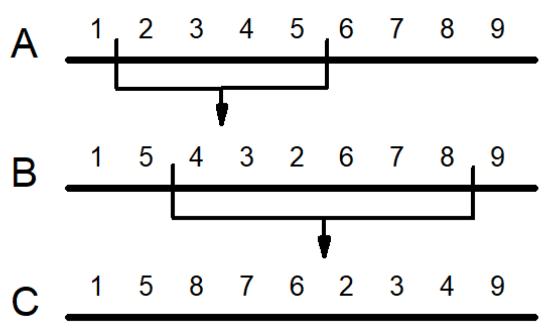
Multiple inversions

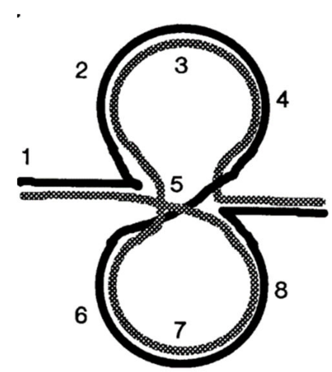
Case 1: Nested inversions





Case 2: Overlapping inversions

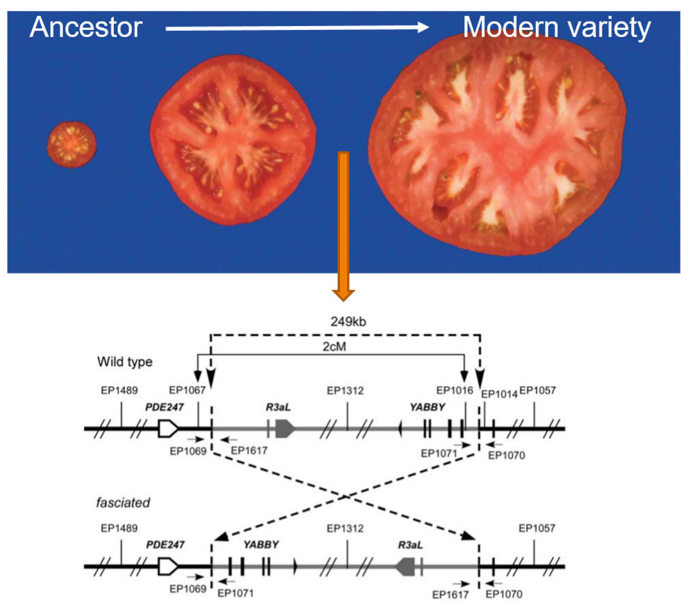




Role of inversions

Structural variants

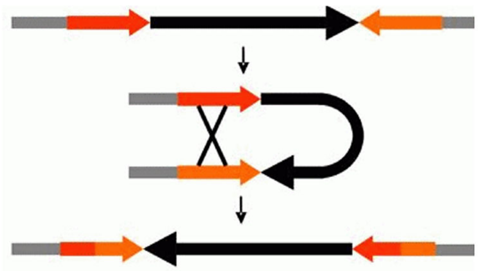
Huang & van der Knaap, 2011



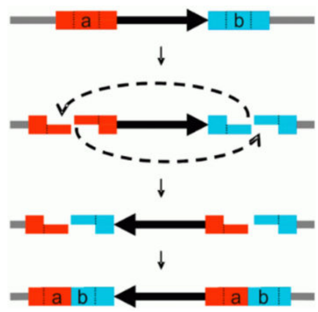
Origin of inversions

Casals & Navarro, 2007

Model 1: Duplications lead to inversions

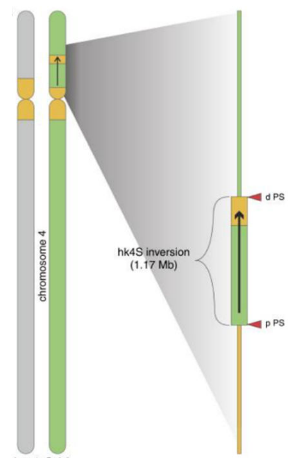


Model 2: Staggered breaks

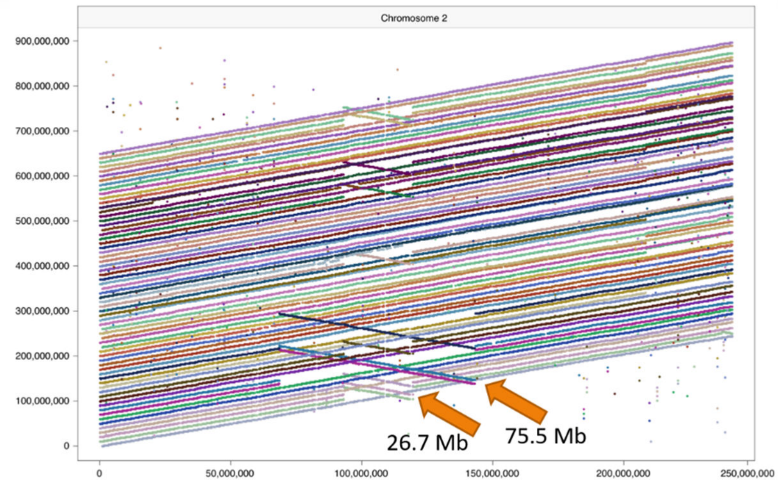


Reversing inversions

Schmidt et al, 2020

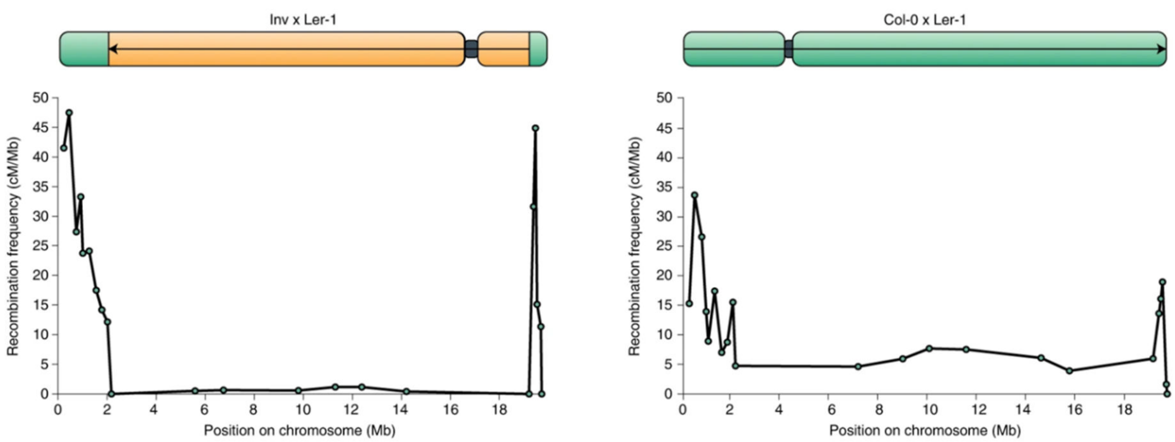


Schwartz et al, 2020

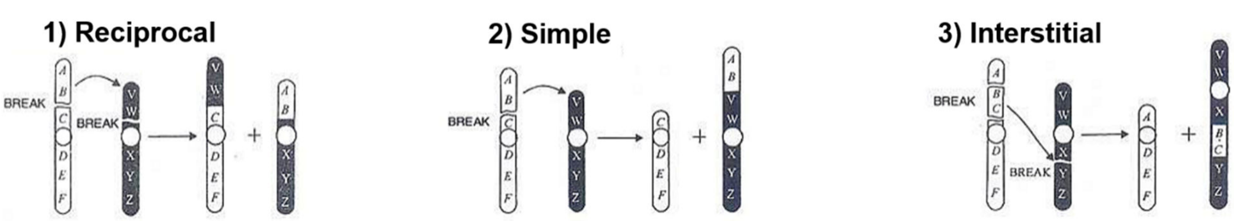


Creating inversions to preseve linkage blocks

Rönspies et al, 2022



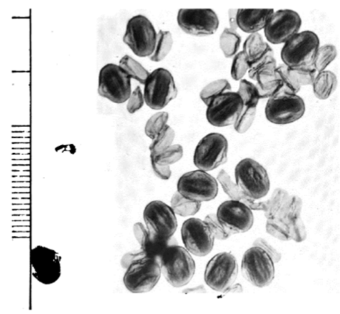
TRANSLOCATIONS or INTERCHANGES



Semisterility in Florida velvet bean

Belling 1914/1915

https://www.etsy.com/listing/635026498/mucuna-pruriens-velvet-bean-cowitch-raw



K/K l/l x k/k L/L

↓

KL K/l k/L k/l

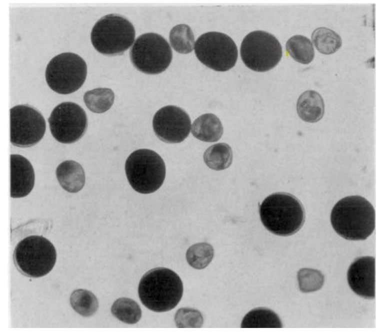
viable viable

Belling & Blakeslee 1924; 1925

Blakeslee 1928

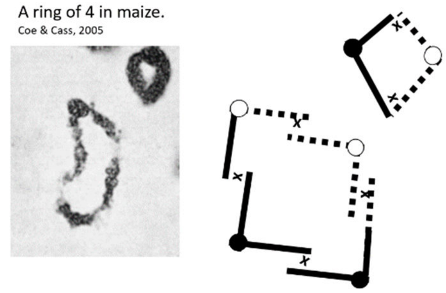
Semisterility in corn

Brink, 1927; Brink & Burnham, 1929

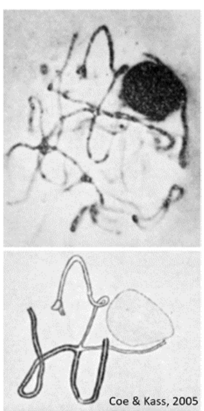


Burnham, 1930

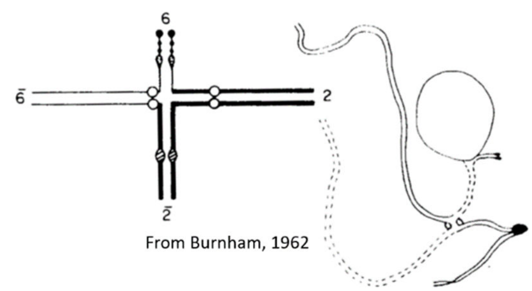
A ring of 4 in maize.
Coe & Cass, 2005



McClintock, 1930



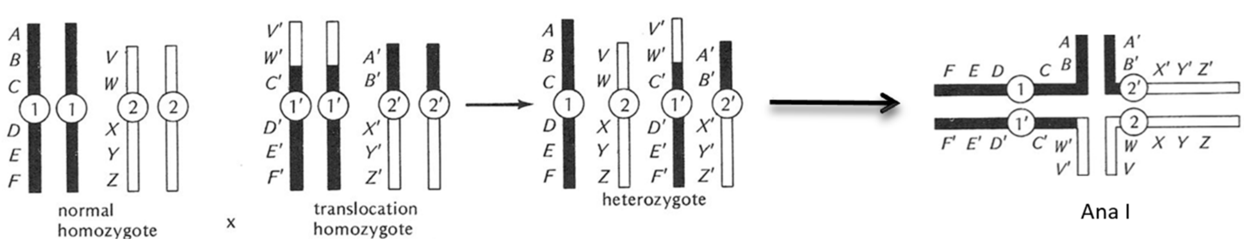
Coe & Kass, 2005



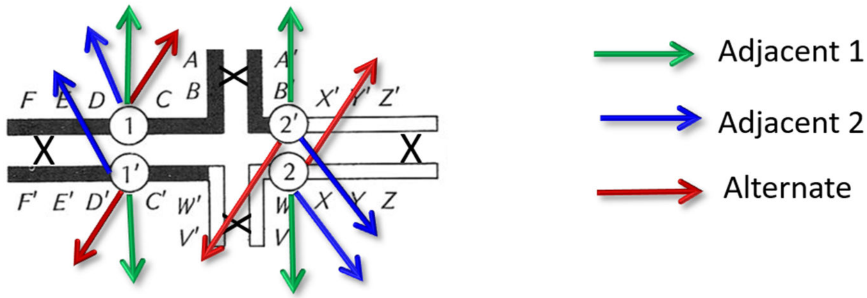
From Burnham, 1962

Meiosis in translocation heterozygotes

graphics from **Strickberger, 1976**

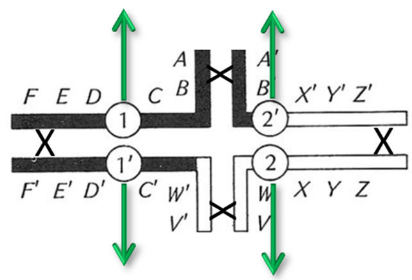


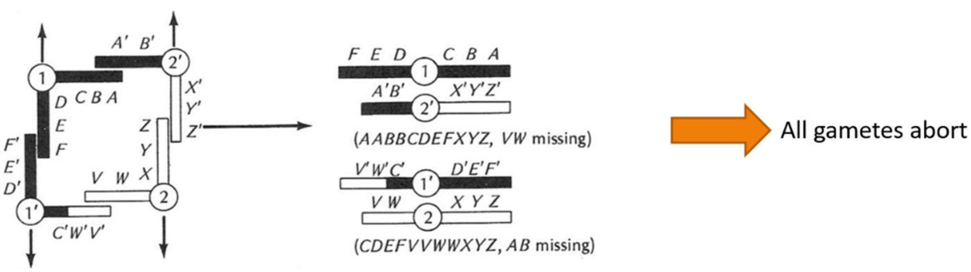
3 possible disjunctions



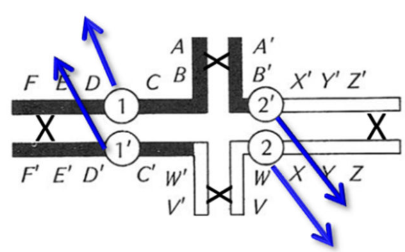
Case 1 – Crossovers in the Arms

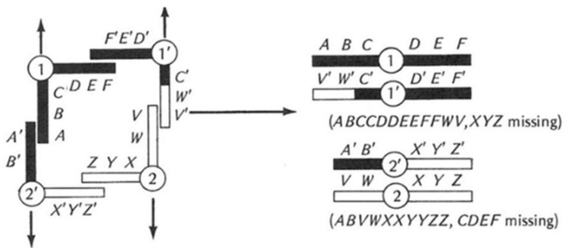
Adjacent 1 separation





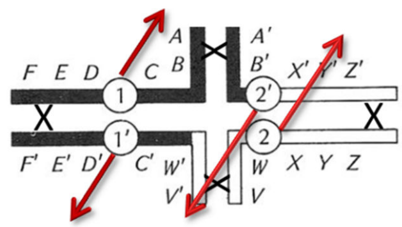
Adjacent 2 separation

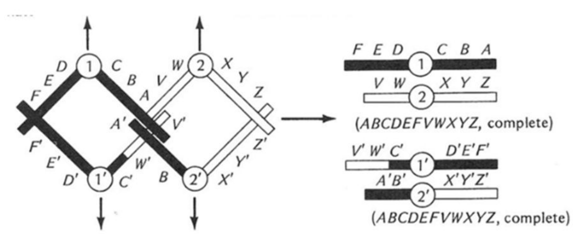




All gametes abort

Alternate separation



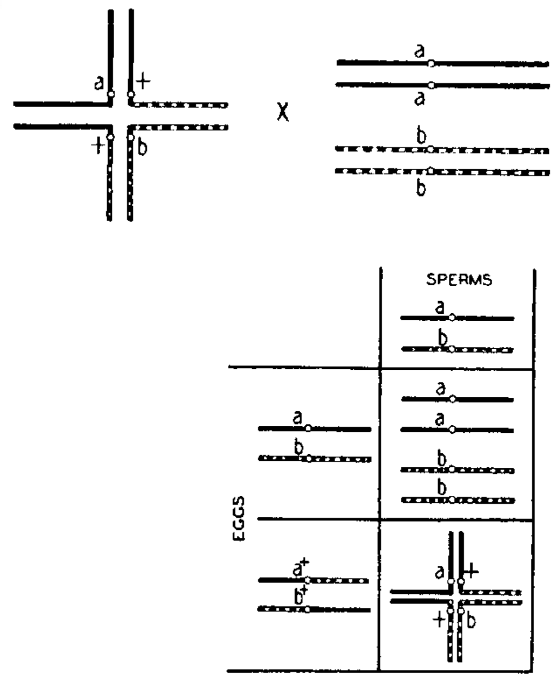


Translocation separations

Type:	Expected	Drosophila	Maize	Barley
Adjacent 1	$^{1}/_{3}$	30	30	30
Adjacent 2	$^{1}/_{3}$	20	20	-
Alternate	$^{1}/_{3}$	50	50	70

Pseudolinkage

From **Sturtevant & Beadle, 1939**



Effect on linkage maps

Effect of crossover number

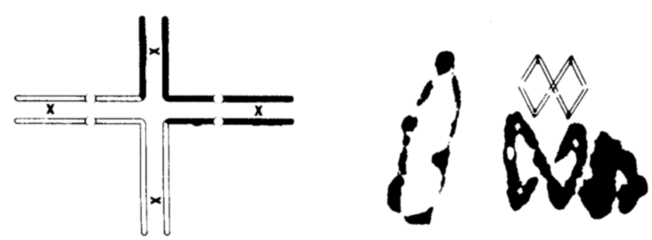


*Figure 8. Two rings of 4 in barley, one undergoing adjacent (left) and the other alternate (center) separation. From **Hagberg, 1960**.*

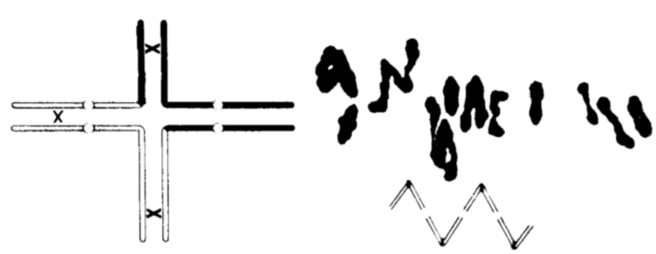
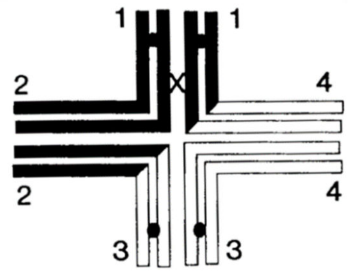
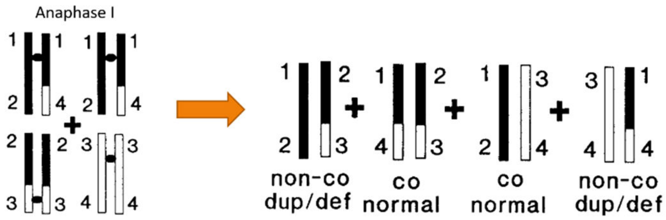


*Figure 9. Two chains of 4 in Agrostis. After **Jones, 1956**.*

Case 2 – Crossovers in the interstitial region

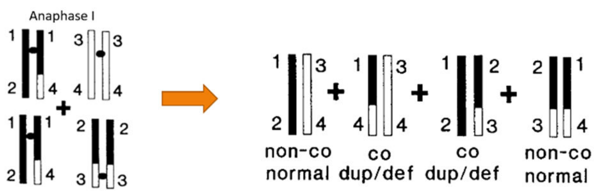


Adjacent 1 separation



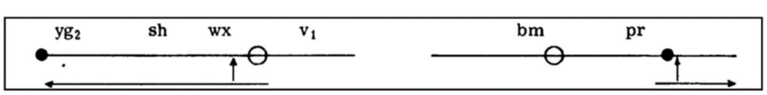
Adjacent 2 separation

Alternate



	Alternate	Adjacent 1	Adjacent 2
Short interstitial	50-57%	19-31%	19-26%
Long interstitial	55-56%	41-45%	0-3%

Effect of Translocations on recombination

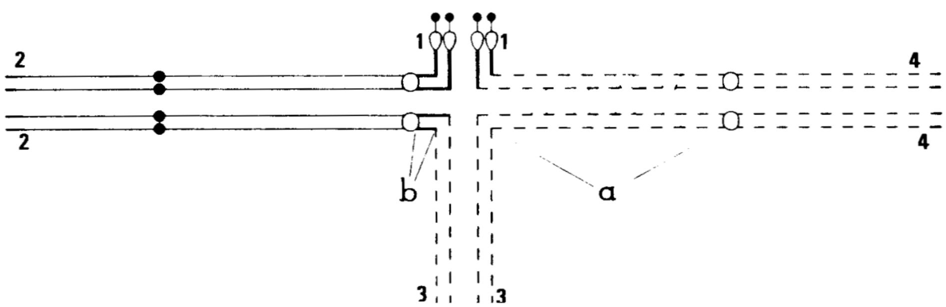


Chromosome 5 (R) and part of chromosome 9 (L) showing break points. Horizontal arrows indicate regions showing variable pairing.

Chromosome	Standard	Heterozygous T5-9a as male	Homozygous T5-9a
Chromosome 9			
yg_2-sh	23	11	--
sh-wx	20	5	18.6
wx-v_1	12	11	independent
Chromosome 5			
bm-pr	27	32	--
pr-wx	independent	28	23.8

Frequency of crossing over in the interstitial region

-

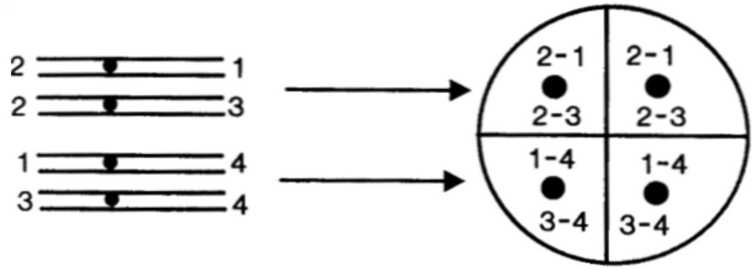


Pachytene configuration of a 5-6 translocation. The interstitial regions are denoted as a and b. (Burnham, 1960).

-
- If

IF NO CROSSING OVER OCCURS:

1) Adjacent 1:



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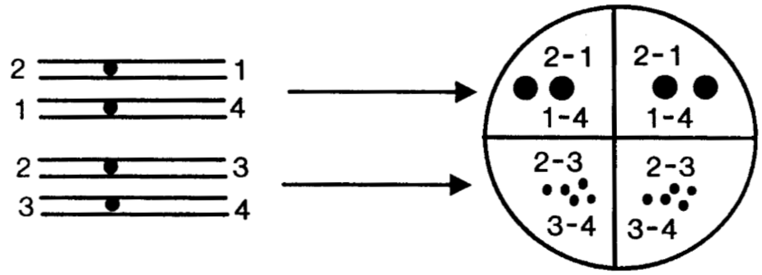
-

-

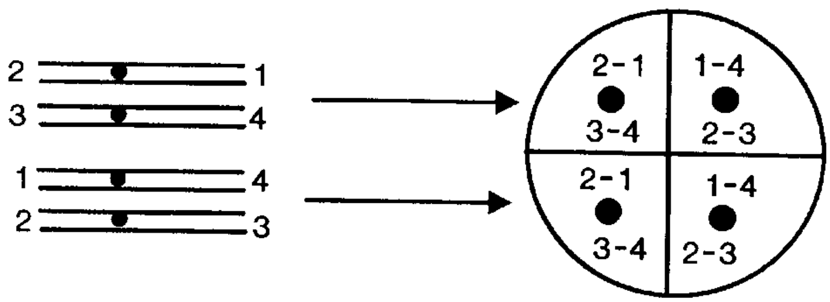
2) Adjacent 2:



-

-

3) Alternate:



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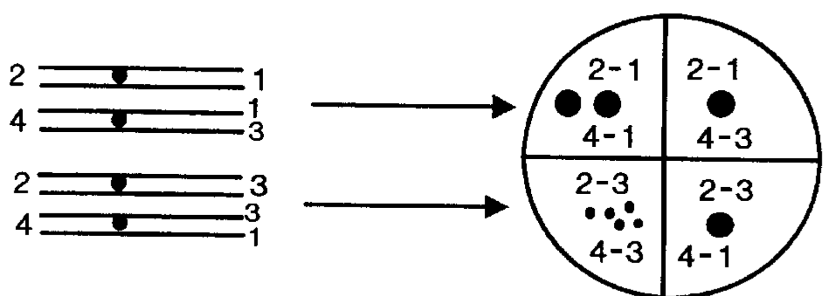
-

IF A SINGLE CROSSOVER TAKES PLACE AT a:

Adjacent 2 -

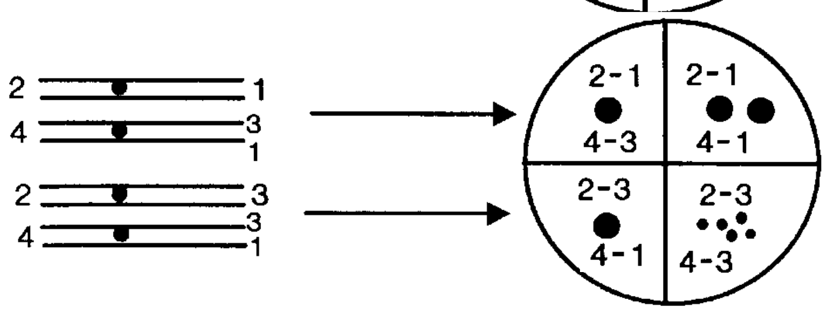
Adjacent 1:



-

-)

Alternate:



- 2

- 2

Problem:

-
-
    -
    -
    -

Permanent translocation heterozygotes

Gates 1908; Golczyk, Massouh & Greiner, 2014

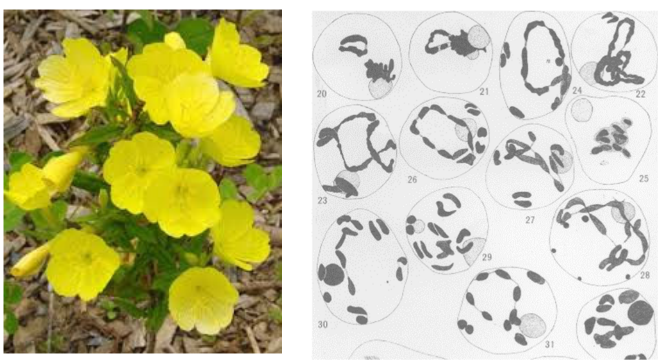
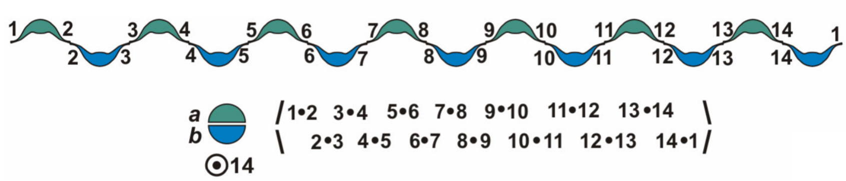
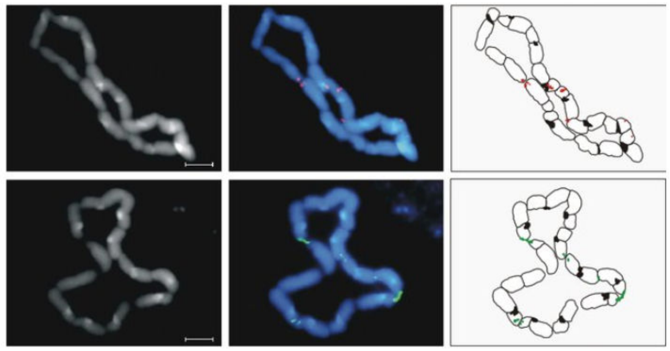


Figure 10. Oenothera



Rhoeo spathacea

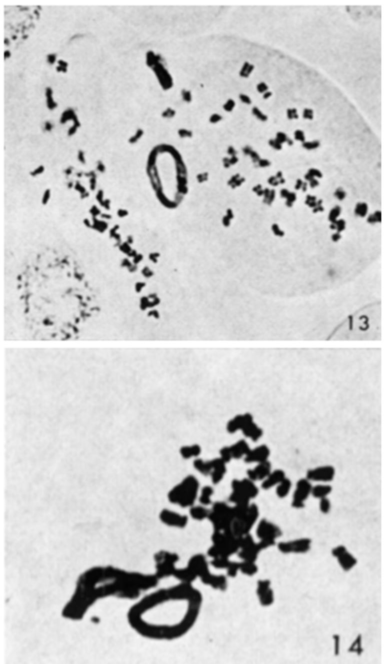


Use of translocations in mapping & breeding

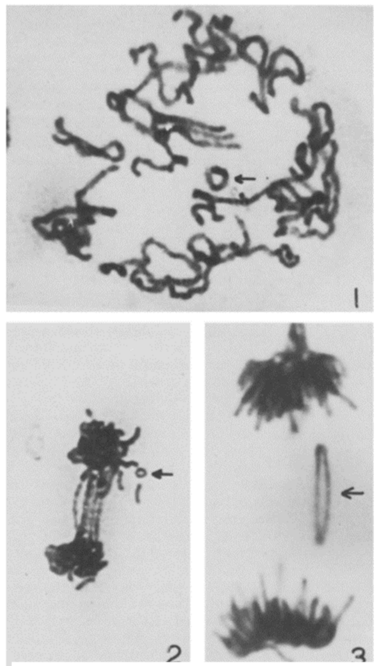
Burnham 1946, Sisodia & Shebeski, 1965; review by **Farré et al., 2014**

Figure 11. ⊙ 14 in barley, Sisodia & Shebeski, 1965

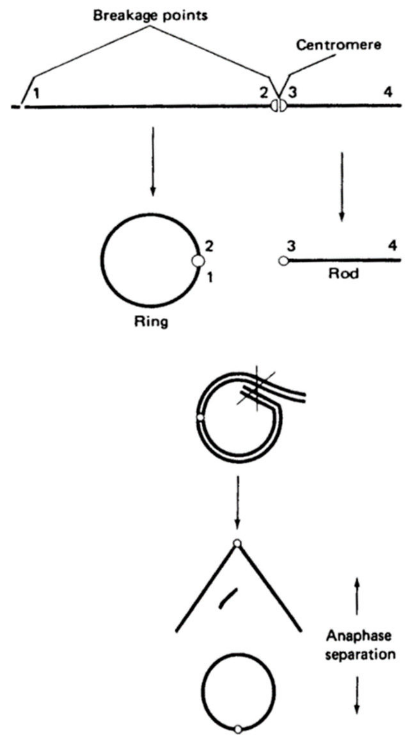
Ring chromosomes



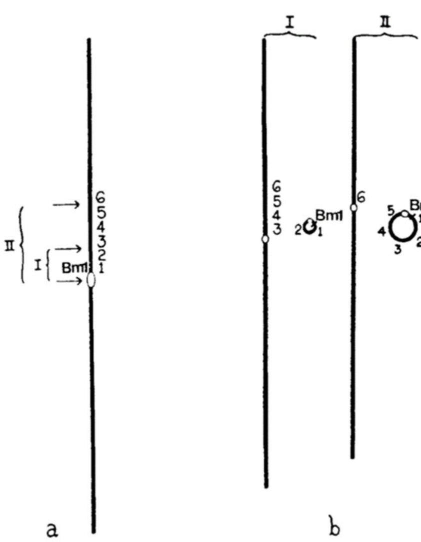
Ring chromosomes in tobacco Gerstel & Burns, 1967



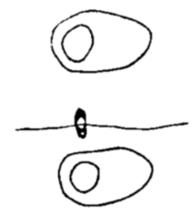
Ring chromosomes in onion, Gohil & Kaul, 1983. Experentia 39: 1152-3.



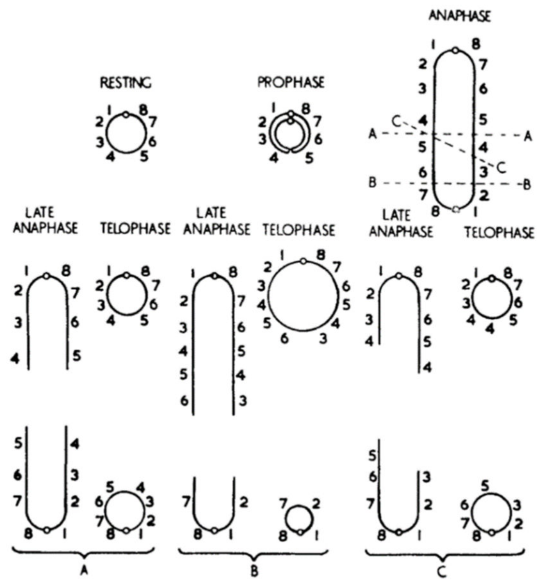
McClintock, 1938



Ring size	Freq. double-sized rings
Same as rod	15-20%
$^{1}/_{10}$ as big	1%
$^{1}/_{25}$ as big	0.2%

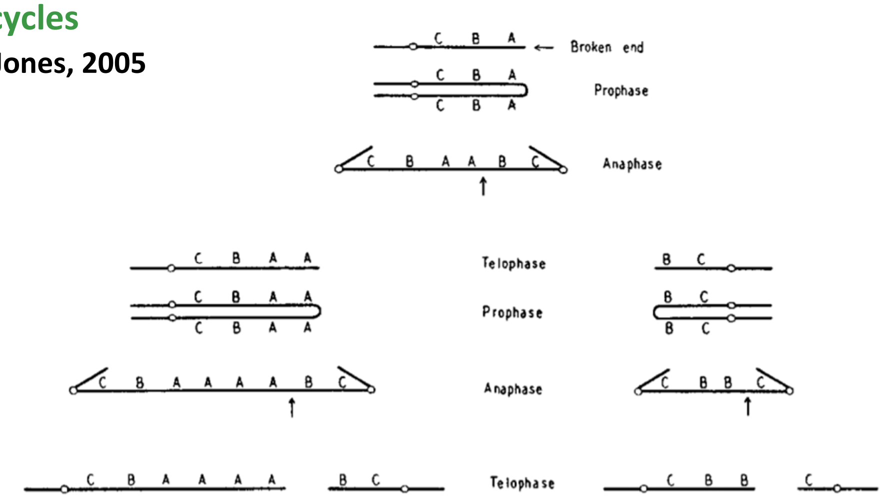


McClintock, 1941



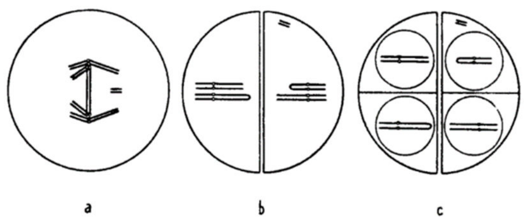
Breakage-Fusion-Bridge cycles

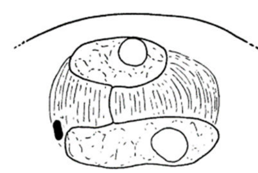
McClintock, 1941; review by Jones, 2005



BFB in mitosis

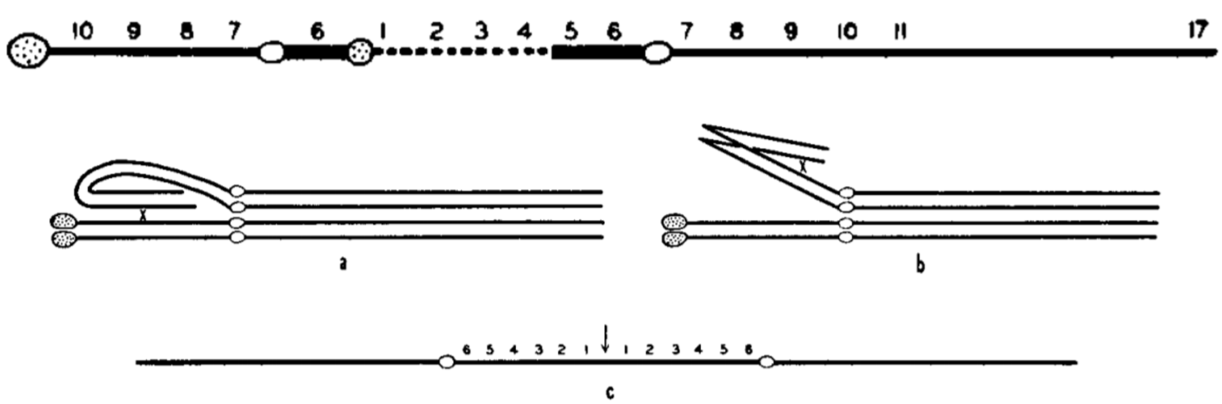
McClintock, 1938



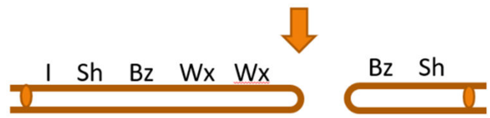


BFB in the endosperm

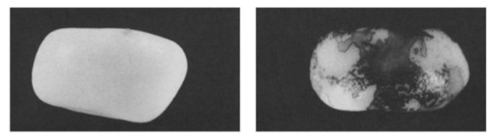
McClintock, 1941

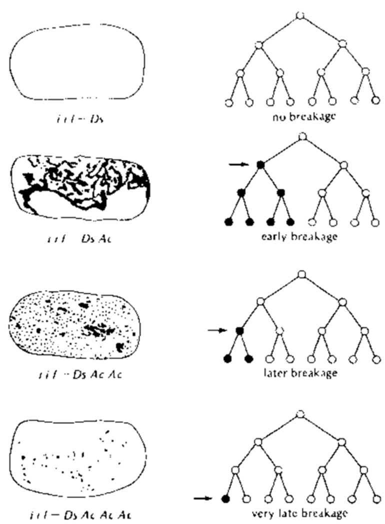


McClintock, 1951



Recessive for *wx* and *C*





from Strickberger, 1972, after McClintock 1951

Rings and herbicide resistance

Palmer amaranth, the king of weeds, cripples new herbicides

Scientists in the US sound the alarm about a crop-smothering weed that is growing resistant to multiple herbicides

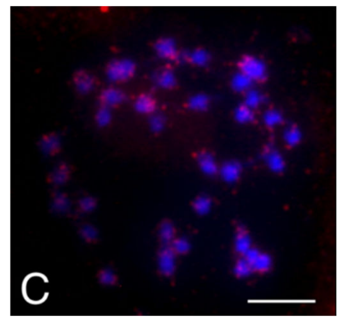
by Melody M. Bomgardner

August 3, 2019 | A version of this story appeared in Volume 97, Issue 31

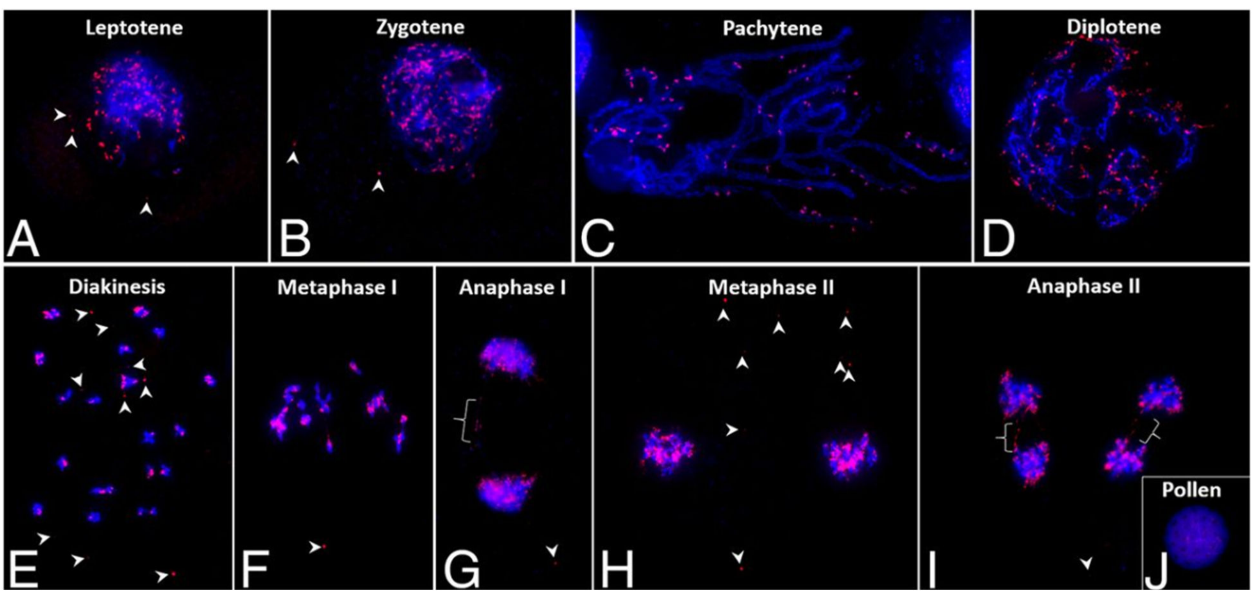
https://cen.acs.org/business/specialty-chemicals/Palmer-amaranth-king-weeds-cripples/97/i31

https://cropwatch.unl.edu/2017

Koo et al, 2018a; Molin et al, 2020



Gaines et al, 2009



Tethered and unthethered eccDNAs during meiosis. From Koo et al, 2018

Rings & BFB in herbicide tolerance

Koo et al., 2018b

https://www.youtube.com/watch?v=DgpaxUkBeZA