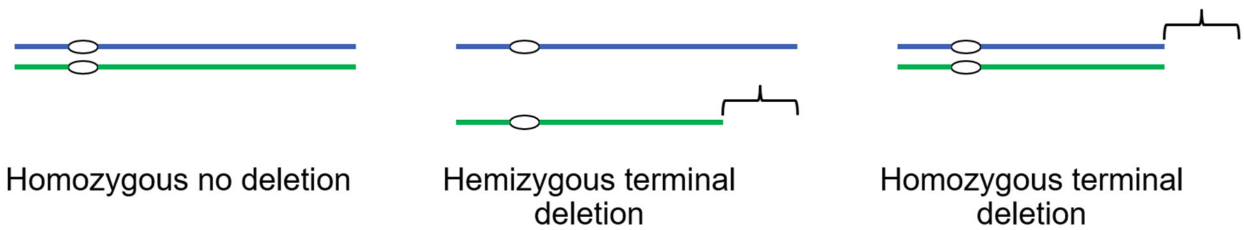
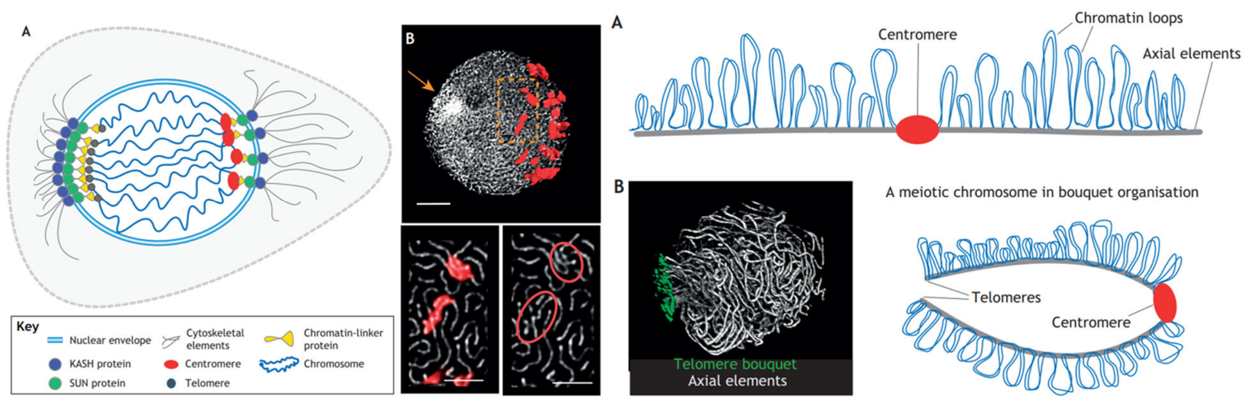
Pairing and crossing over

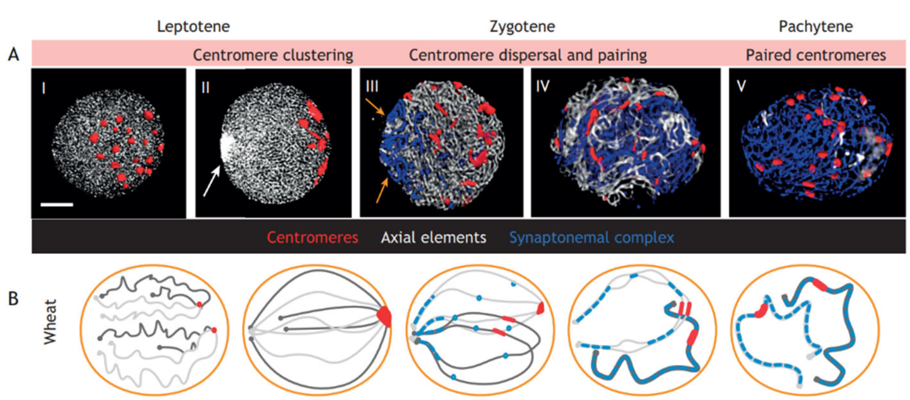
Synapsis

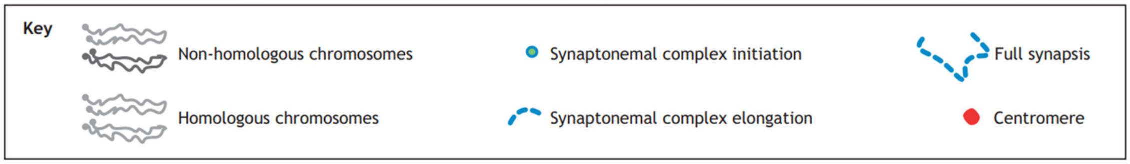
Lukaszewski, 1997; Abirached-Darmeny et al., 1983



Sepsi & Schwarzacher, 2020







The synaptonemal complex

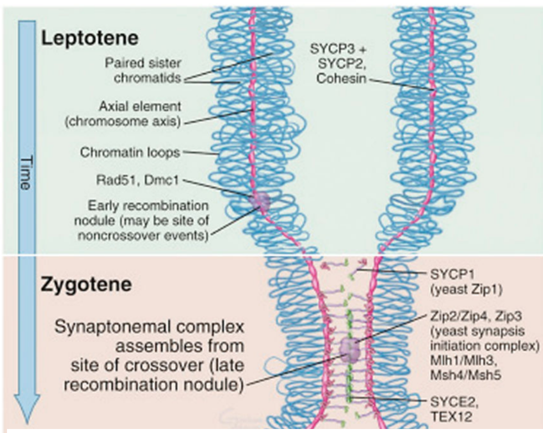


Figure 1. Cell Biology, third edition (2017)

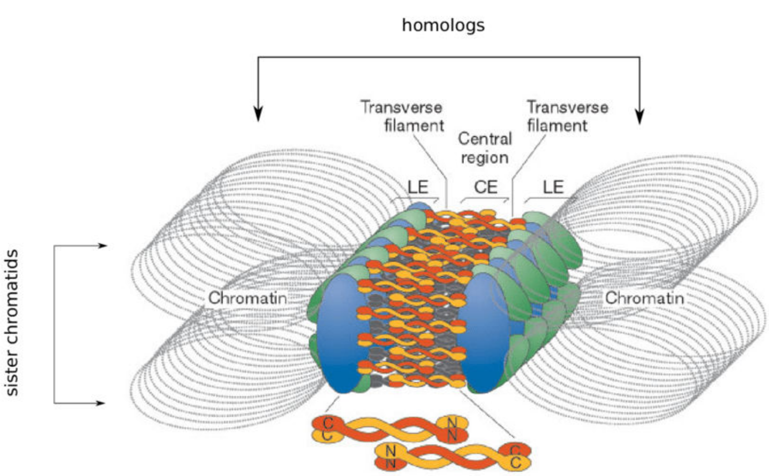


Figure 2. Alexandra Popa. The evolution of recombination and genomic structures: a modeling approach.. Bioinformatics [q-bio.QM]. Université Claude Bernard - Lyon I, 2011. English. <tel-00750370>

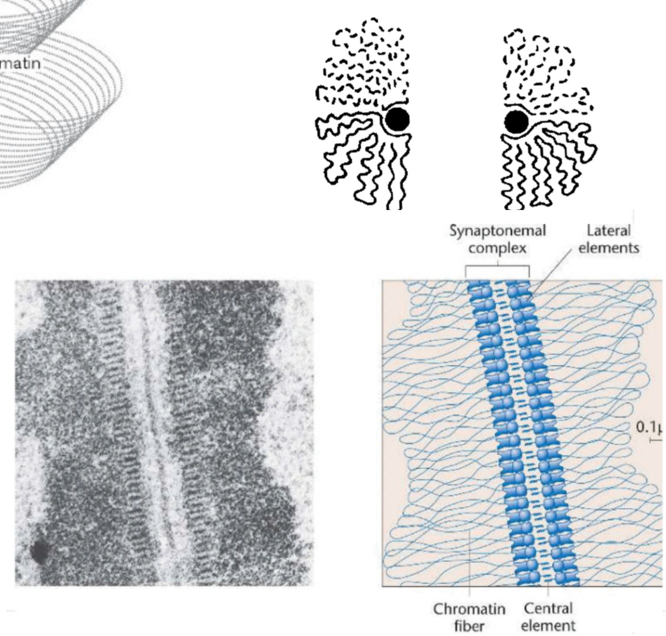
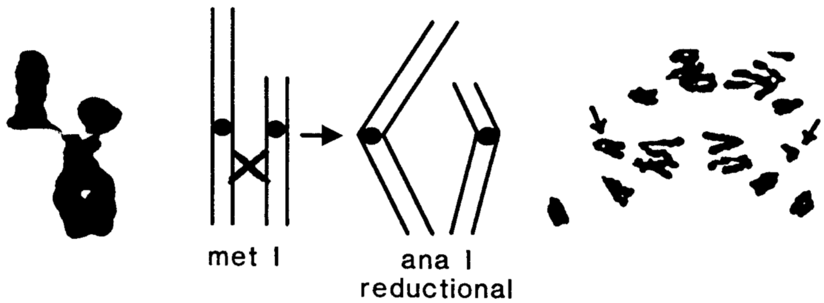


Figure 3. http://bio3400.nicerweb.net/Locked/media/ch02/02_14-synaptonemal_complex.jpg

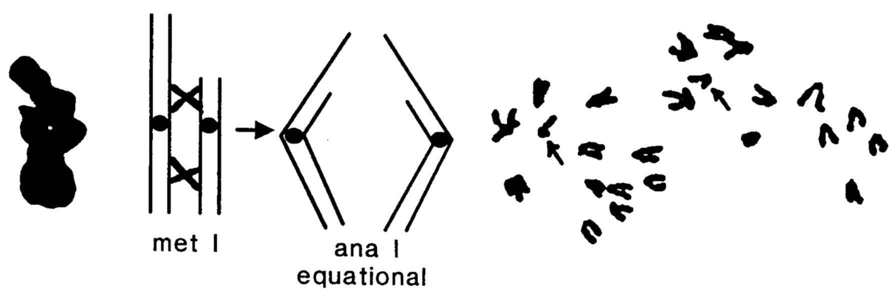
Fundamental concepts

Frequency of chiasmata = frequency of CO

Brown and Zohary, 1955



Photographs and interpretive drawing of events leading to a reductional anaphase I.



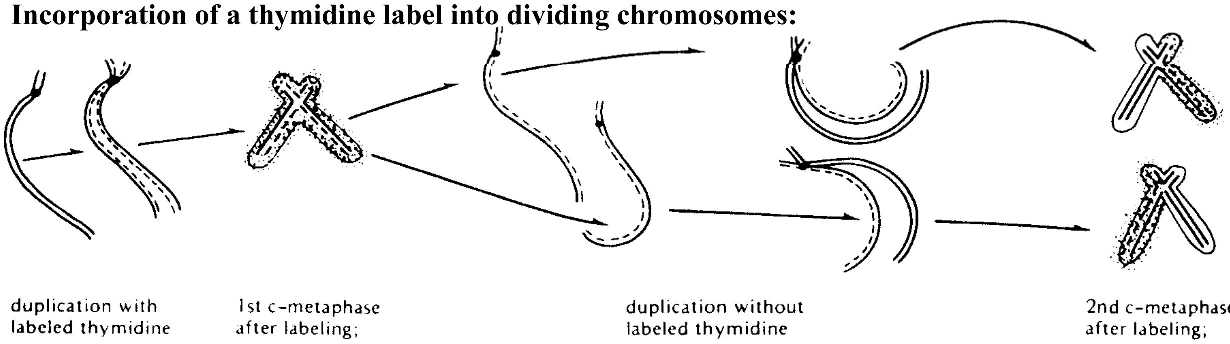
Photographs and interpretive diagram of events leading to equational anaphase I.

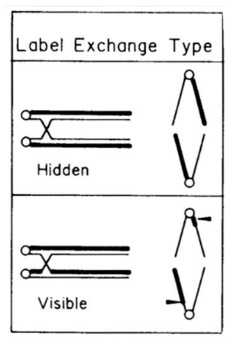
Behavior of the heteromorphic arms:

	Metaphase I		Anaphase I		
	Chiasmata	No chiasmata	Equational	Reductional	p=
Year: 1951	71%	29%	71%	29%	<0.05
Year: 1953	51%	49%	55%	45%	<0.05

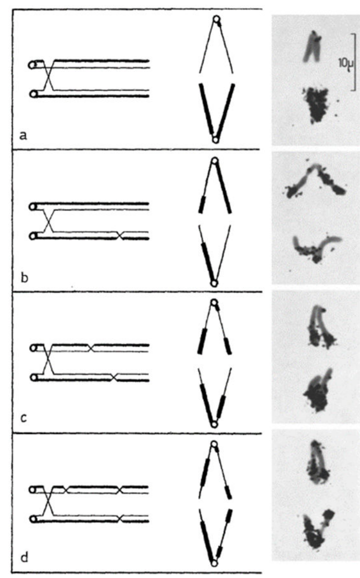
Jones, 1971

Incorporation of a thymidine label into dividing chromosomes:





Stethophyma grossum
Wikipedia commons



Recombination takes place between homologs

Stern, 1931 (Drosophila)
Creighton & McClintock, 1931 (Maize)

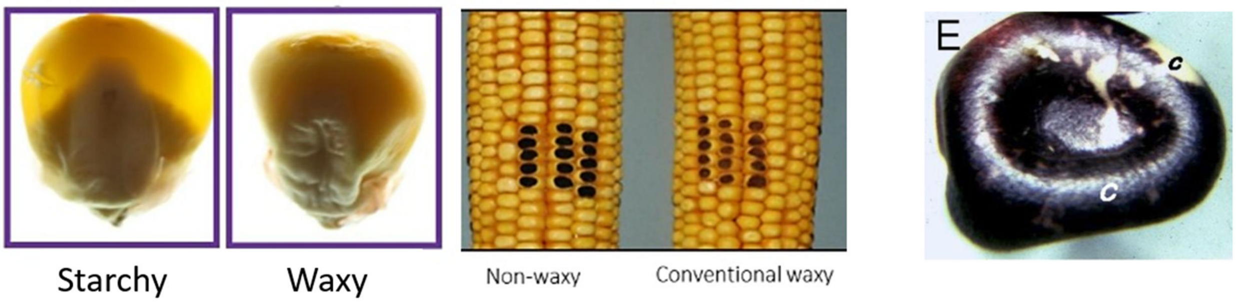
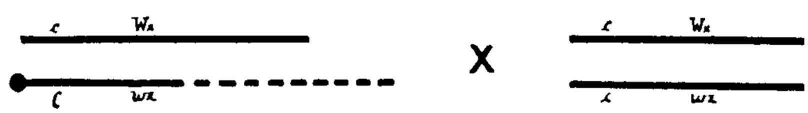
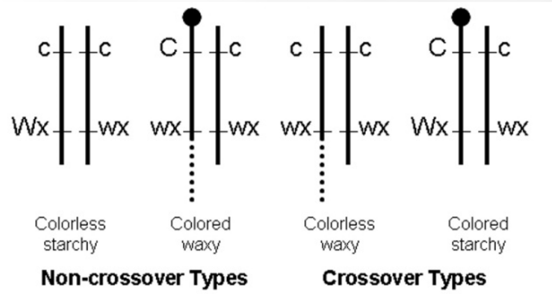


Figure 4. Corteva; Fedoroff NV. 2012. PNAS 109: 20200-20203; https://doi.org/10.1073/pnas.1215482109



Colored, starchy × colorless, starchy

$$\frac{knobless \cdot c \cdot Wx \cdot normal}{knob \cdot C \cdot wx \cdot interchange} \times \frac{knobless \cdot c \cdot Wx \cdot normal}{knobless \cdot c \cdot wx \cdot normal}$$



https://www.nature.com/scitable/content/mcclintock-and-creighton-s-work-in-maize-41556/

Progeny types	Cytological Features	Attributed cytological mechanism
Colored, waxy (*C_*, *wxwx*)	Knob, Interchanged	Non-CO
Colorless, waxy (*cc*, *wxwx*)	Knobless, Interchanged	Crossovers
Colored, starchy (*C_*, *Wx_*)	Knob, normal	Crossovers
Colorless, starchy (*cc*, *Wx_*)	Knobless, Interchanged	Crossovers
	Knobless, normal	Non-CO

Crossing over occurs at the 4-strand stage

The linear sporads of *Neurospora*

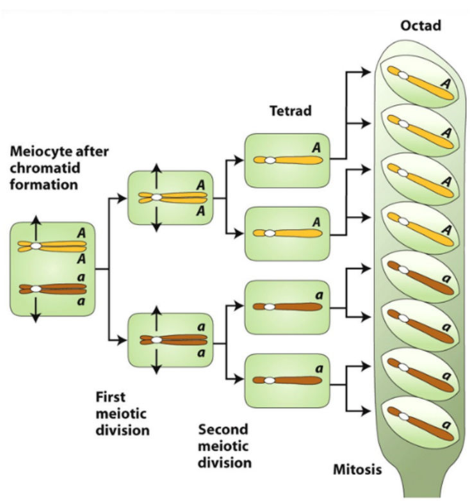


Figure 3-10b
Introduction to Genetic Analysis, Tenth Edition

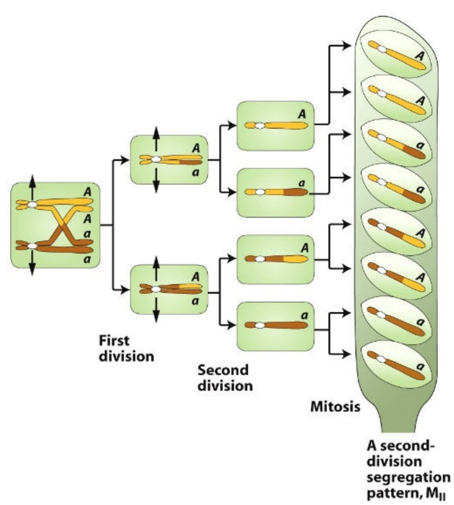


Figure 4-17
Introduction to Genetic Analysis, Tenth Edition

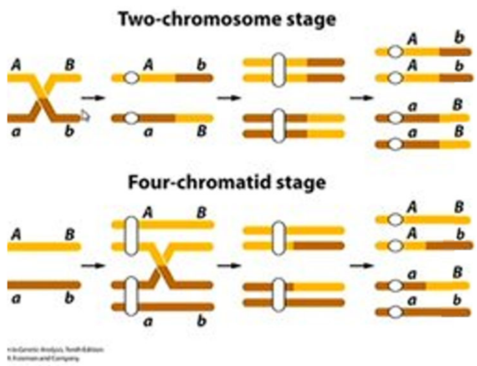


Figure 5. https://quizlet.com/

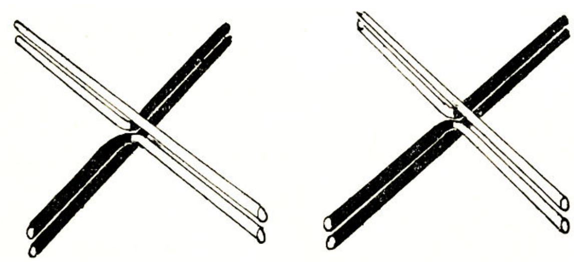
Models of chiasma

Sax, 1932

Any model of CO must account for these facts:

The chiasmatype or 1-plane model

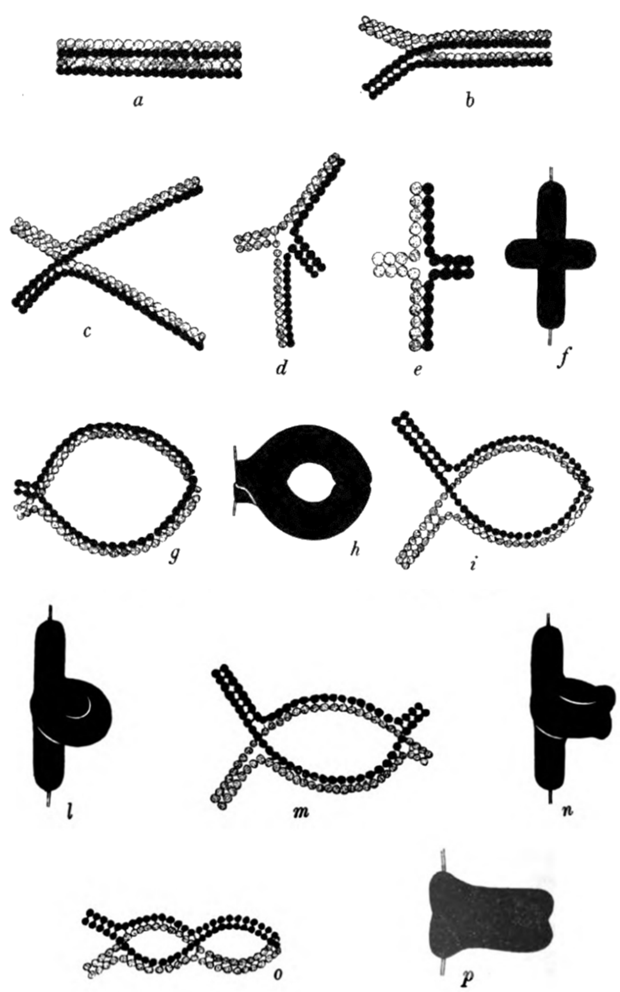
Janssens, 1909



Frans Alfons Janssens
1865-1924

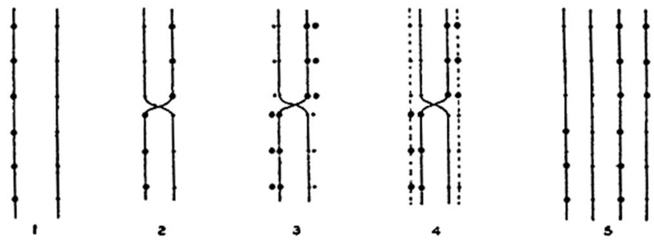
The 2-plane model

Granata, 1910

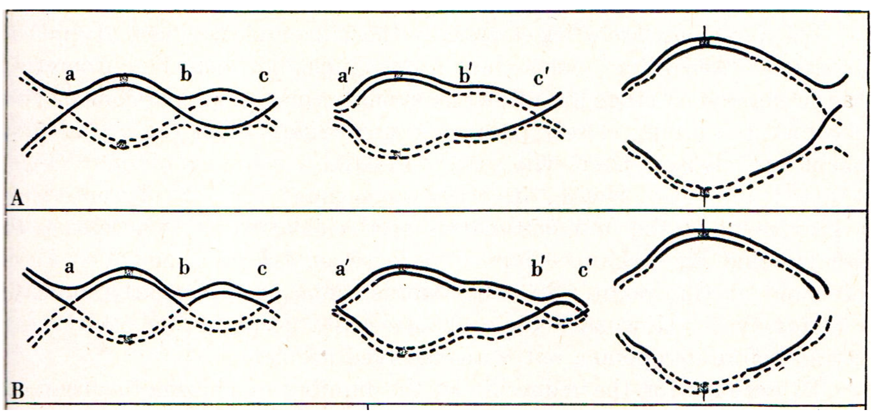


The copy choice model

Belling 1933; Frease 1957

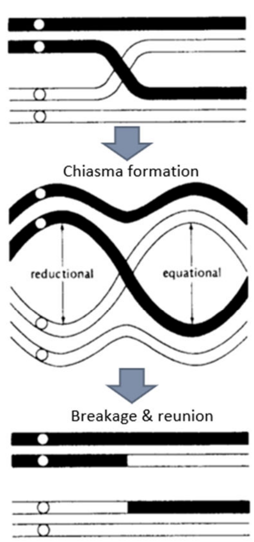


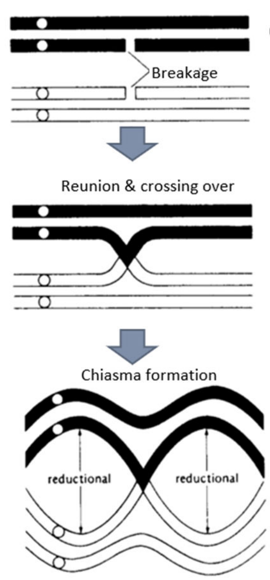
1 & 2-plane models summarized by Sharp, 1934



Classical or 2-plane model

Blamed on **Sharp, 1934**, based on McClung and Sax, but it precedes him – he just explained what others thought





Chiasmatype or 1-plane model

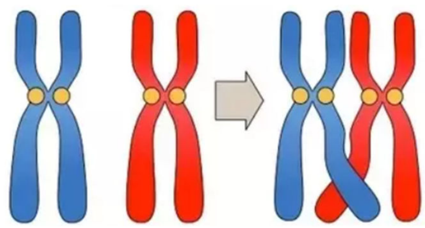
Janssens, 1909, with follow-ups by Belling and Darlington

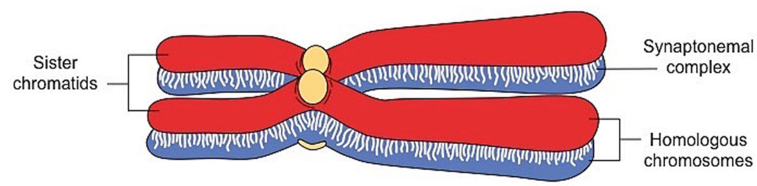
Strickberger 1976

Evidence for the chiasmatype hypothesis

The synaptonemal complex

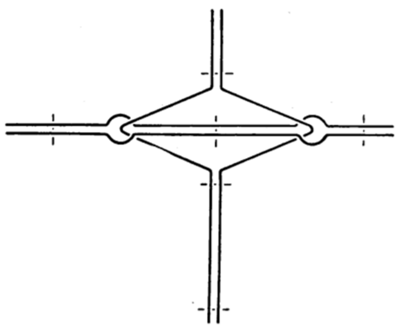
Pairing and chiasma as commonly depicted

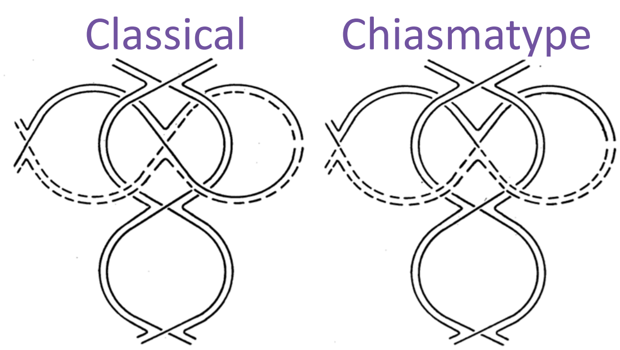




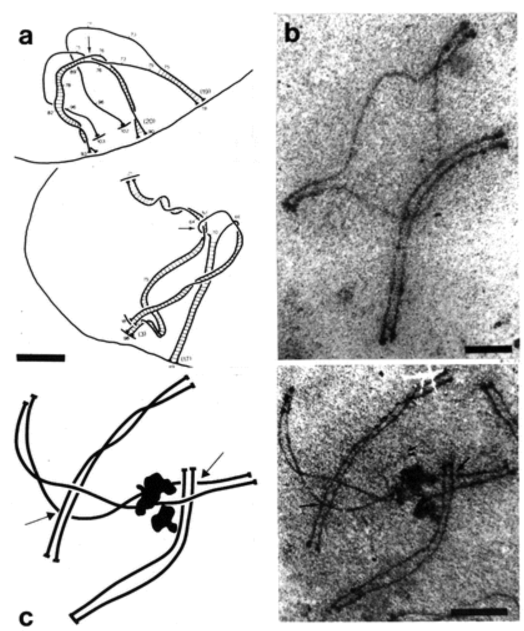
Interlocking bivalents

Mather, 1934



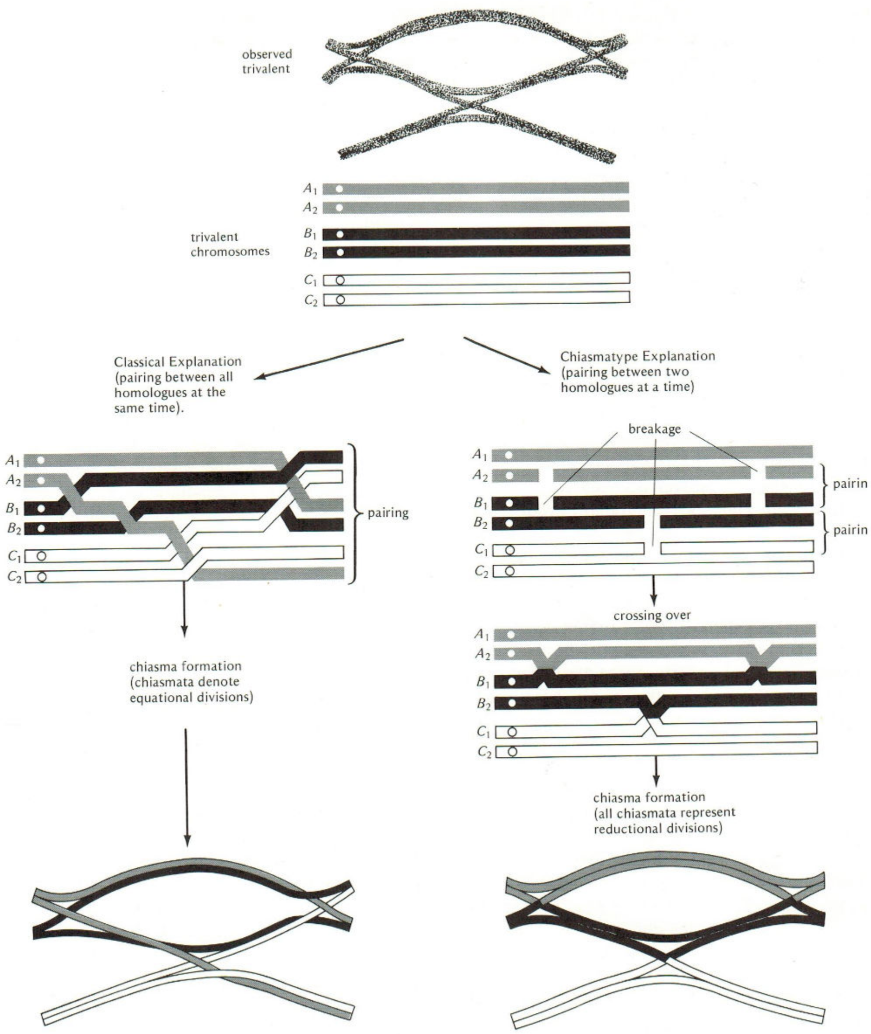


Interlocking bivalent in Lilium regale. https://www.jstor.org/stable/pdf/2471717.pdf

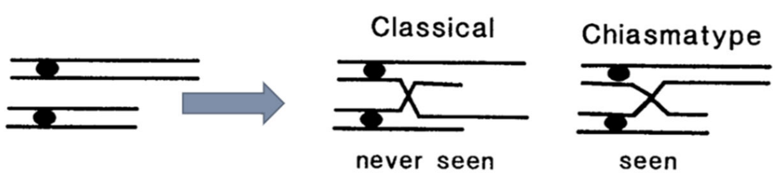


Examples of interlockings seen in Bombyx mori. Zickler & Kleckner, 1999

Chiasmata in trisomics

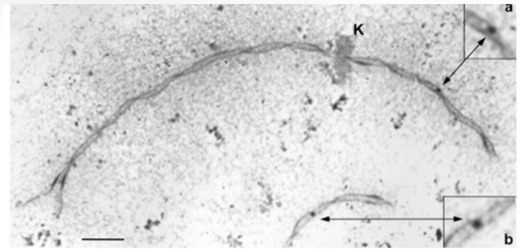


Heteromorphic pairs @ pachytene



Recombination nodules

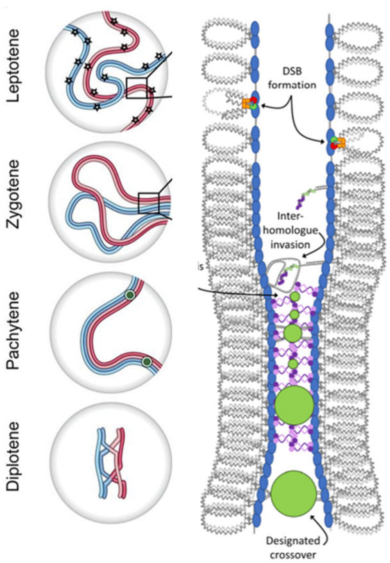
Sherman and Stack, 1995

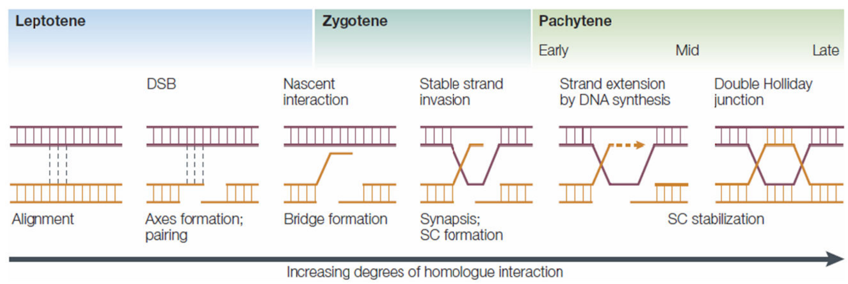


Anderson et al., 2003. *Two recombination nodules in early diplotene chromosomes – note the large chromosome has started to desynapse. K=kinetochore.*

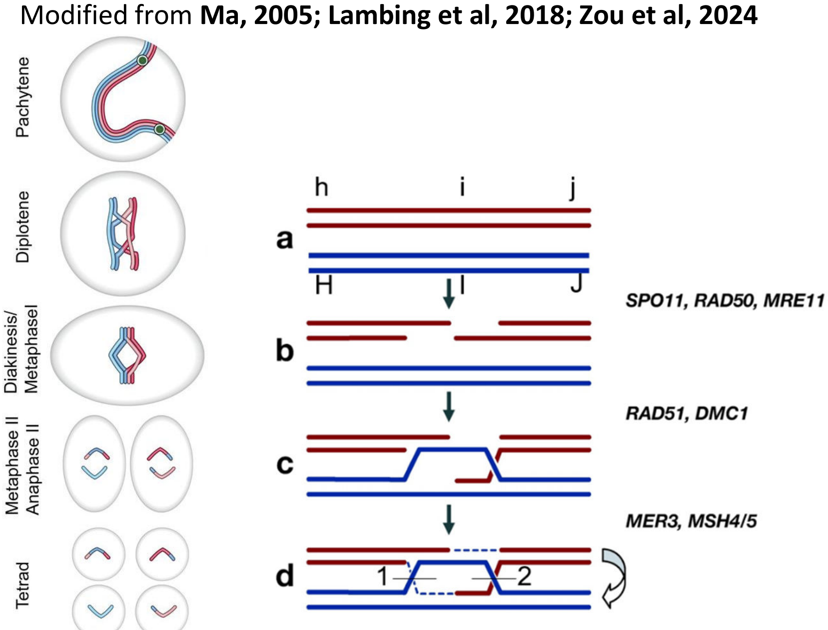
Crossing over

Gerton and Hawley, 2005; Lambing et al, 2018; Sepsi & Schwarzacher, 2020; Lloyd, 2022





Modified from **Ma, 2005; Lambing et al, 2018; Zou et al, 2024**



Holliday junction

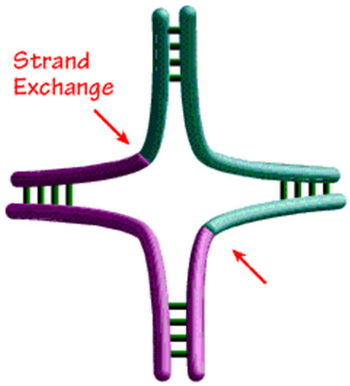
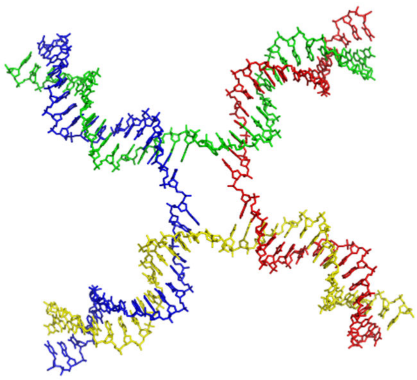
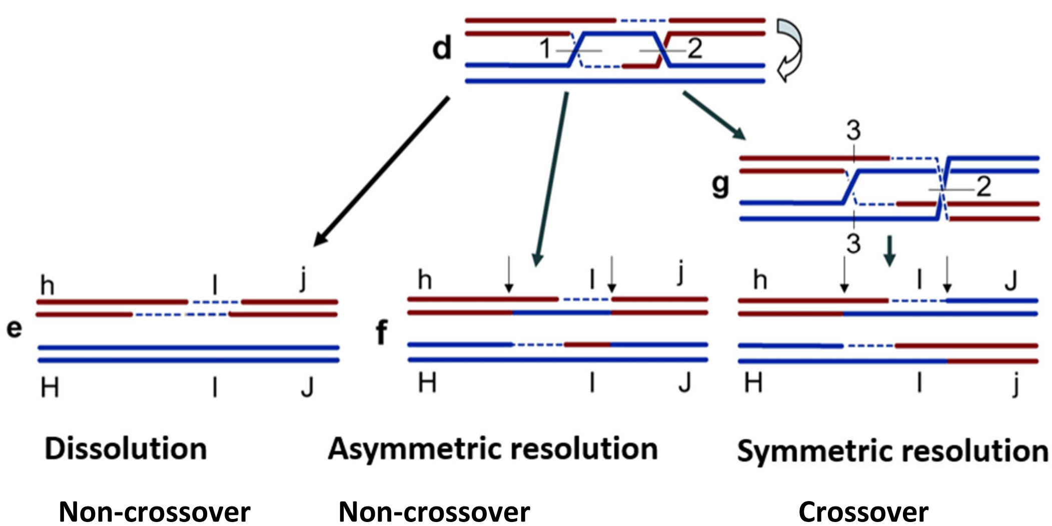
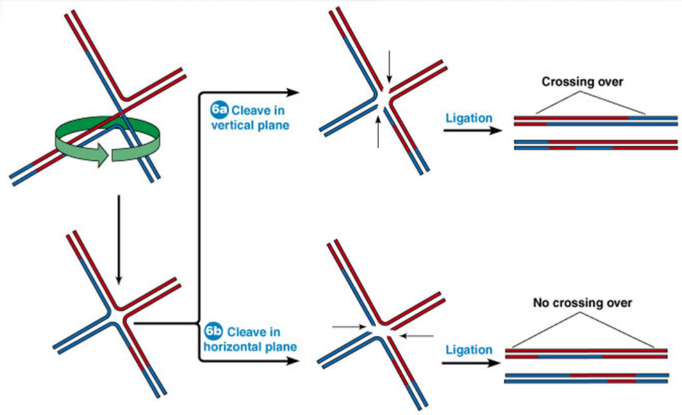


Figure 6. http://engels.genetics.wisc.edu/Holliday/holliday3D.html



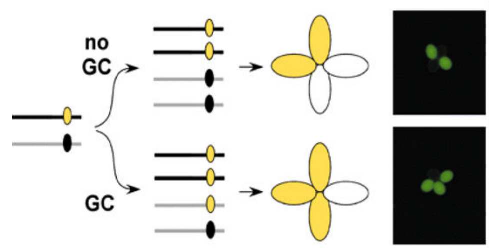




Gene conversion

Pollen tetrad of arabidopsis. Preuss et al., 1994

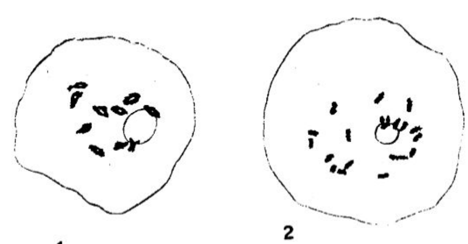
Francis et al., 2007



Yang et al., 2012

Pairing mutants

Soost, 1951



Diakinesis in normal and asynaptic maize (*Beadle, 1930*).

Asynaptic mutants –

Desynaptic –

Synaptic -

Metanaphase

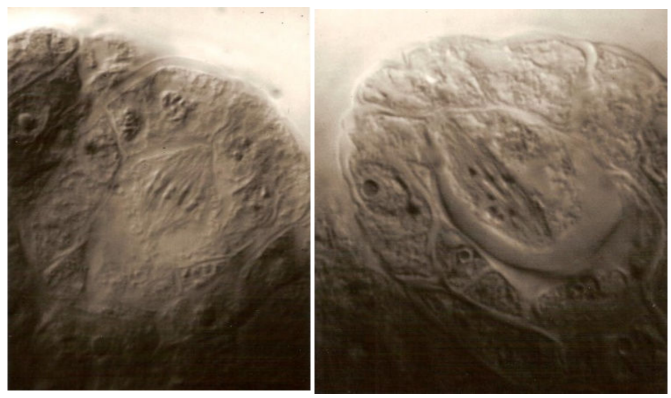


Figure 7. (left) Metaphase I in normal and (right) Metanaphase I in asynaptic megaspores of potato.

Behavior of univalents

Figure 8. Lagging chromosomes in a pollen mother cell of buffelgrass. Bar = 10 µm

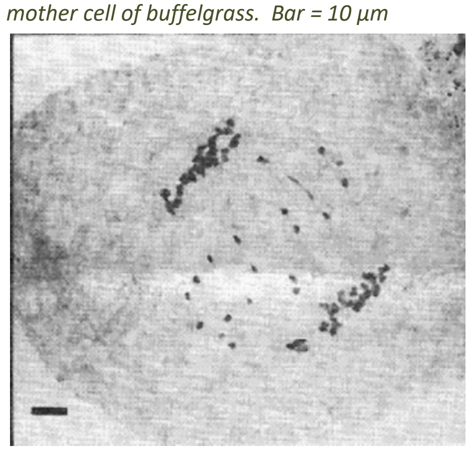
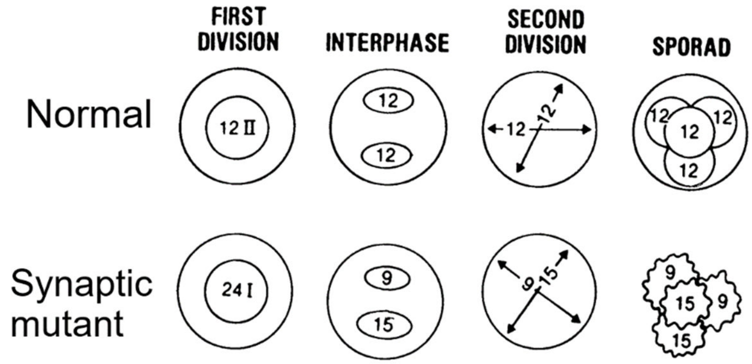
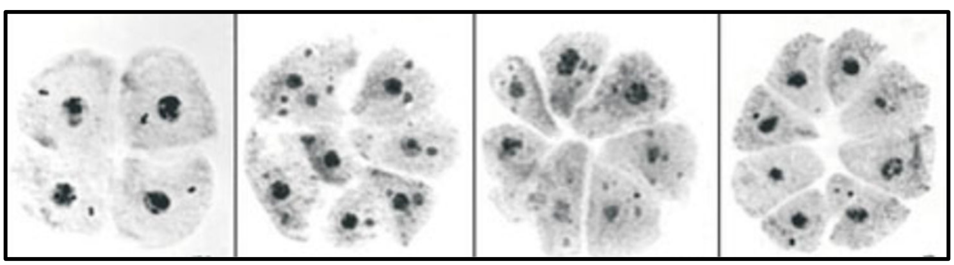


Photo: Visser NC, JJ Spies, and HJT Venter. The presence of synaptic and chromosome disjunction mutants in Cenchrus ciliaris (Poaceae: Paniceae). Bothalia 29:327-334.

Meiosis in synaptic mutants

Peloquin 1983





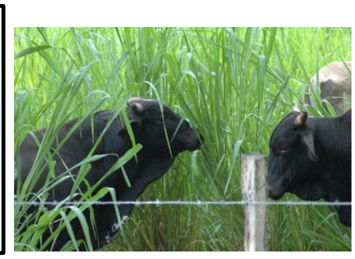


Figure 9. Polyads from 4x Brachyaria brizantha. Mendes-Bonato et al., 2009.

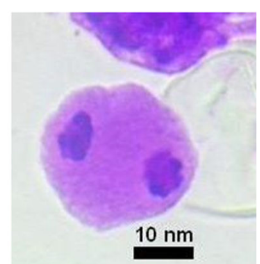
Disjunction in synaptic mutants

Belling & Blakeslee, 1927

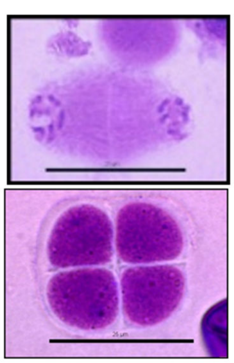
Figure 10. Pollen from asynaptic (top) and normal maize. Notice even normal maize has some aborted pollen grains [Beadle, 1930]

Correction for small *n*

Jackson and Jordan, 1975



Class alumnus Aaron Hoskins
Jalapeño pepper



Class alum Doug Heckart
Seashore paspalum

$$\frac{4}{4(2^n)-2}$$

$$\frac{4}{4(2^n)-4}$$

Class alumna Rebecca Tashiro
White clover

Chromosome #	$(0.5)^n$	$4/[4(2^n)-2]$	$4/[4(2^n)-4]$
1	50.00	66.67	100.00
2	25.00	28.57	33.33
3	12.50	13.33	14.29
4	6.25	6.45	6.67
5	3.13	3.17	3.23
6	1.56	1.57	1.59
7	0.78	0.78	0.79
8	0.39	0.39	0.39
9	0.20	0.20	0.20
10	0.10	0.10	0.10
11	0.05	0.05	0.05
12	0.02	0.02	0.02
13	0.01	0.01	0.01