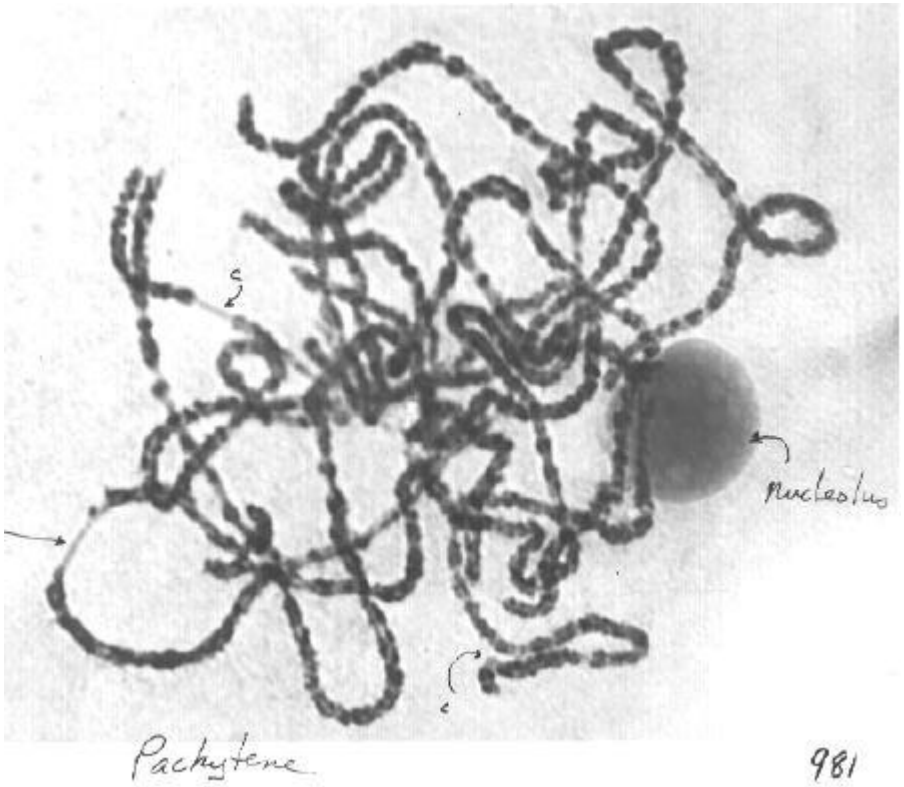
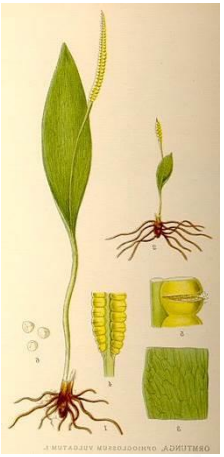
Meiosis and mitosis



Meiotic chromosome dance

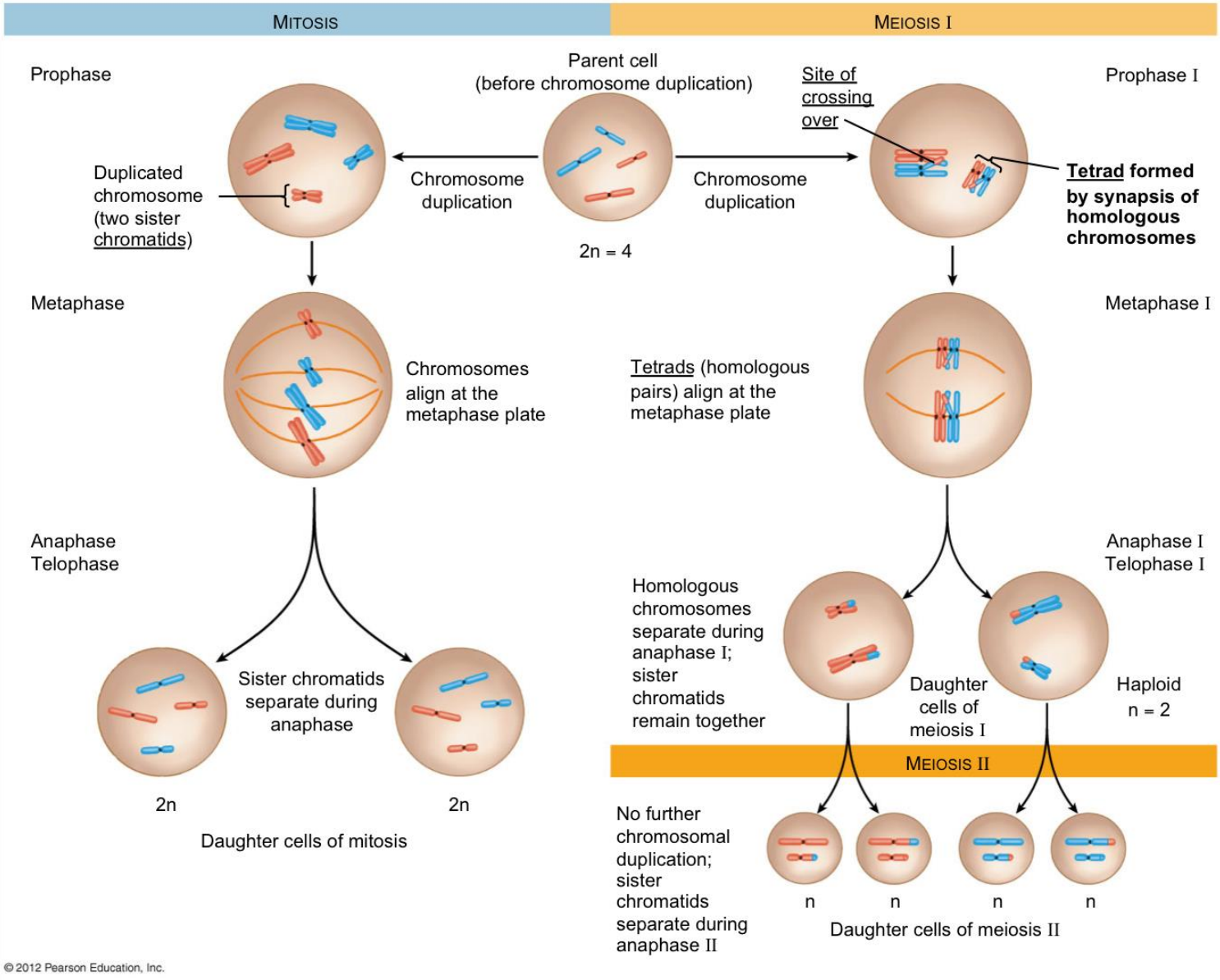


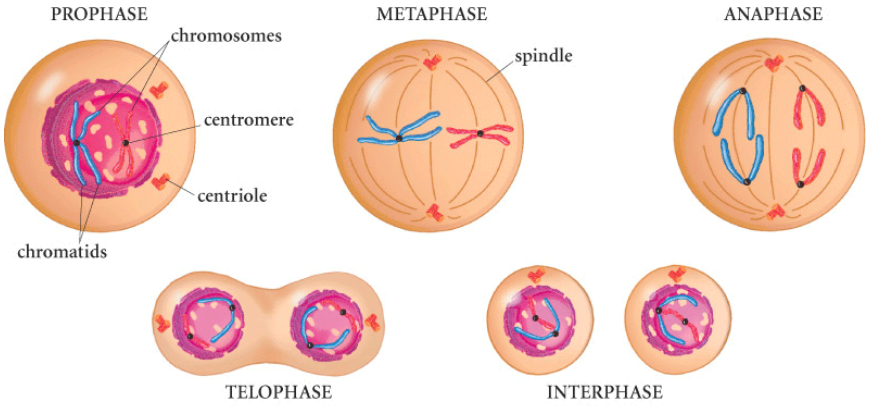
The function of meiosis is to generate cells that contain exactly half of the genetic materials of the parental cells and that develop into germ cells.

Chromosome rarrangements could occur during meiosis, get fixed in populations, and eventually can contribute to genetic differentiation and speciation.

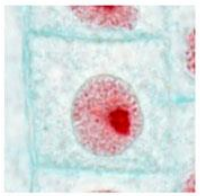
Meiotic prophase (diakinesis) in a sporocyte of *Ophioglossum reticulatum*, showing about 630 bivalents.

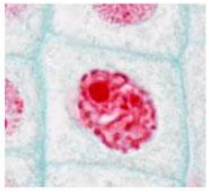
Mitosis vs. Meiosis

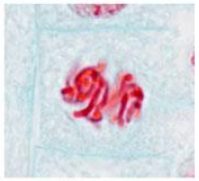


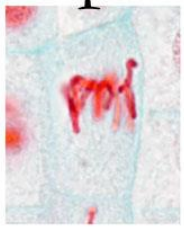


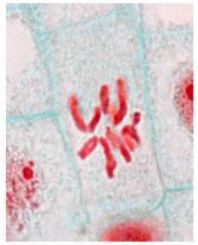
Mitosis - *Allium* Root Tip


Interpahase

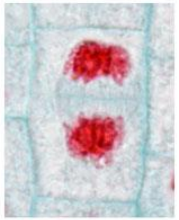

Prophase

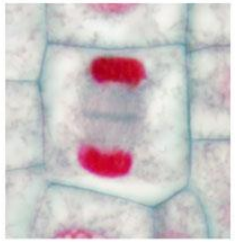

Later Phrophase


Metaphase


Early Anaphase


Anaphase


Telophase


Later Telophase

Meiotic phases

- premeiotic S-phase

Meiosis I (reductional division)

- **prophase**

leptotene

zygotene

pachytene

diplotene

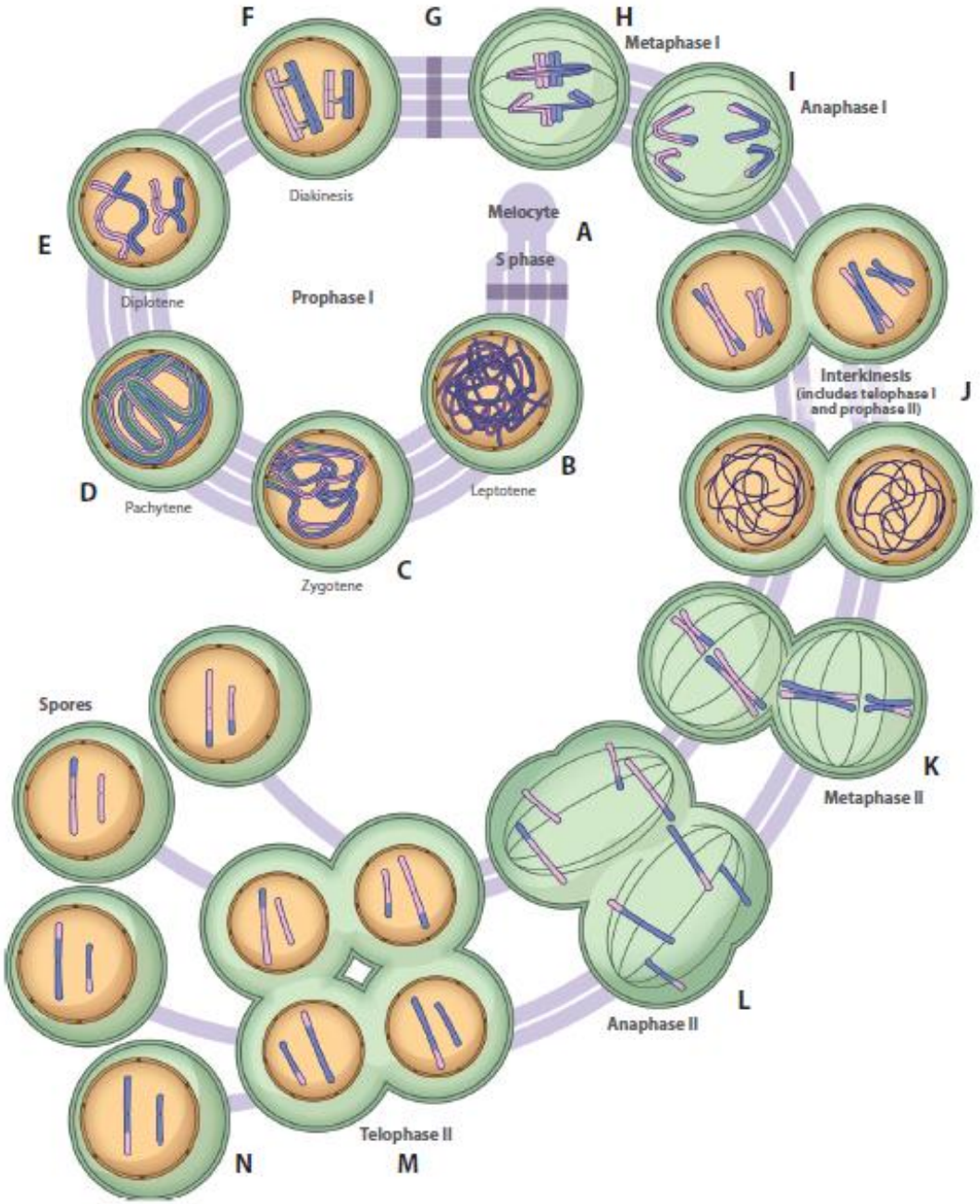
diakinesis

- **metaphase**
- **anaphase**
- **telophase**

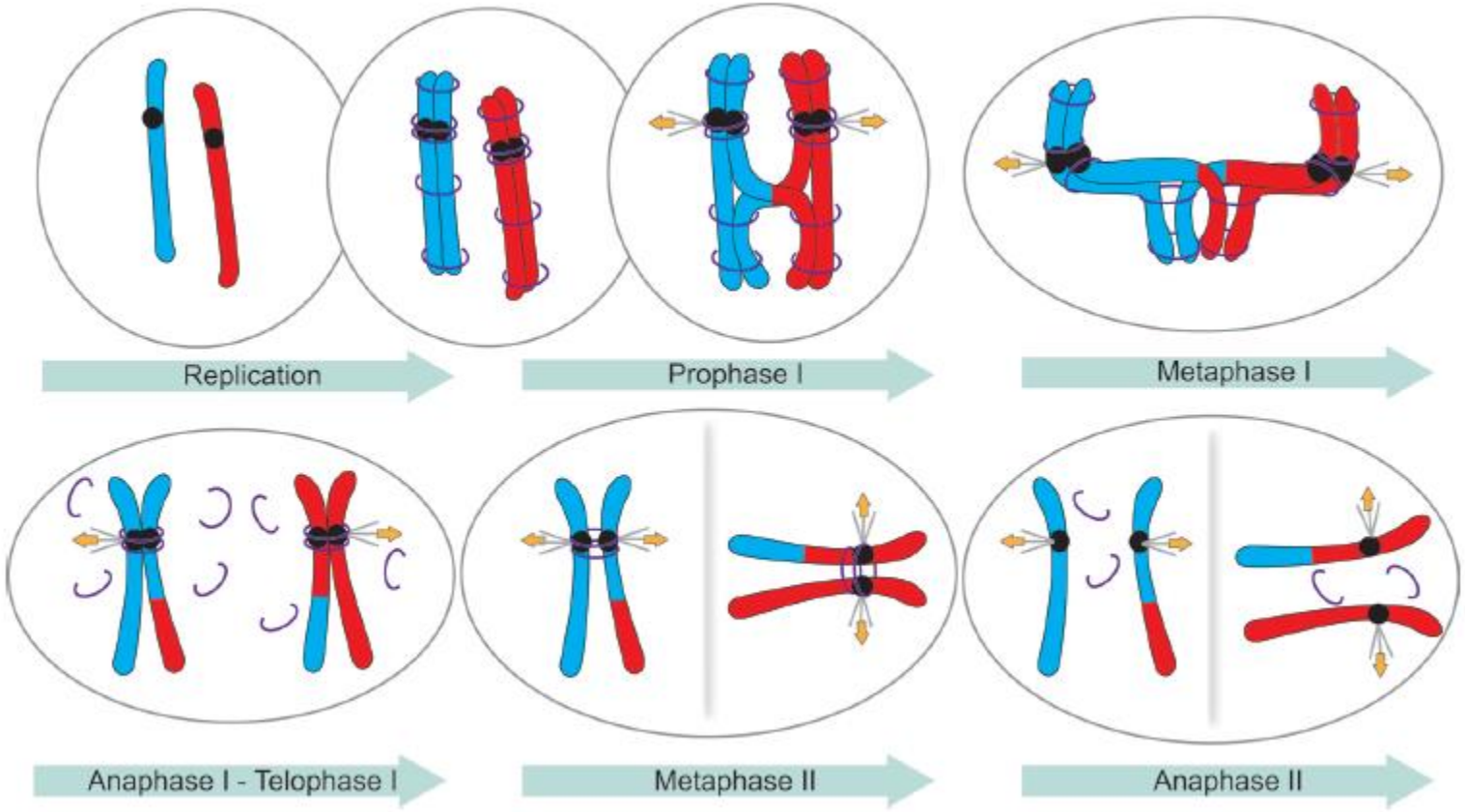
Meiosis II (equational division)

- **prophase**
- **metaphase**
- **anaphase**
- **telophase**

Meiosis

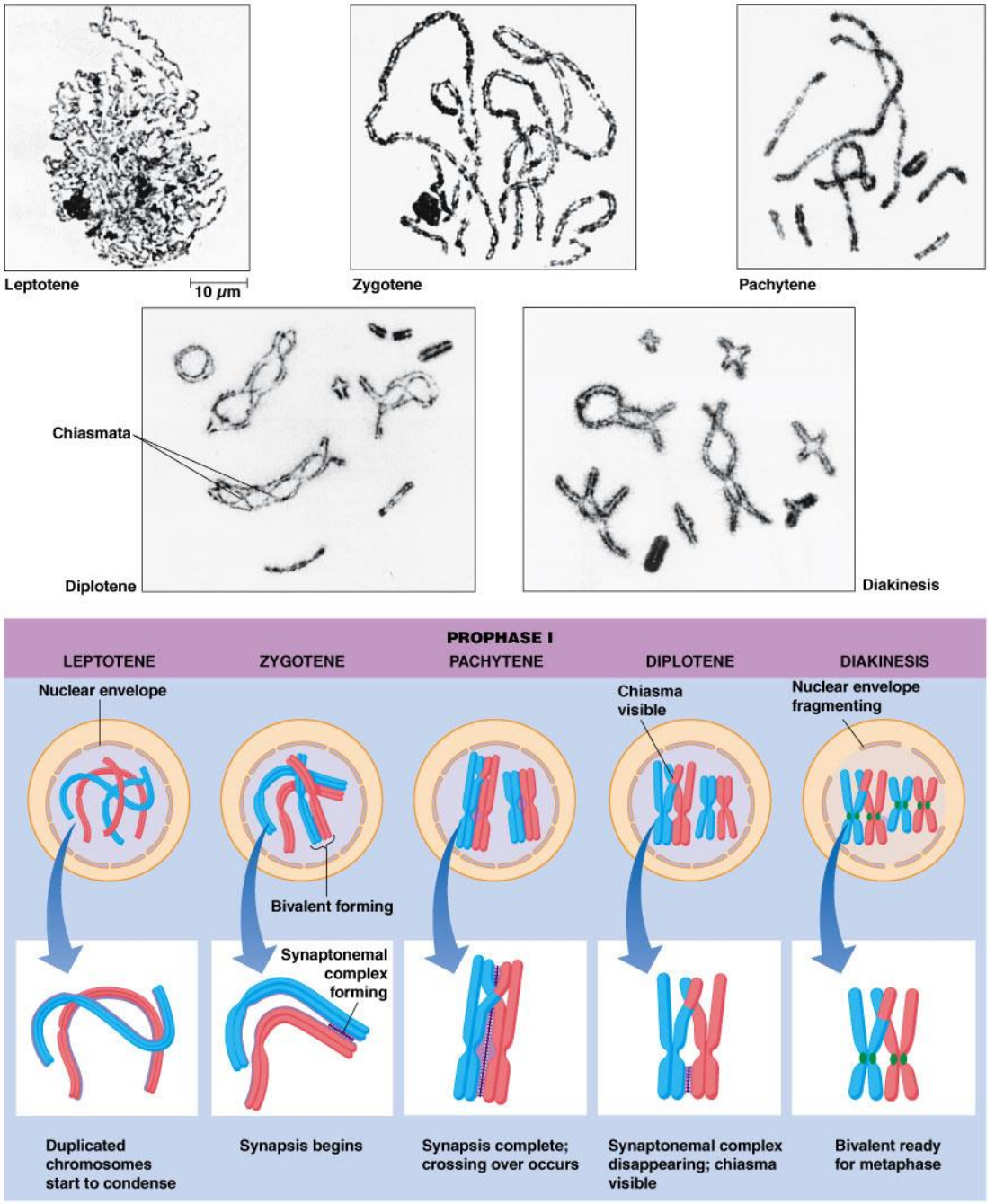

F
G
H
Metaphase I
I
Anaphase I
Diakinesis
Meiocyte
A
S phase
E
Diplotene
Prophase I
Interkinesis
(includes telophase I
and prophase II)
J
D
Pachytene
B
Leptotene
C
Zygotene
K
Metaphase II
Spores
L
Anaphase II
Telophase II
N
M

Meiotic phases

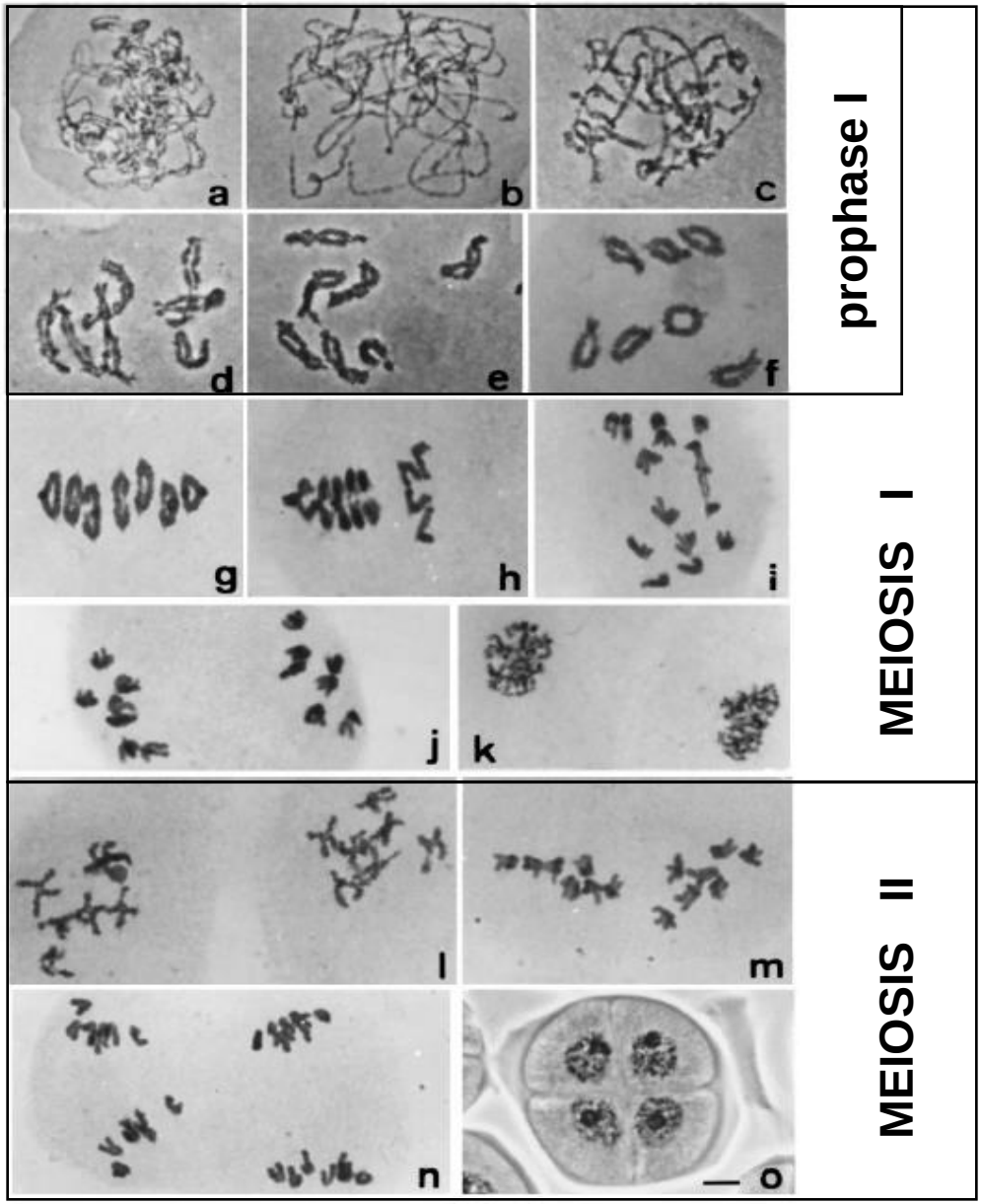


Prophase I

- leptotene
- zygotene
- pachytene
- diplotene
- diakinesis



Meiotic divisions I and II in the rye (*Secale cereale*)



(a – f) prophase I

(*a*) early zygotene

(*b* - *d*) early to late pachytene

(*e*) diplotene

(*f*) diakinesis

(*g*, *h*) metaphase I

(*i*, *j*) anaphase I

(*k*) telophase I

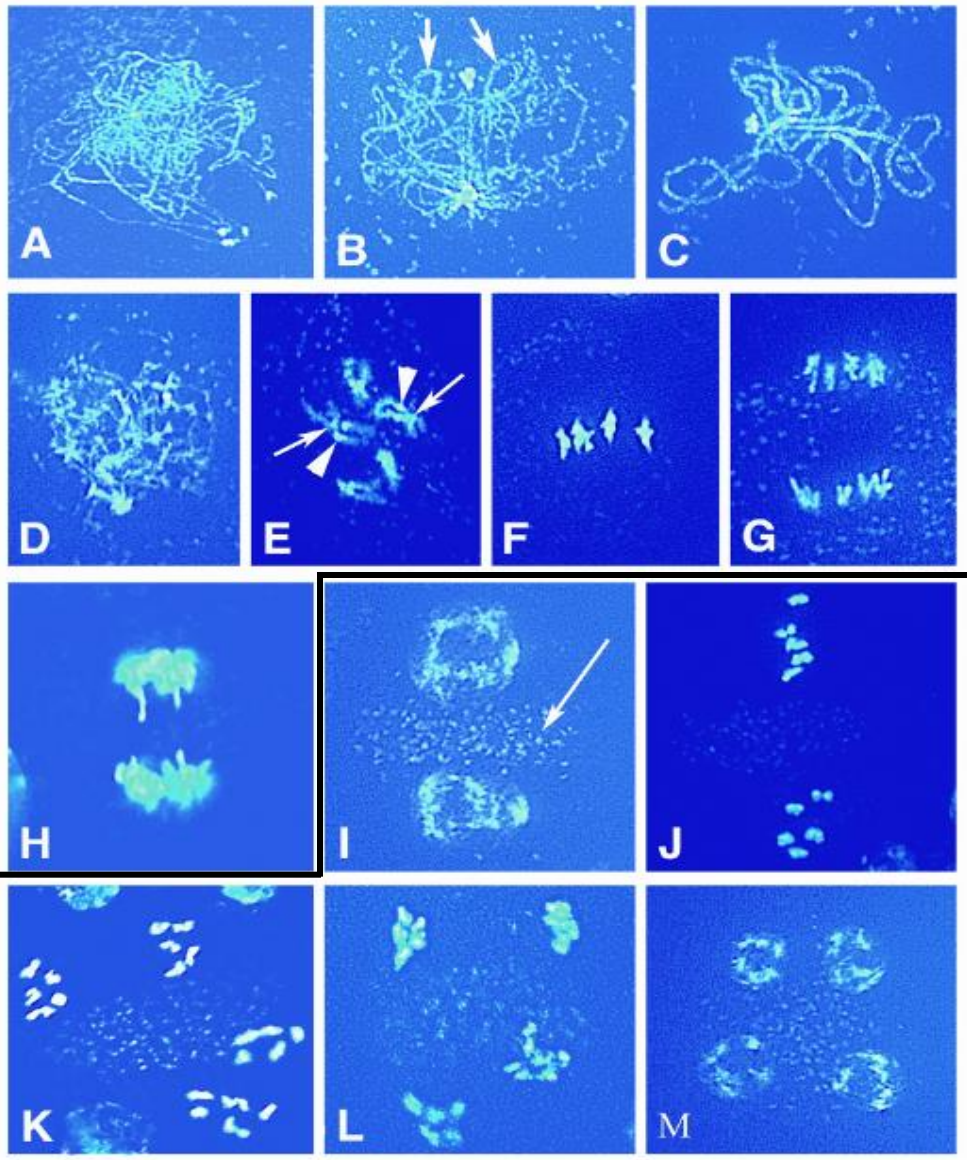
(*l*) prophase II

(*m*) metaphase II

(*n*) anaphase II

(*o*) telophase II (four haploid pollen mother cells)

Meiotic divisions I and II in *Arabidopsis thaliana*



MEIOSIS I

MEIOSIS II

(A - H) prophase I

(A) leptotene

(B) zygotene

(C) pachytene

(D) diplotene

(E) diakinesis

(F) metaphase I

(G) anaphase I

(H) telophase I

(I) prophase II

(J) metaphase II

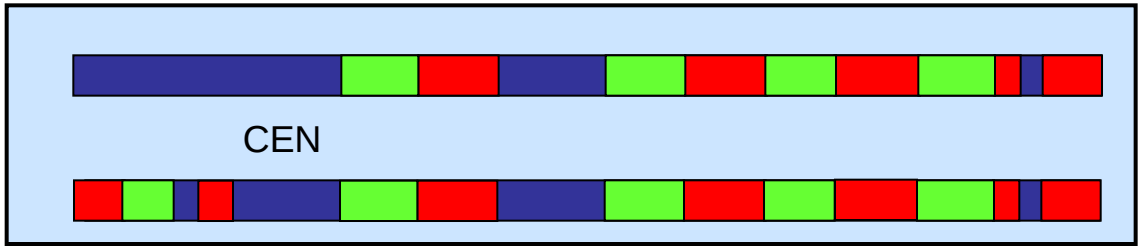
(K) anaphase II

(L) telophase II

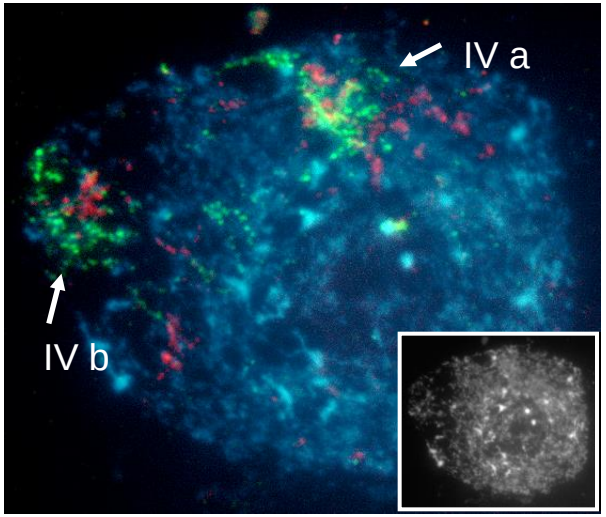
(M) four newly formed nuclei

Prophase I in *Arabidopsis thaliana* as revealed by chromosome painting

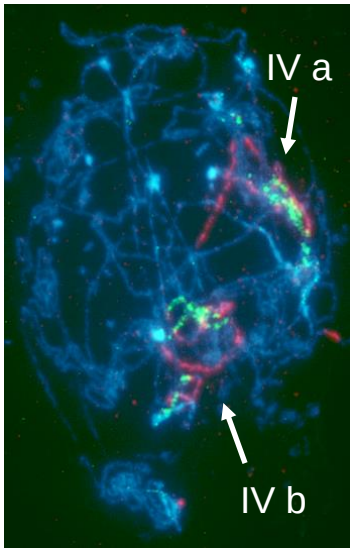
139 clones of a BAC tiling path covering *Arabidopsis* chromosome 4 were divided into 11 pools of 8-18 BACs. Individual pools were labelled either by biotin-dUTP (red) or digoxigenin-dUTP (green) for painting of either the long arm (113 BACs) or the entire chromosome (139 BACs).



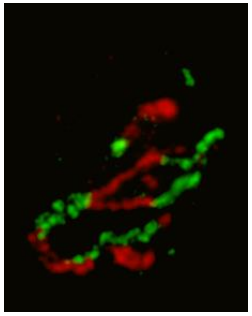
early prophase I

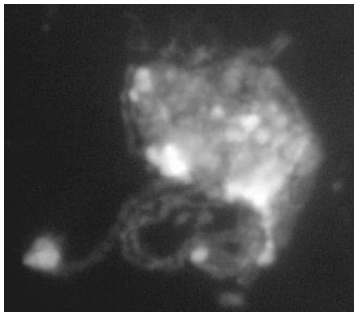


leptotene

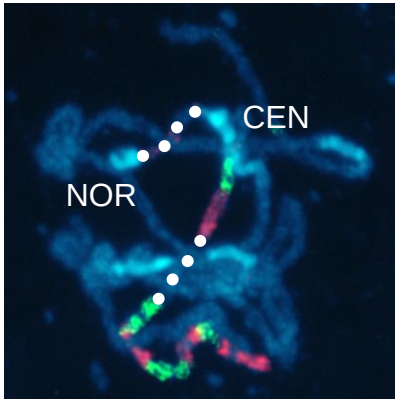


zygotene





pachytene



Key events of meiosis I

Links between chromosome **pairing**, **synapsis** and **recombination** are not well undestood. Recombination plays a key role in unifying meiotic events in prophase I.

Chromosome pairing

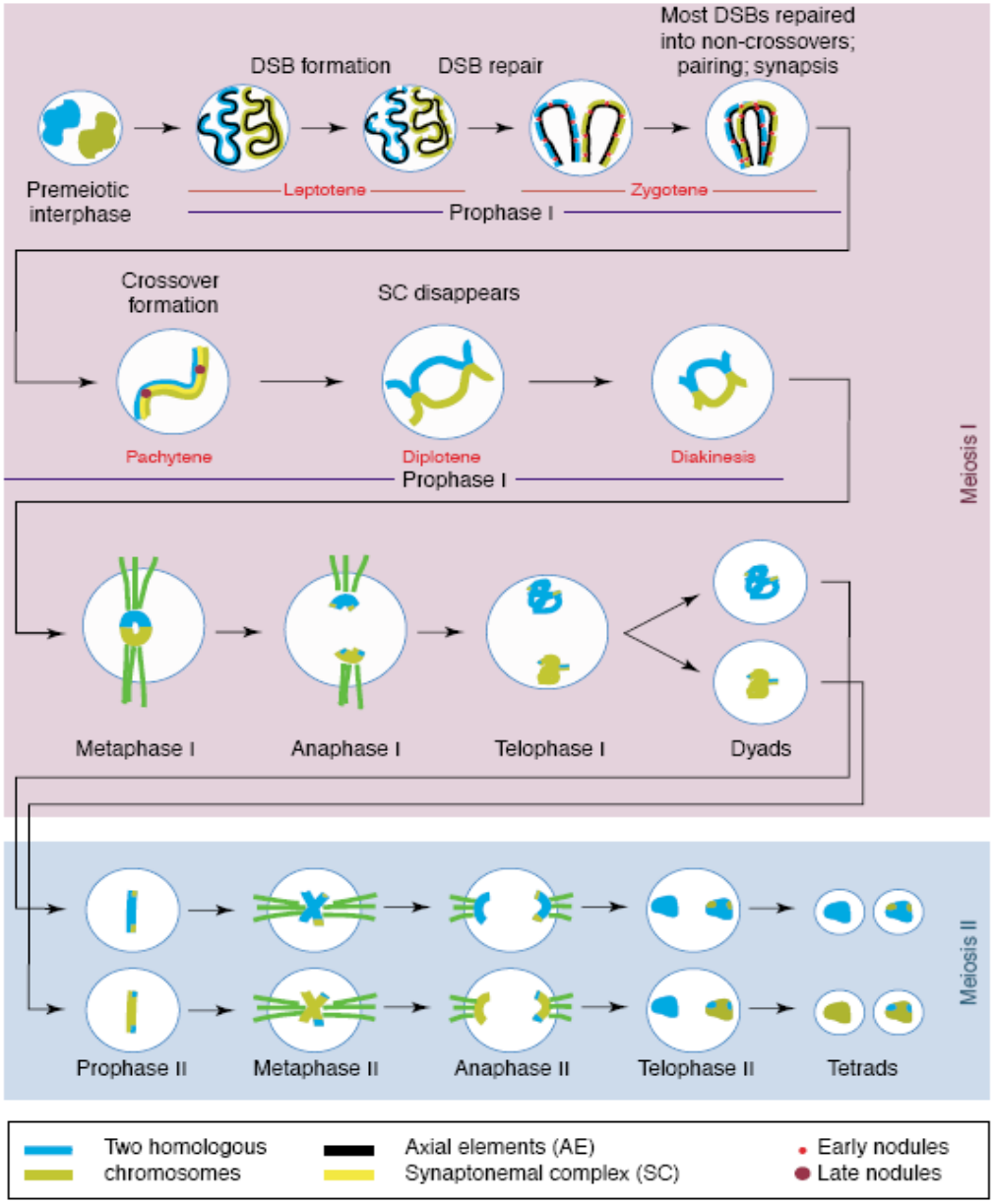
- the mechanism is not known

Synapsis

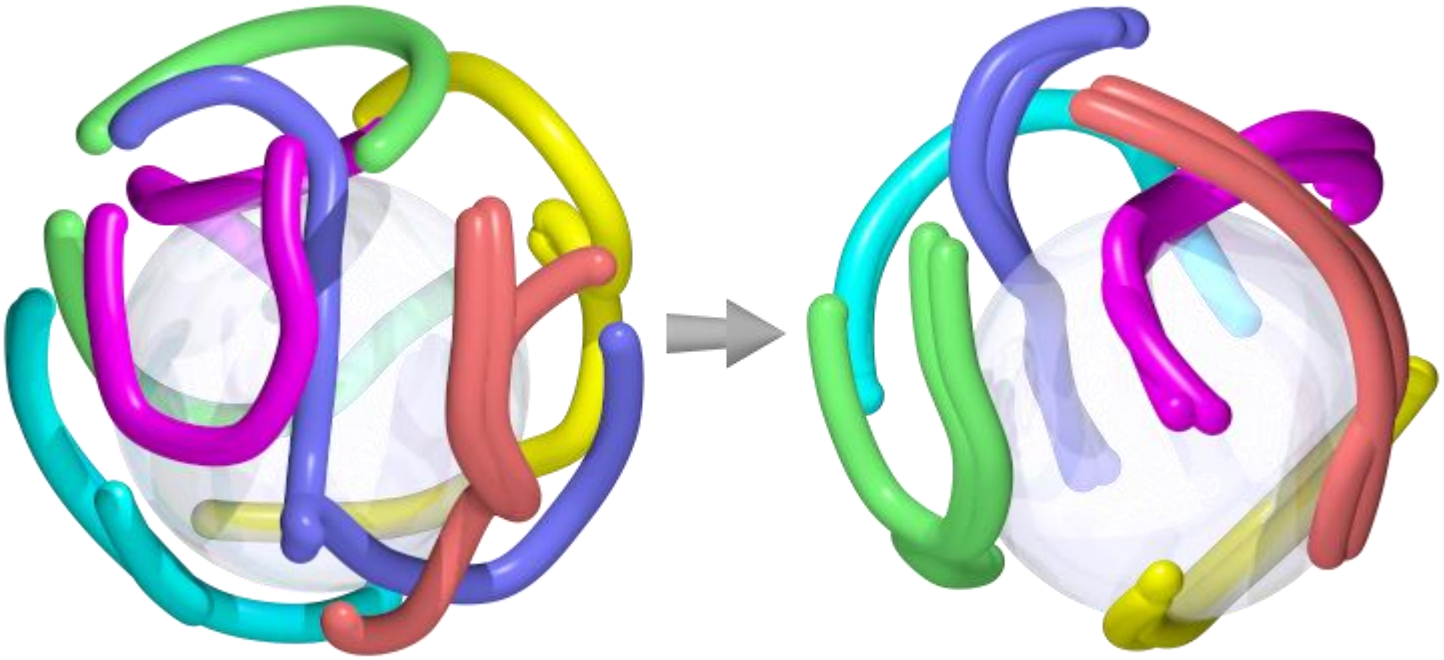
- synaptonemal complex (SC)
- the link between synapsis and recombination is not well understood

Meiotic recombination

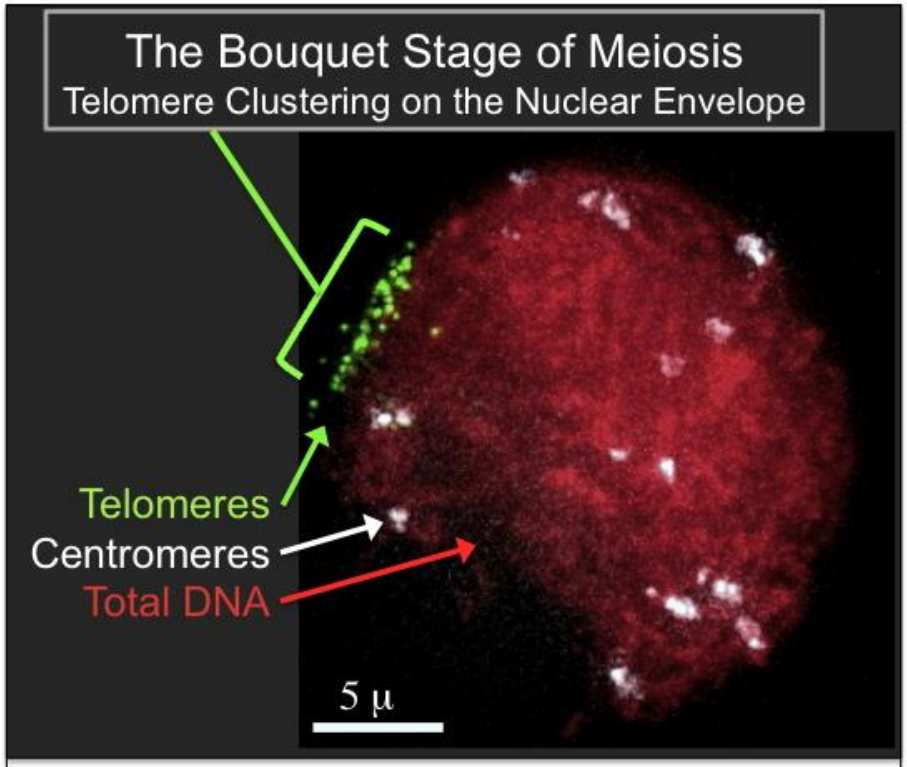
- process of formation of double-strand breaks (DSBs) and their subsequent repair
- results in formation of crossover and non-crossover products



Homologous chromosome recognition and pairing

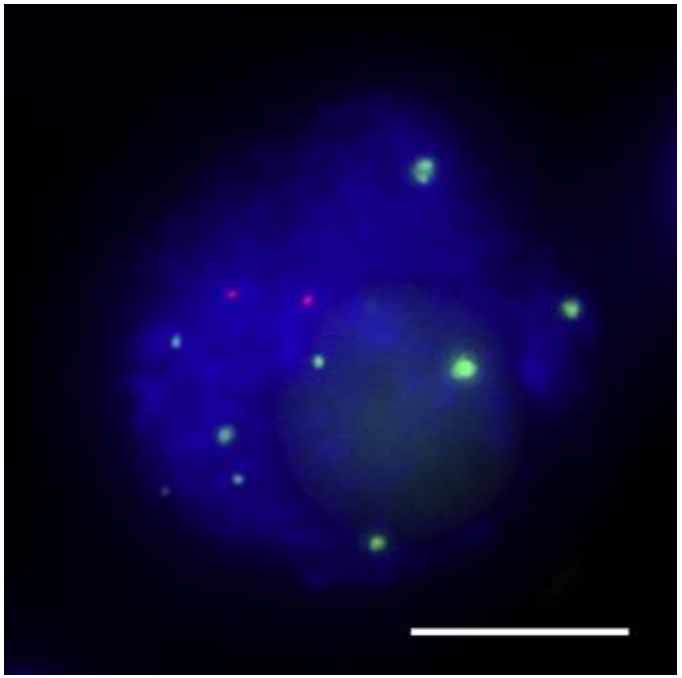


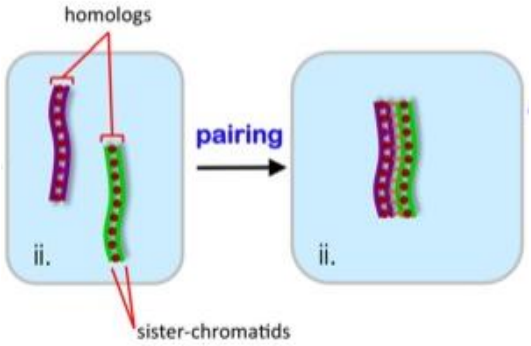
Homologous chromosome pairing facilitated by telomere and centromere clustering (?)



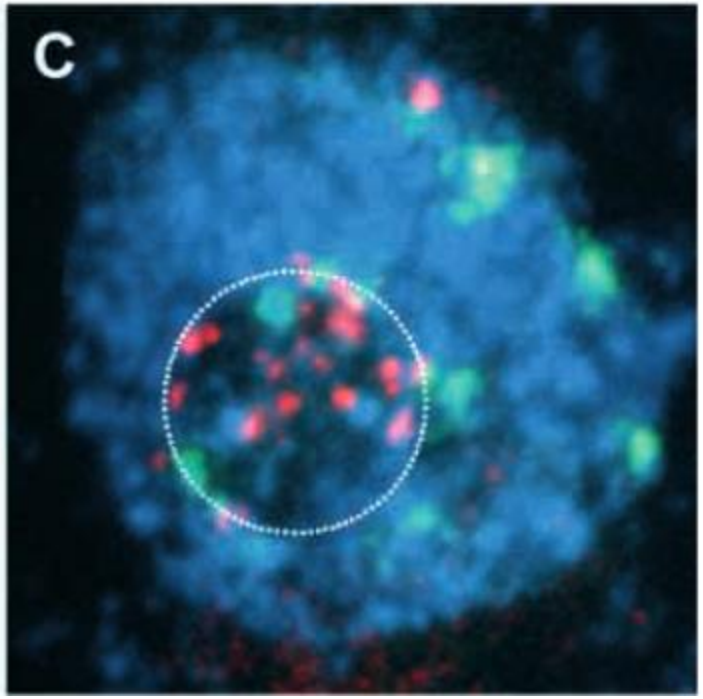
The meiotic telomere cluster is visualized by telomere FISH. Microscopic image of a maize nucleus fixed at meiotic prophase (zygotene stage), subjected to telomere (green) and centromere (white) FISH, and counterstained for total DNA with DAPI (red). This pseudo-colored image is a 2-D projection of a 3-D, multi-color image dataset, courtesy of SP Murphy and HW Bass, Florida State University.

Centromere pairing is prior to the alignment of chromosome arms at the leptotene stage (maize)





Arabidopsis: telomere clustering around nucleolus



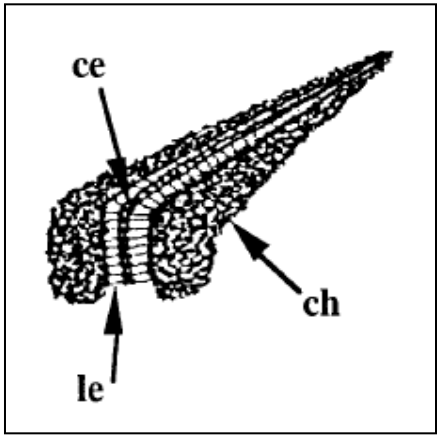
Armstrong et al. 2001, JCS

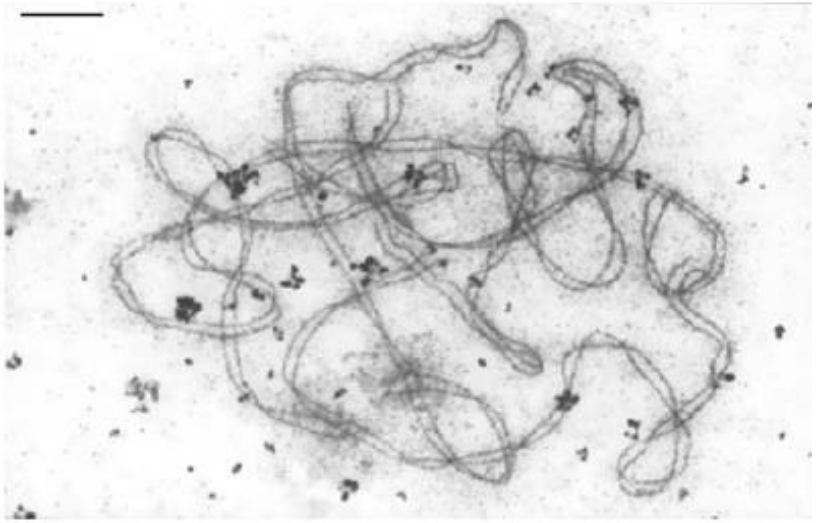
Synaptonemal complex (SC)

- synapsis

- consists of two lateral elements (**le**) connected by a central element (**ce**) [the lateral elements formed as axial elements (AEs, also called the chromosome axis) in leptotene]

- the central element assembles following chromosome pairing during zygotene



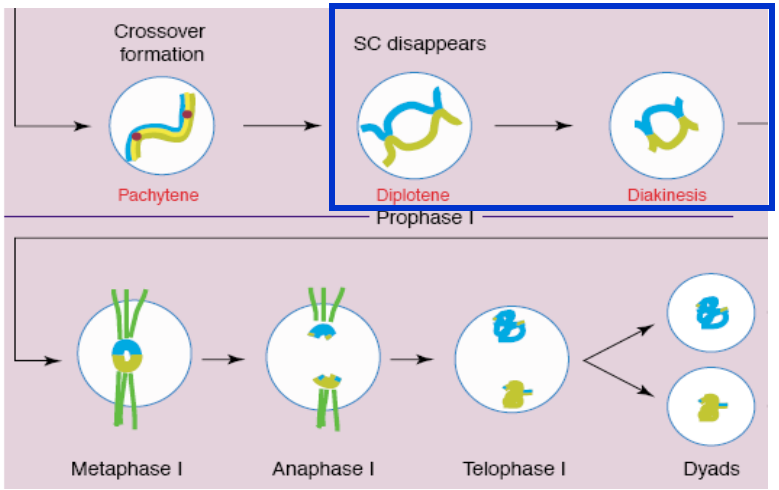


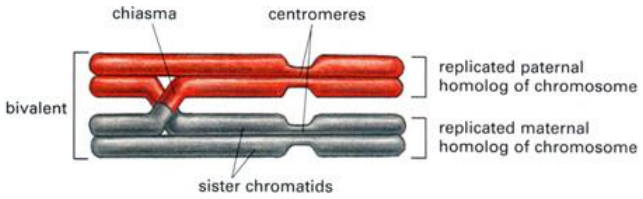
Synaptonemal complex in *Arabidopsis thaliana*

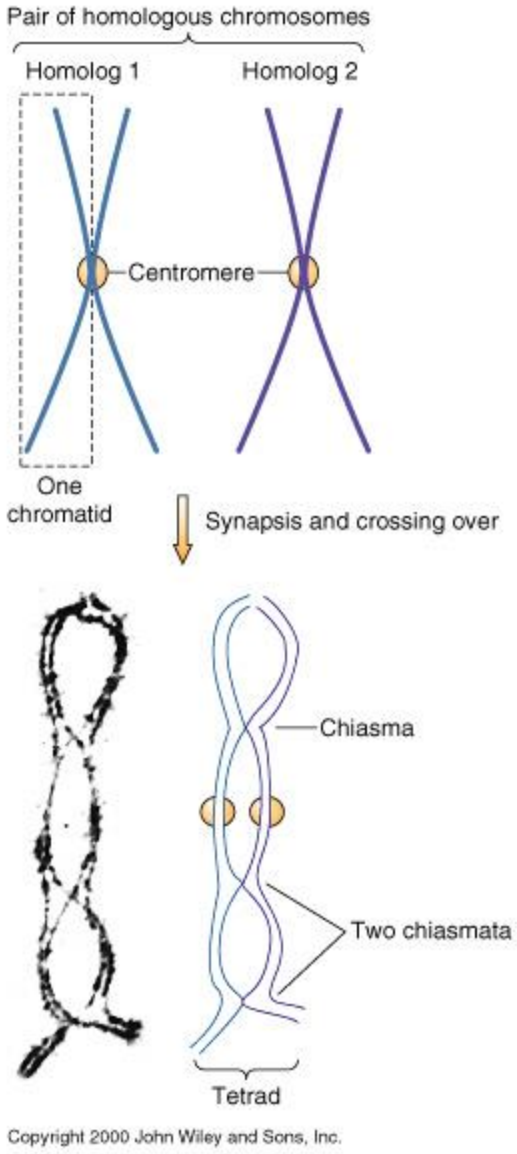
Recombination (crossing over) and chiasmata

Recombination (crossing over) and chiasmata

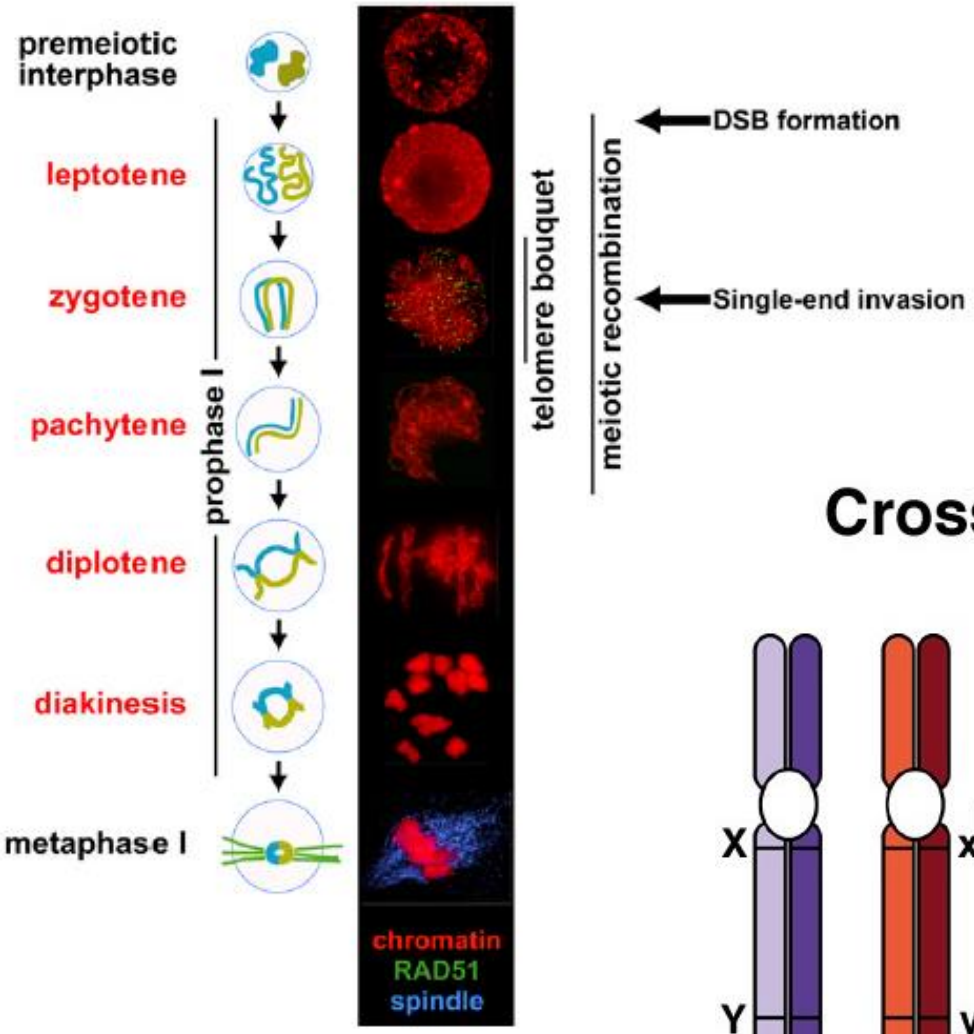
chiasma formation



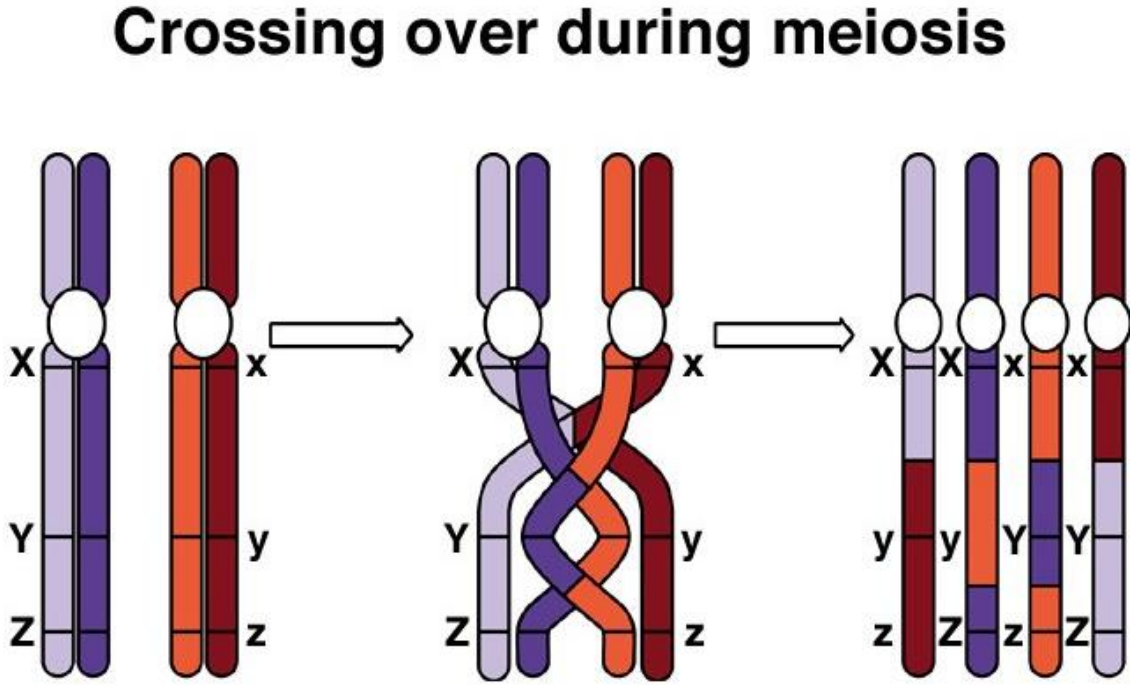




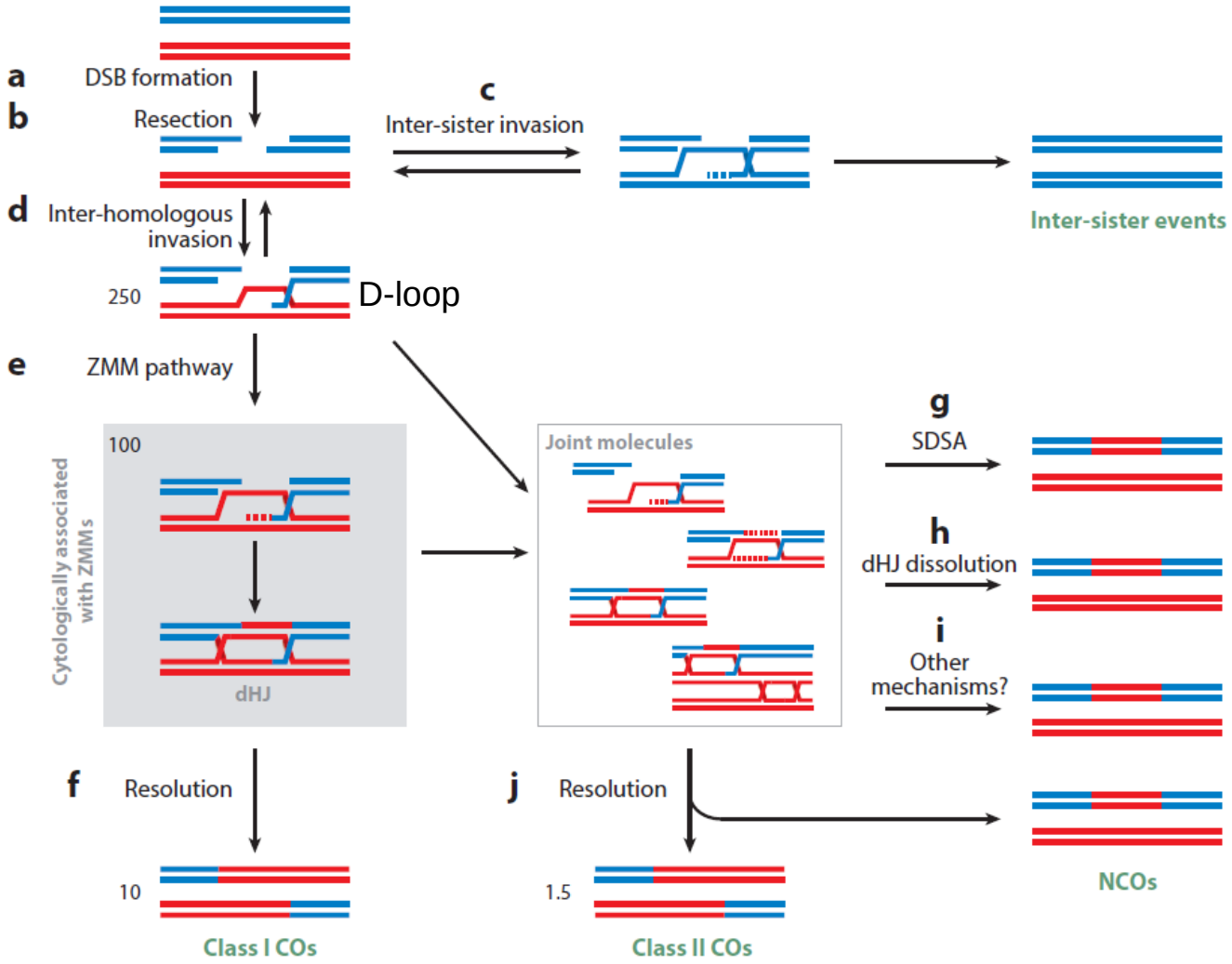
Prophase I: crossing over



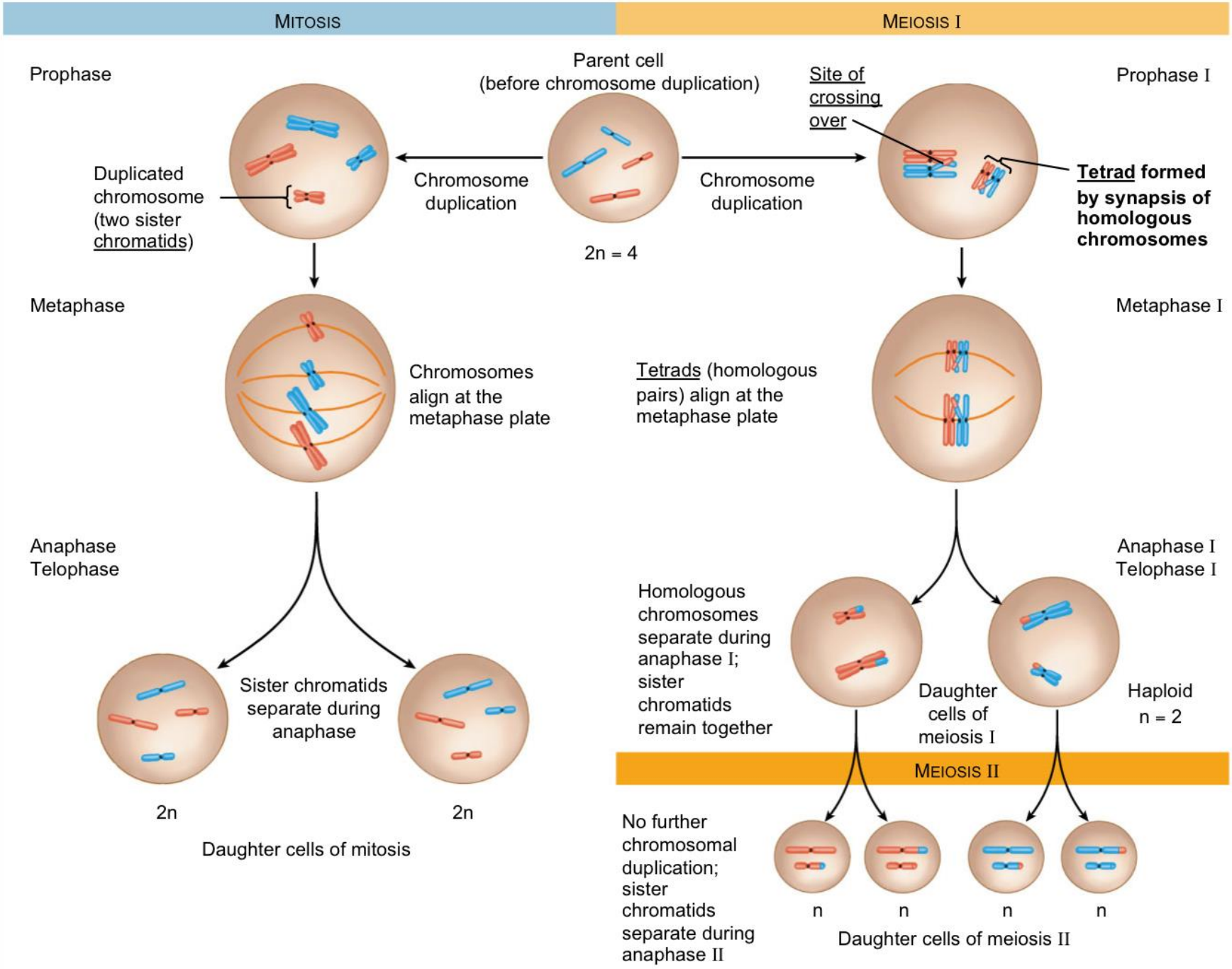
- SPO11 protein introduces DSBs into chromosomal DNA
- DNA ends adjacent to these breaks are later bound by **RAD51** and **DMC1** that catalyze single-end invasion of the broken DNA ends into the homologous chromosome



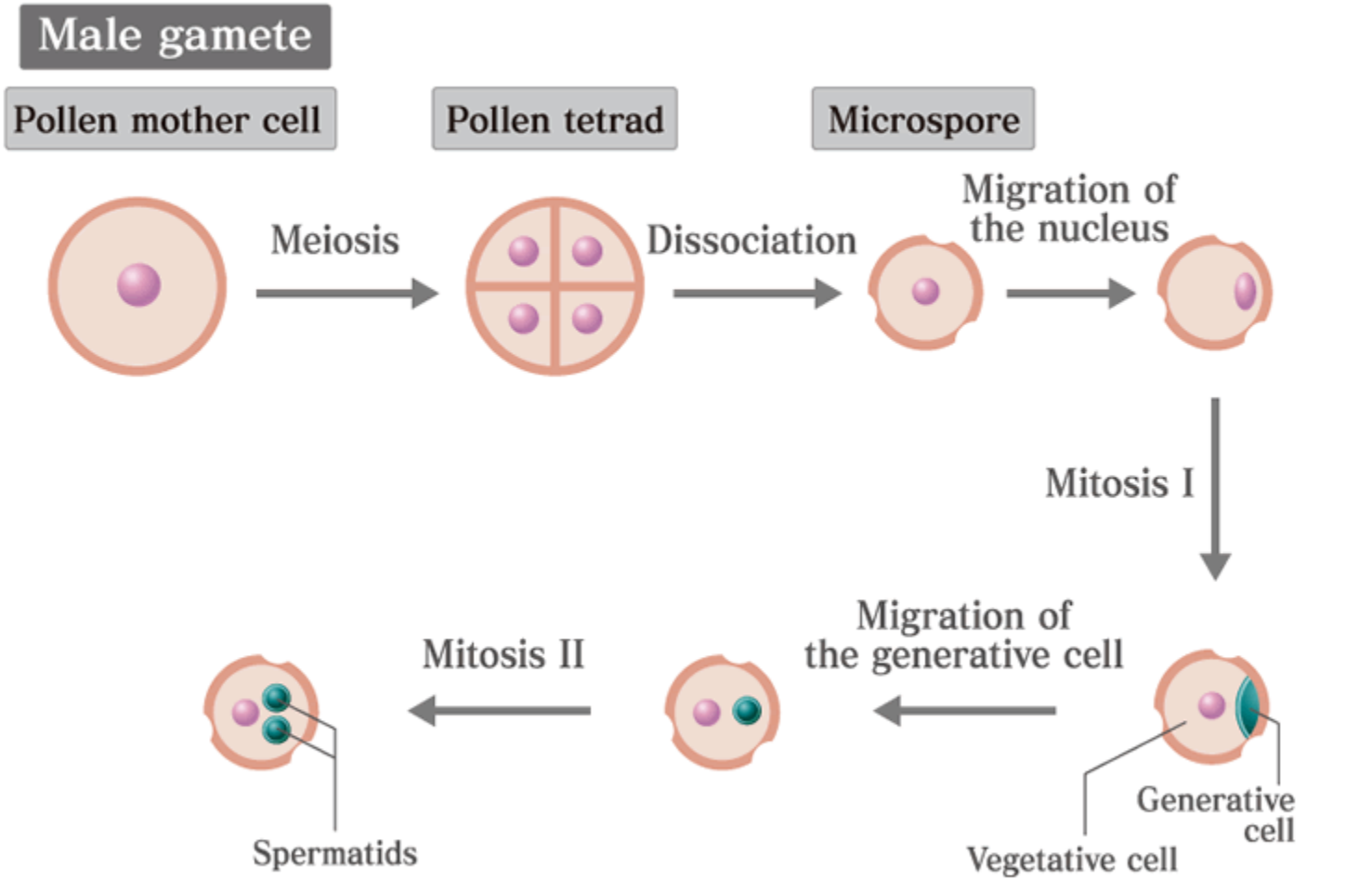
Recombination: double-strand breaks (DSBs) and their repair



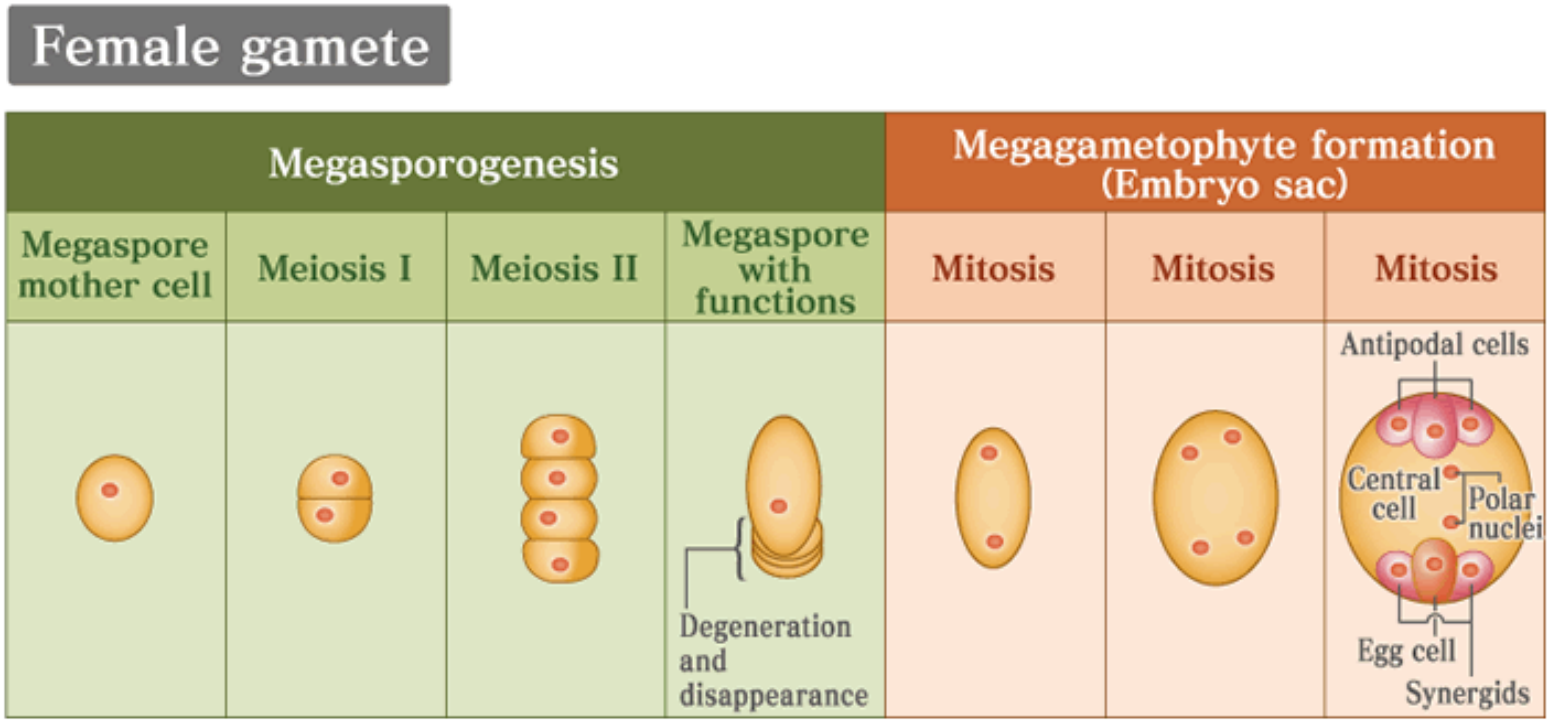
dHJ: double-Holliday junction; SDSA: synthesis-dependent strand annealing; COs: crossovers; NCOs: noncrossovers



Plants – male gametogenesis



Plants – famale gametogenesis



Plants – fertilization