# Meiosis (减数分裂)

- In sexual reproduction, each new individual begins with the union of two gametes.

- If the gametes had the same chromosome number as the parents, the gamete would inherit twice as many chromosomes as each parent.

- A special division to reduce the chromosome number (to half the parental number) is required prior to fertilization.

# Meiosis

- Meiosis, the reductional division preceding fertilization, is actually two cell divisions with only a single round of DNA replication.

- DNA Replicates

- Meiosis is two division steps linked to produce (usually) 4 haploid daughter cells, each of which contains only one copy of each chromosome.

# Meiosis

- Two divisions are referred to as meiosis I and meiosis II;

  Meiosis I: sister chromatids move together to one pole of the cell.

  Meiosis II: sister chromatids separate (as in mitosis) to two poles.

- Each division is divided into 4 stages seen in mitosis (prophase, metaphase, anaphase, and telophase).

- The stage name is followed by a Roman Numeral to indicate which division is being described.

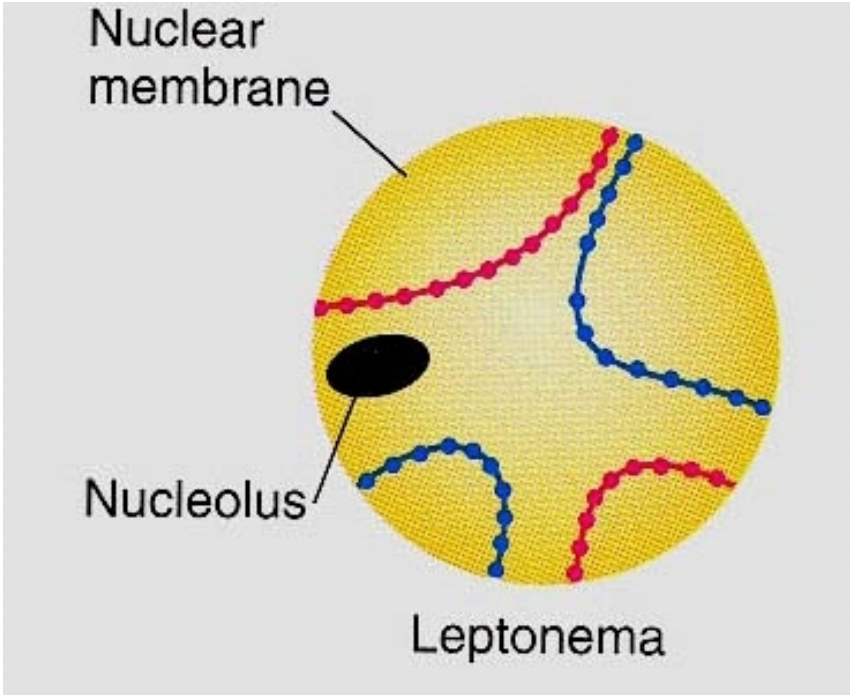
# Meiosis I;
# 5 stages of Prophase I

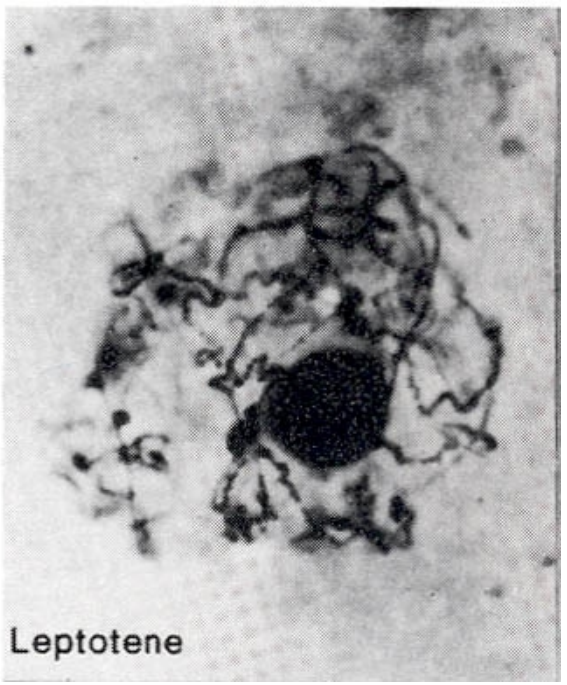
1) Leptonema (leptotene stage, 细线期)

- 2) Zygonema (zygotene stage， 偶线期)
- 3) Pachynema (pachytene stage，粗线期)
- 4) Diplonema (diplotene stage，双线期)
- 5) Diakinesis （终变期）

# Meiosis I; 5 stages of Prophase I

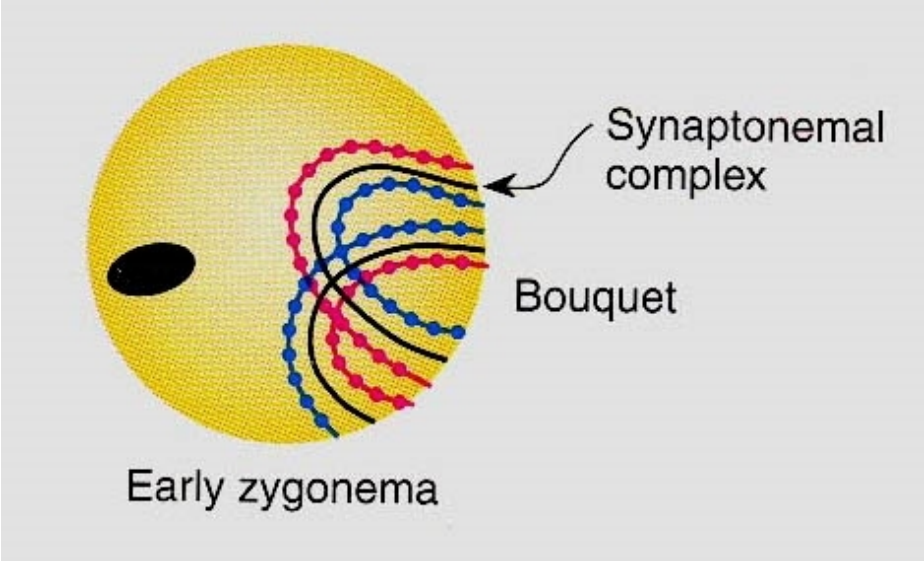
- 1) Leptonema（细线期）
  - Thin threads of chromatin
  - Tips associated with nuclear membrane



# Meiosis I; 5 stages of Prophase I

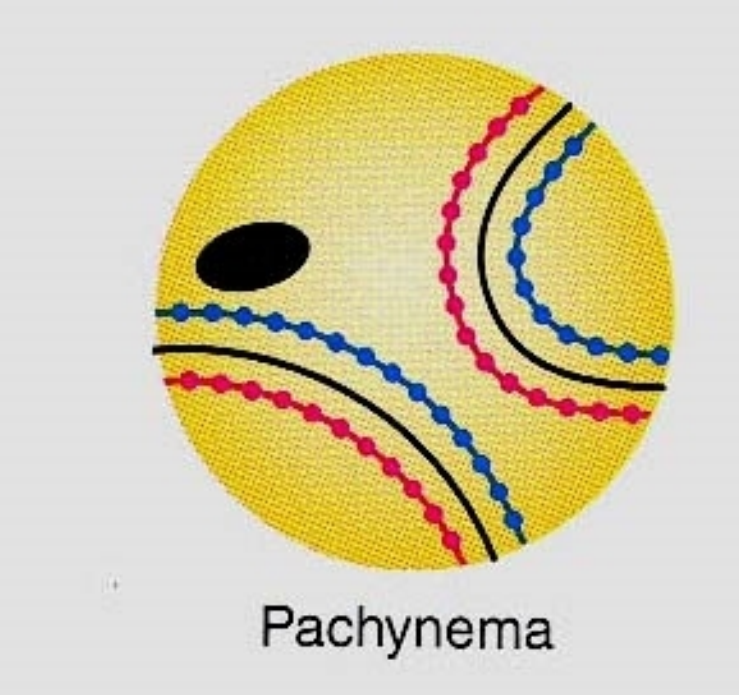
- 2) Zygonema（偶线期）
  - Begins with “bouquet” (花束)arrangement
  - pairing of homologous chromosomes
  - Synapsis: synaptonemal complex（联会复合体）attaches homologous chromosomes along their entire length
  - “bivalents（双价体）” are the associated chromosome pairs
  - Recombination nodules are visible

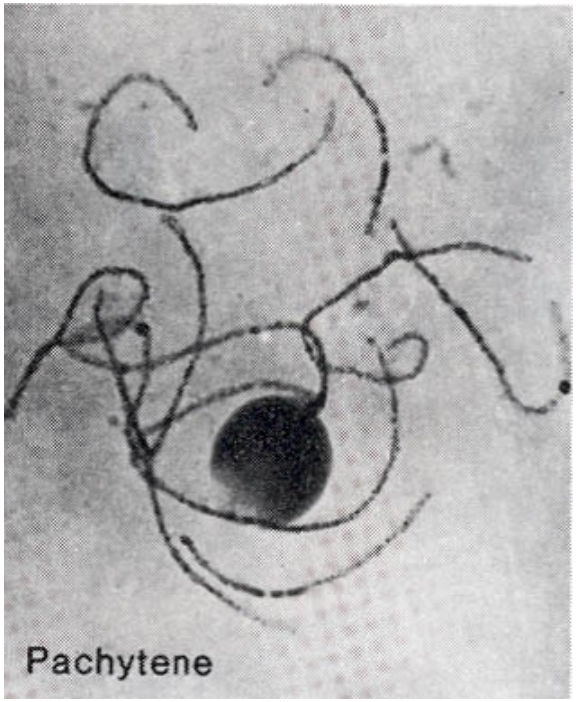


# Meiosis I; 5 stages of Prophase I

3) Pachynema（粗线期）:

- Chromosomes (bivalents) shorten and thicken
- Recombination nodules are visible

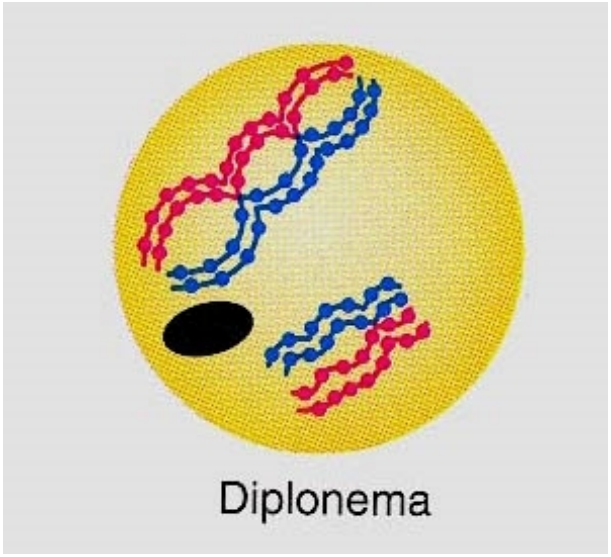


# Meiosis I; 5 stages of Prophase I

4) Diplonema（双线期）:

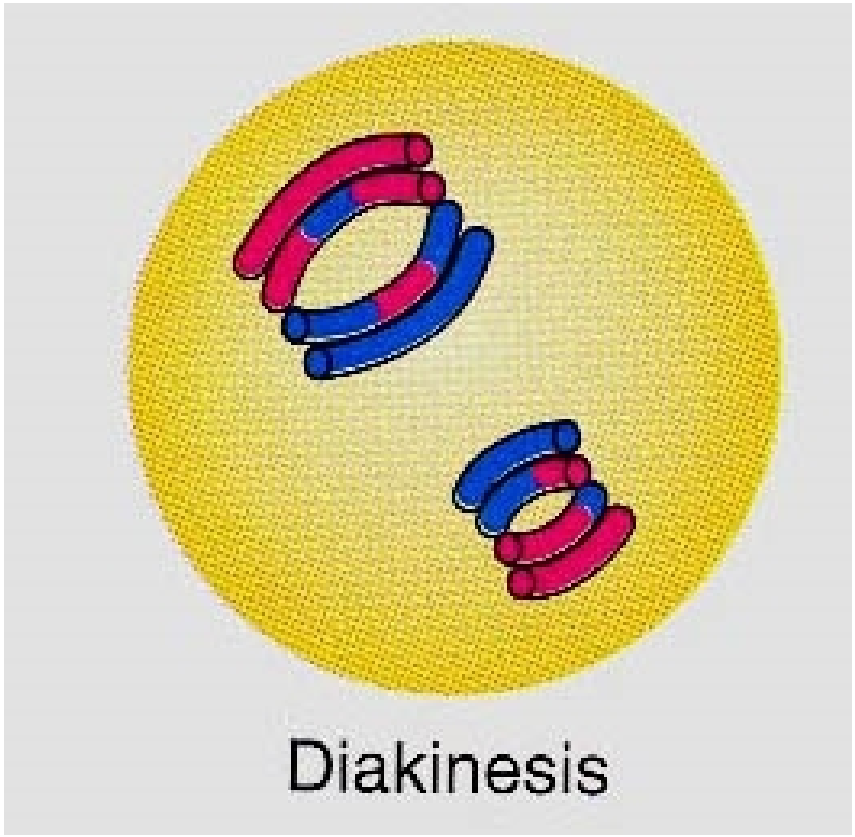
- Continued chromosomal condensation
- Chromosomes start to separate, can be seen as paired chromosomes of two chromatids, called tetrads（四分体）
- Synaptonemal complex released except at points of crossing over (chiasmata，交叉)
- Immature oocytes are “stored” in this state in human



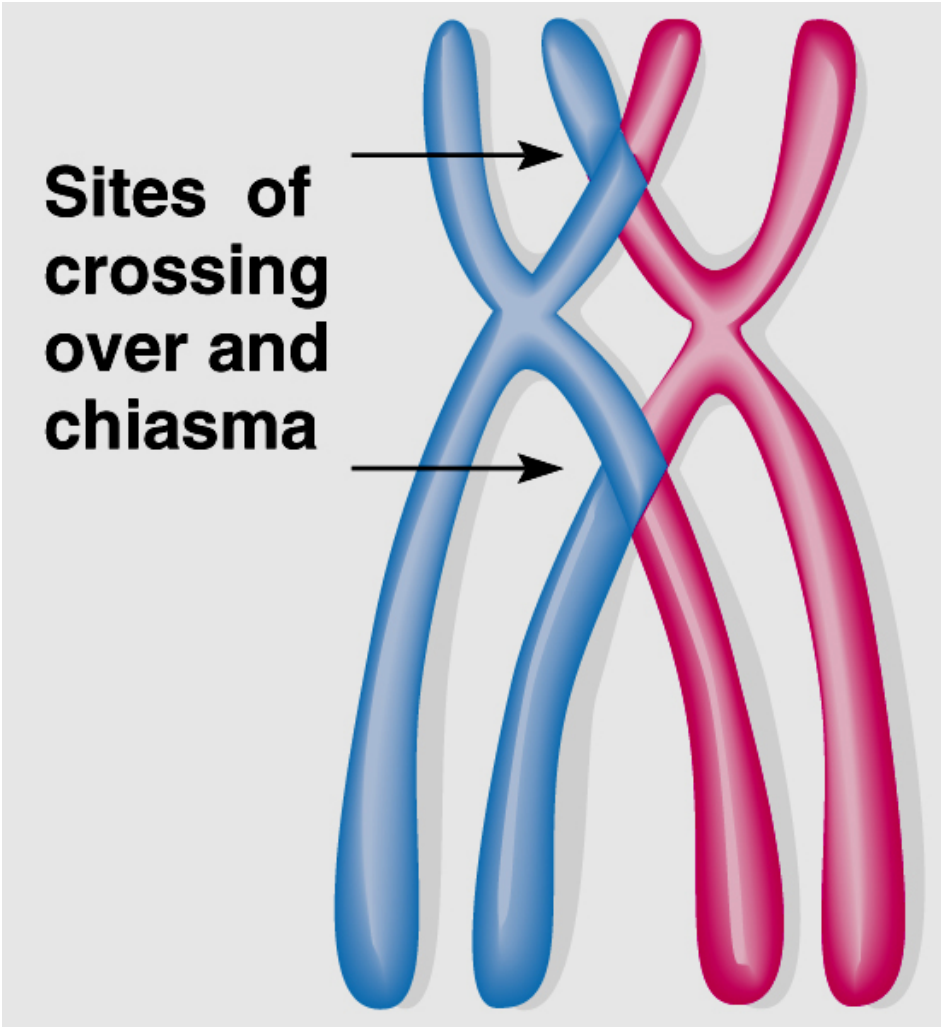

# Meiosis I; 5 stages of Prophase I

5) Diakinesis（终变期）：

– Further condensation of chromosomes




# Crossing Over (交换)

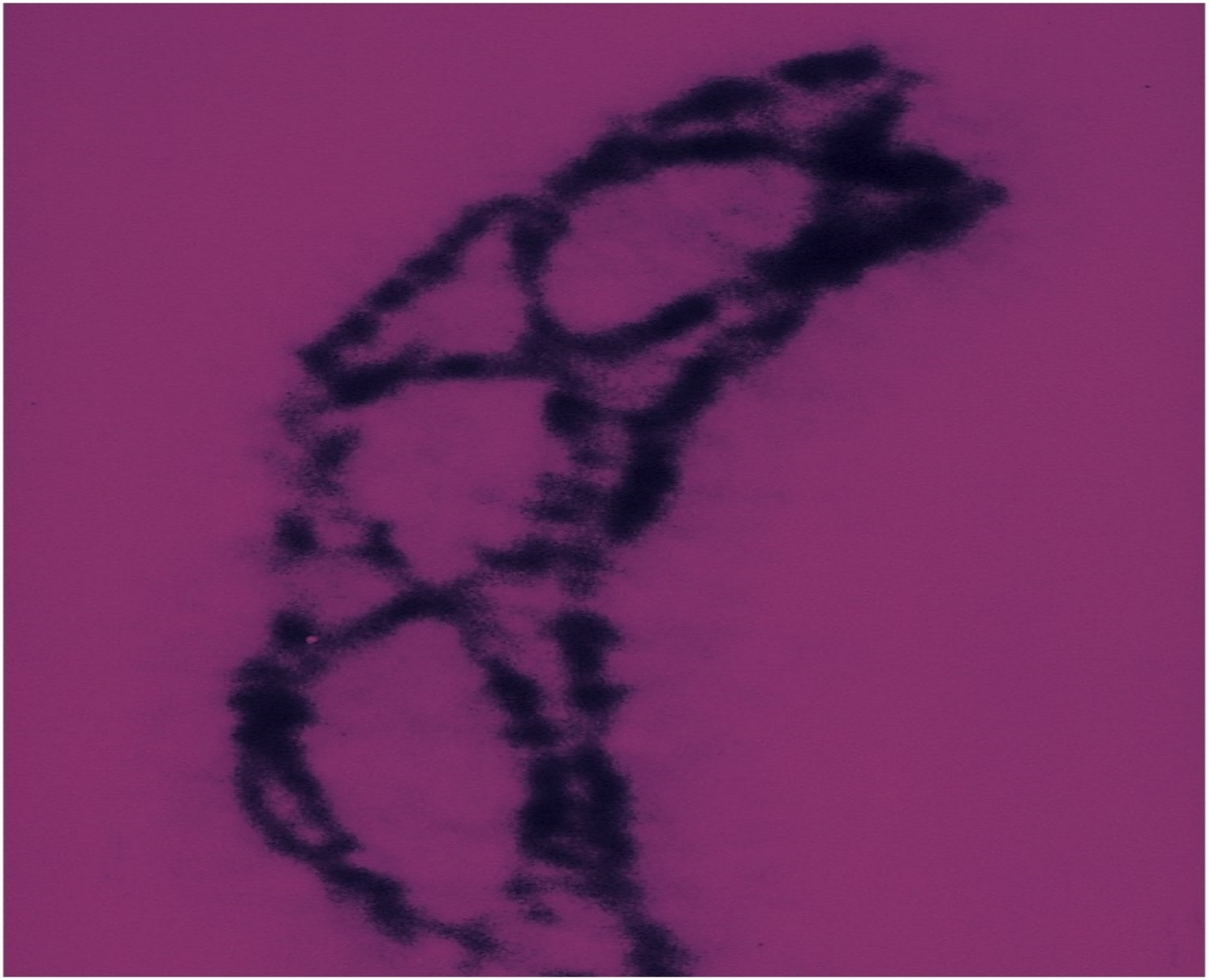



- One major event occurring during meiosis is

  crossing over (or meiotic recombination) which is exchange of pieces of two homologous chromosomes.

- The points at which crossing over （交换）occurs are called chiasmata（交叉）.

Chiasmata: the physical manifestation of **crossing over**.



# Recombination Intermediates（中间体）

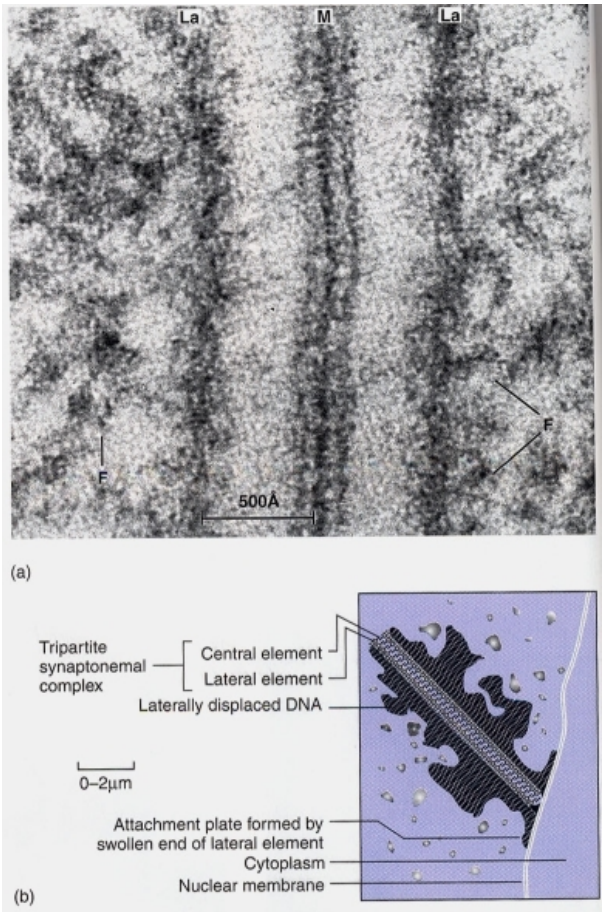



**Figure 3.20** The synaptonemal complex. *(a)* In the electron micrograph, *M* is the central element, *La* are lateral elements, and *F* are chromosome fibers. Magnification 400,000×. *(b)* Diagram of the structure. ([a] R. Wettstein and J. R. Sotelo, "The molecular architecture of synaptonemal complexes," in E. J. DuPraw, ed., *Advances in Cell and Molecular Biology*, vol. 1 (New York: Academic Press, 1971), p. 118. Reproduced by permission. [b] From B. John and K. R. Lewis, *Chromosome Hierarchy*. Copyright © 1975 Oxford University Press, London, England. Reprinted by permission of the Oxford University Press.)

Recombination Nodules: zygonema to pachynema

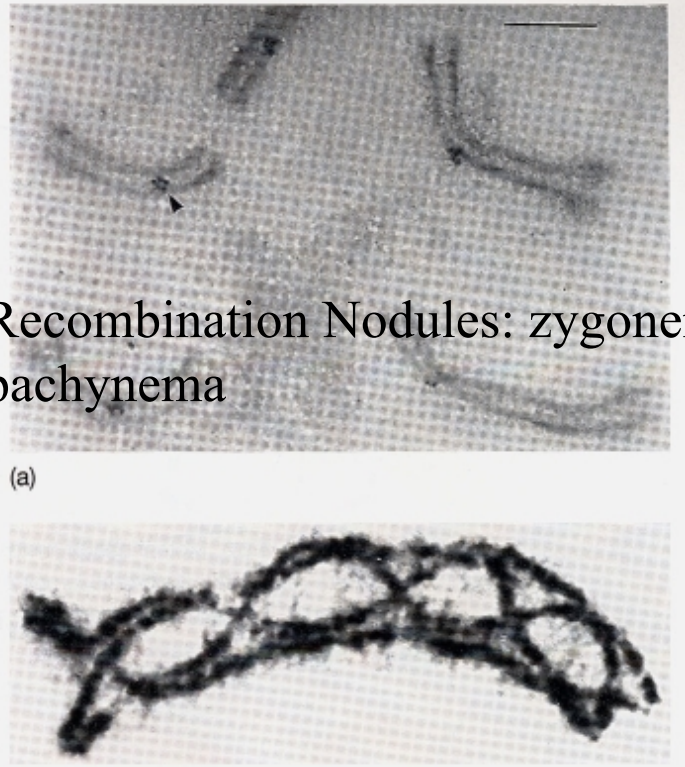



**Figure 3.22** *(a)* Recombination nodules (*arrowhead*) in spermatocytes of the pigeon, *Columba livia*. (Bar = 1 μm.) *(b)* A tetrad from the grasshopper, *Chorthippus parallelus*, at diplonema with five chiasmata. ([a] From M. I. Pigozzi and A. J. Solari, "Recombination Nodule Mapping and Chiasma Distribution in Spermatocytes of the Pigeon, *Columba livia*," in *Genome*, 42: 308–314, 1999. Reprinted by permission. [b] Courtesy of Bernard John.)

Synaptonemal Complex: zygonema (Bivalents)

Chiasmata: diplonema (tetrads)

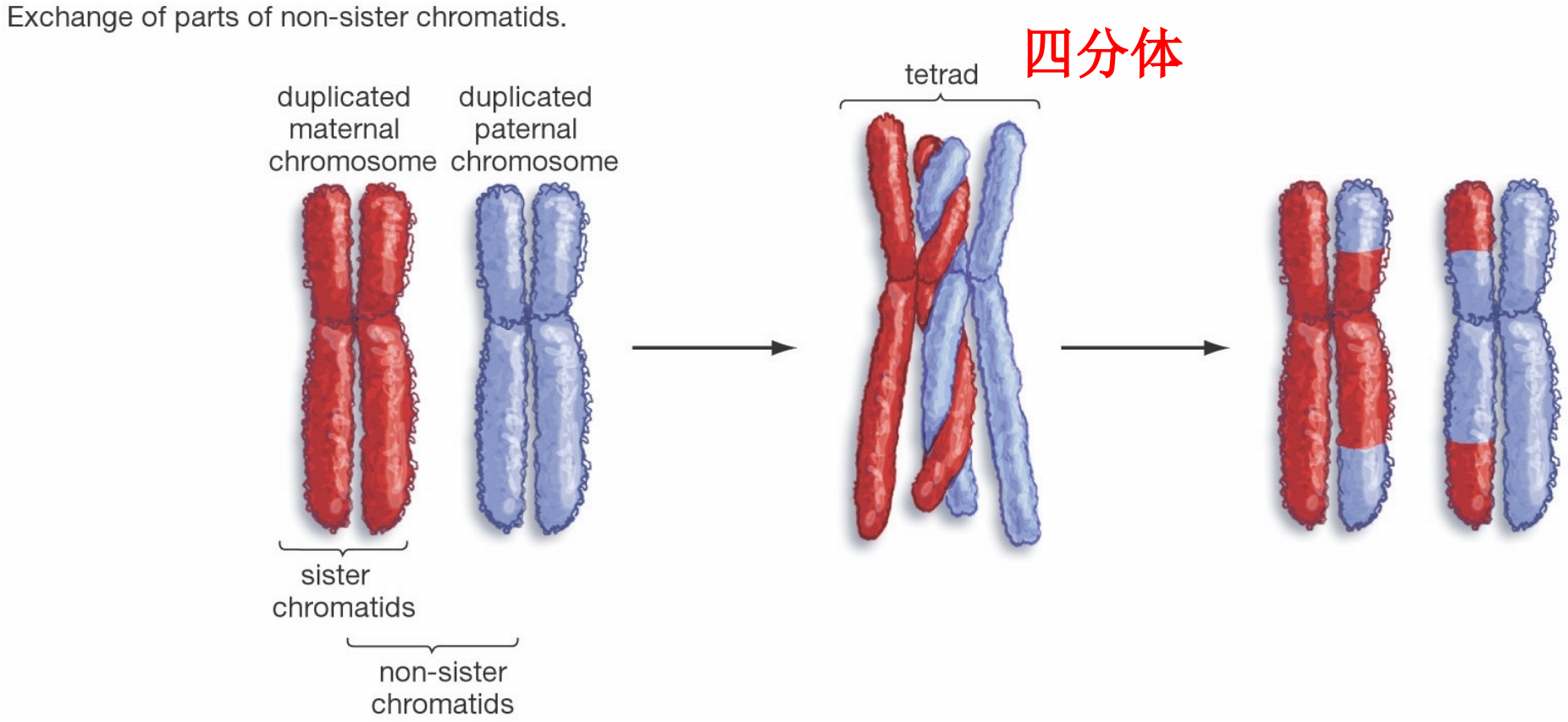
# Crossing Over (交换)

- One of the important features of meiosis is that, in meiosis I, all four sister chromatids (of a chromosome pair) interact to form tetrads.

- Within the tetrad (during prophase I) segments of chromatin are exchanged between various chromatids.

- Crossing over adds an extra level of variation in the combinations of genes possible in the next generation.

# Crossing Over (交换)



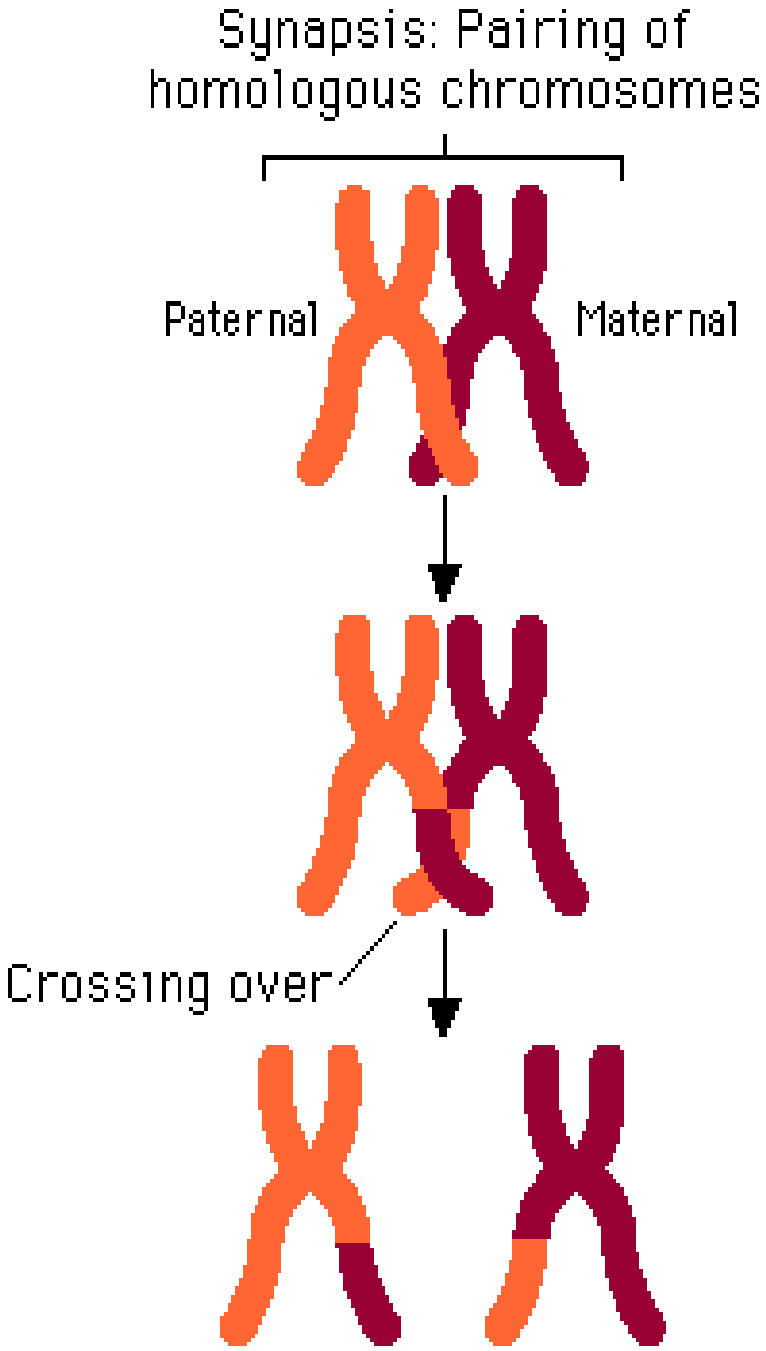

Crossing-over multiplies the already huge number of different gamete types produced by **independent assortment**.

- **Crossing over** is a cytological phenomenon that occurs during the first of the two meiotic divisions.
  - Two strands of DNA from complimentary chromosomes cross over each other, and a break forms.
  - The break is quickly repaired, switching stretches of DNA among the two compliments to create two new chromosomes.

  - A pair of chromosomes can cross over once, several times, or not at all. The farther apart two genes are on a chromosome, the more likely it is that crossing over will create recombination between the two of them.

- Crossing over creates new combinations of alleles on chromosomes, and permits favorable alleles to combine together on the same chromosome.

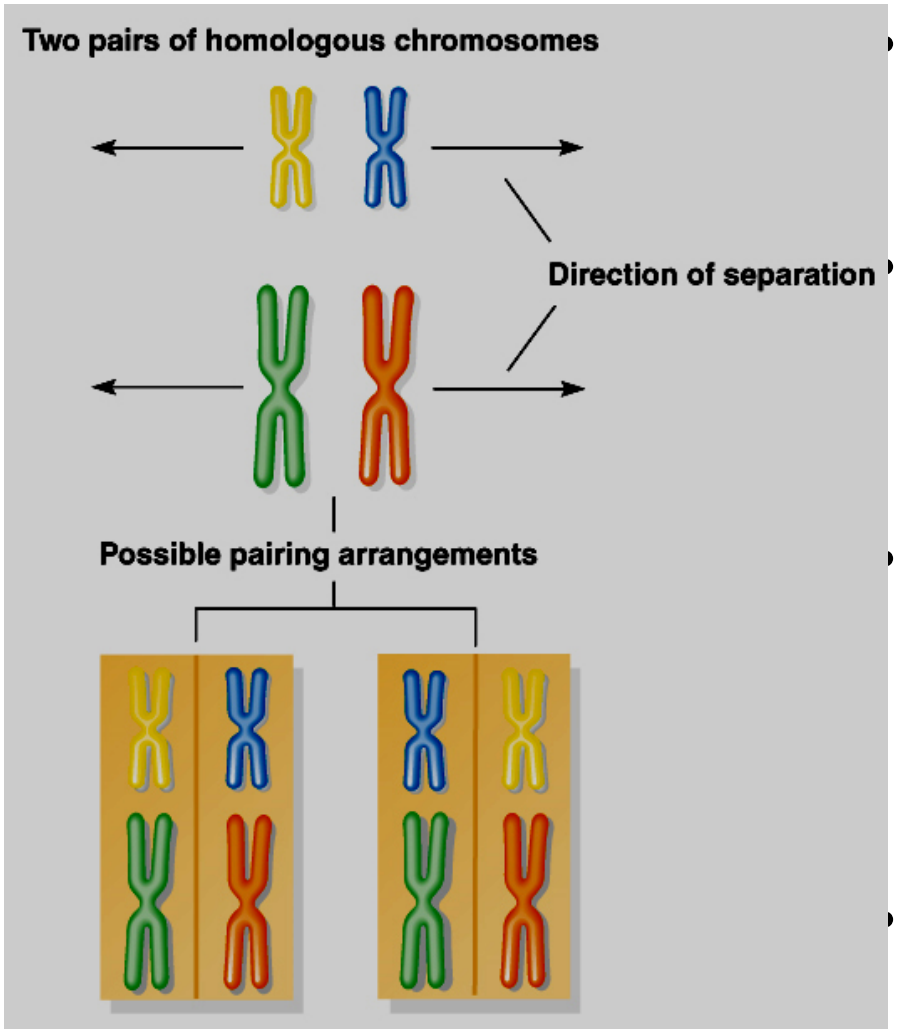
- The genetic result is called **recombination**.




•When geneticists speak about genes, they prefer to use the word locus. The two are virtual synonyms, but locus means *location*, and it refers to the place where variation can occur. Using the word gene emphasizes its information content.

•Thus, as you might be able to intuit (直观看出来) from the diagram to the left, the more distant the loci (locus的复数), the more likely it is for a particular recombination event to switch them between chromosomes.

# Pairing of Homologs During Meiosis I




- Meiosis I allows each chromosome pair to act independently.
- Maternally and paternally derived chromosomes segregate randomly, allowing "mixing" of the traits in the next generation.
- There are $2^n$ (where n is the haploid chromosome number) possible nuclei combinations after meiosis II ($2^{23}$ or 8388608 possibilities for humans)
- Crossing over allows even more possible gene combinations in the gametes.

# Some points on recombinations

**(1) Recombinations happen only during meiosis (during the generation of egg- or spermcells).**

**(2) Recombinations occur in each generation, usuallyat least once per chromosome.**

**(3) Recombinations are in theory random, but in principle the likelyhood of recombinations at a particular point in the genome is quite variable.**

**(4) Almost no recombination at the centrimere, higher frequency of recombinations closer to the telomeres**