PowerPoint® Lecture Presentation for

Concepts of Genetics

Ninth Edition

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Chapter 2
Mitosis and Meiosis

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Chapter 2 Contents

Chapter 2 Introduction

- In **eukaryotes**, transmission of genetic material from one generation of cells to the next involves mitosis and meiosis.

Chapter 2 Introduction

- **Meiosis** leads to production of gametes.
- **Mitosis** leads to production of two cells, each with the same number of chromosomes as the parent cell.

2.1 Cell Structure Is Closely Tied to Genetic Function

Section 2.1

- In eukaryotes, DNA resides in the nucleus and organelles reside in the cytoplasm (**Figure 2.1**).

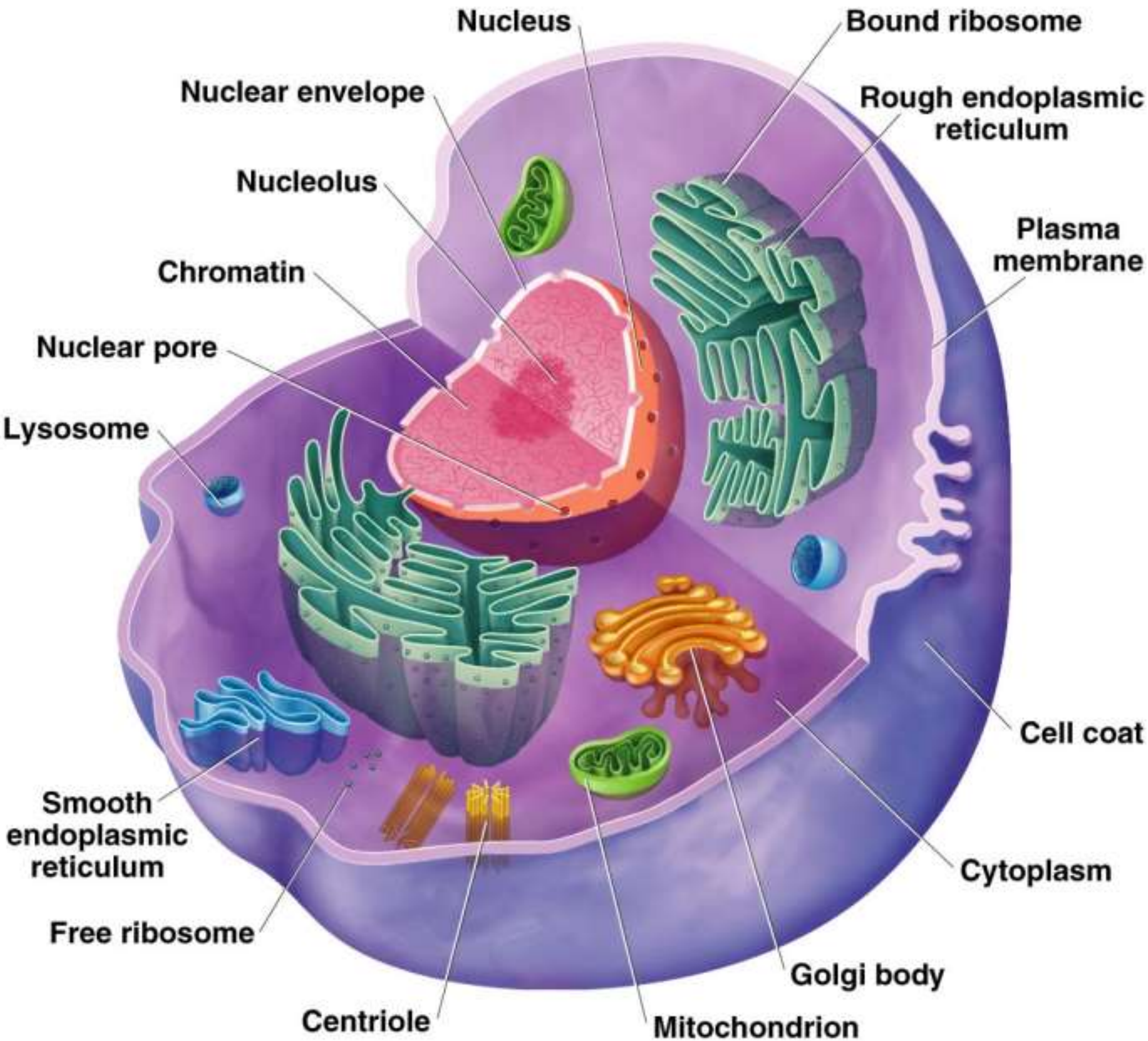
Nucleus
Bound ribosome
Nuclear envelope
Rough endoplasmic reticulum
Nucleolus
Plasma membrane
Chromatin
Nuclear pore
Lysosome
Cell coat
Smooth endoplasmic reticulum
Cytoplasm
Free ribosome
Golgi body
Centriole
Mitochondrion

Figure 2.1

Section 2.1

- The cell is surrounded by a plasma membrane.
- Plant and bacterial cells also have a cell wall composed mainly of cellulose and peptidoglycan, respectively.

Section 2.1

- DNA in the nucleus is complexed with an array of acidic and basic proteins into thin fibers.
- During nondivisional phases of the cell cycle, these fibers are uncoiled and dispersed into chromatin.
- Chromatin fibers coil and condense to form **chromosomes** during mitosis and meiosis.

Section 2.1

- Centrioles in the cytoplasm are located in a specialized region called the centrosome.
- Centrioles organize spindle fibers for movement of chromosomes during meiosis and mitosis.

2.2 Chromosomes Exist in Homologous Pairs in Diploid Organisms

Section 2.2

- In each homologous pair of chromosomes, one member is derived from each parent.

Section 2.2

- Each diploid organism contains two copies of each gene.
- The members of each pair of genes need not be identical.
- Alternative forms of the same gene are called alleles.

Section 2.2

- Meiosis converts the diploid number (2*n*) of chromosomes to the haploid number (*n*).

Section 2.2

- Gametes contain a haploid set of chromosomes.
- Fusion of two gametes at fertilization results in a diploid zygote.

Section 2.2

- Sex-determining chromosomes are usually not homologous (**Figure 2.4**) yet behave as homologs in meiosis.

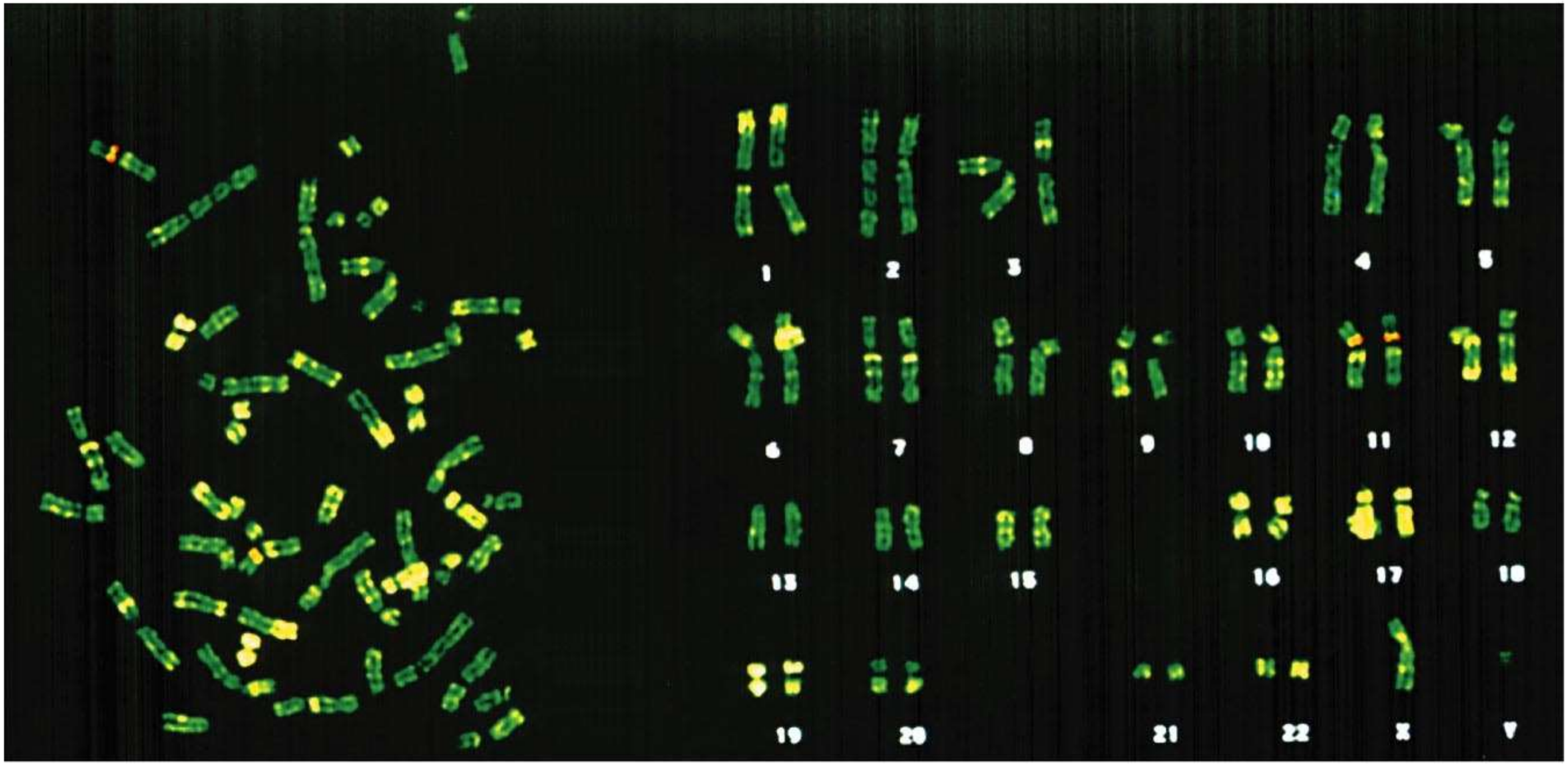

Figure 2.4

2.3 Mitosis Partitions Chromosomes into Dividing Cells

Section 2.3

- Genetic material is partitioned to daughter cells during nuclear division (karyokinesis).
- Cytoplasmic division (cytokinesis) follows.

Section 2.3

- The cell cycle is composed of interphase and mitosis.
- Interphase includes:
  - S phase, during which DNA is synthesized
  - Two gap phases (G1 and G2)
- G0 is a point in the G1 phase where cells withdraw from the cell cycle and enter a nondividing but metabolically active state.

Section 2.3

- Mitosis has discrete stages:
  - prophase
  - prometaphase
  - metaphase
  - anaphase
  - telophase

(see **Figure 2.7**)

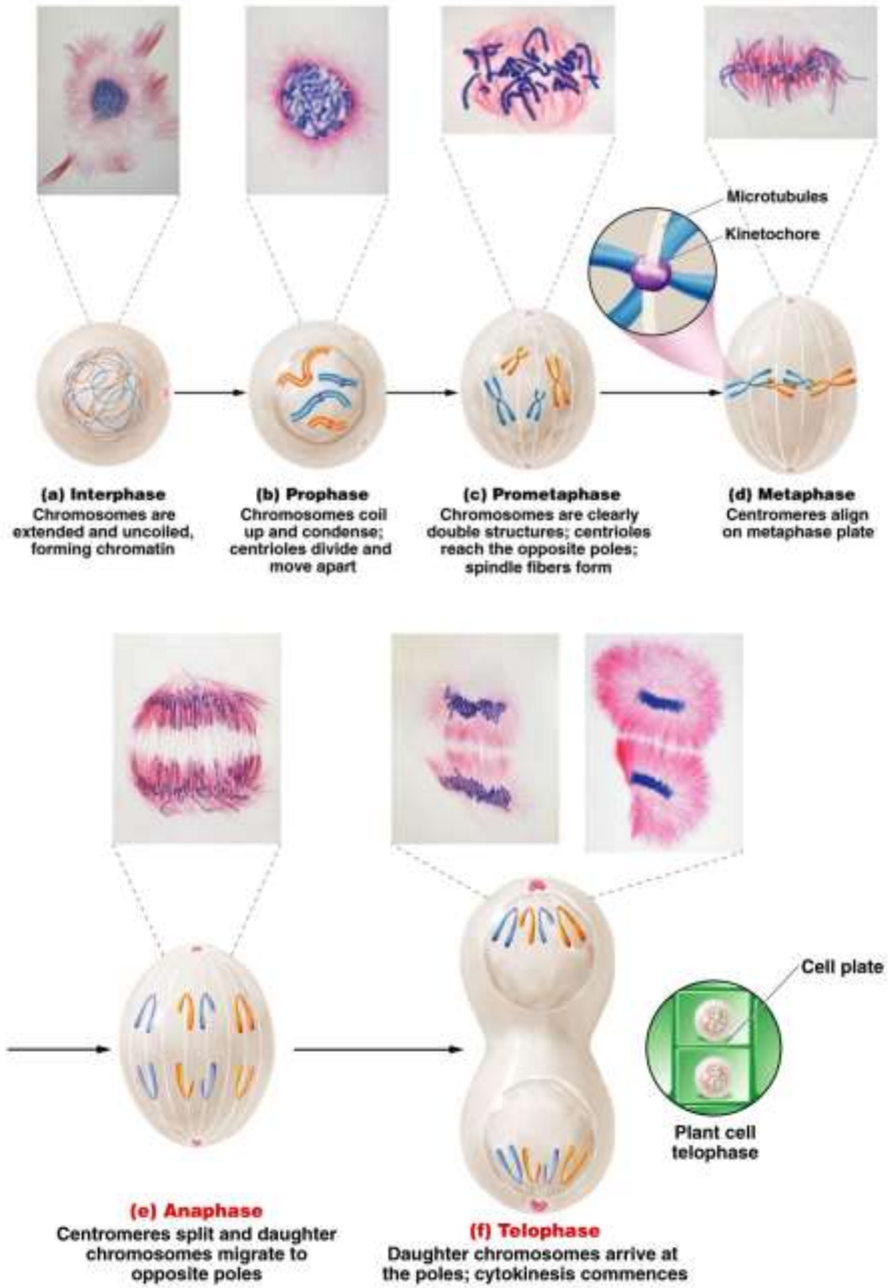
Microtubules
Kinetochore
(a) Interphase
Chromosomes are extended and uncoiled, forming chromatin
(b) Prophase
Chromosomes coil up and condense; centrioles divide and move apart
(c) Prometaphase
Chromosomes are clearly double structures; centrioles reach the opposite poles; spindle fibers form
(d) Metaphase
Centromeres align on metaphase plate
Cell plate
Plant cell telophase
(e) Anaphase
Centromeres split and daughter chromosomes migrate to opposite poles
(f) Telophase
Daughter chromosomes arrive at the poles; cytokinesis commences

Figure 2.7

Section 2.3

- During **prophase**, the centrioles divide and move apart, the nuclear envelope breaks down, and chromosomes condense and become visible.
- Sister chromatids are connected at the centromere.

Section 2.3

- During **prometaphase**, the chromosomes move to the equatorial plane of the cell.

Section 2.3

- During **metaphase**, the centromeres/chromosomes are aligned at the equatorial plane.
- Spindle fibers bound to kinetochores associated with centromeres are responsible for chromosome movement.

Section 2.3

- Sister chromatids separate from each other and migrate to opposite poles during **anaphase**.
- The separated sister chromatids are called daughter chromosomes.

Section 2.3

- The main events during **telophase** are:
  - cytokinesis
  - uncoiling of the chromosomes
  - re-formation of the nuclear envelope

Section 2.3

- Mitosis produces daughter cells with a full diploid complement of chromosomes.

2.4 Meiosis Reduces the Chromosome Number from Diploid to Haploid in Germ Cells and Spores

Section 2.4

- Meiosis reduces the amount of genetic material by one-half to produce haploid gametes or spores containing one member of each homologous pair of chromosomes.

Section 2.4

- Meiosis I is a reductional division.
- Meiosis II is an equational division (**Figure 2.8**).
- DNA synthesis occurs during interphase before the beginning of meiosis I but does not occur again before meiosis II.

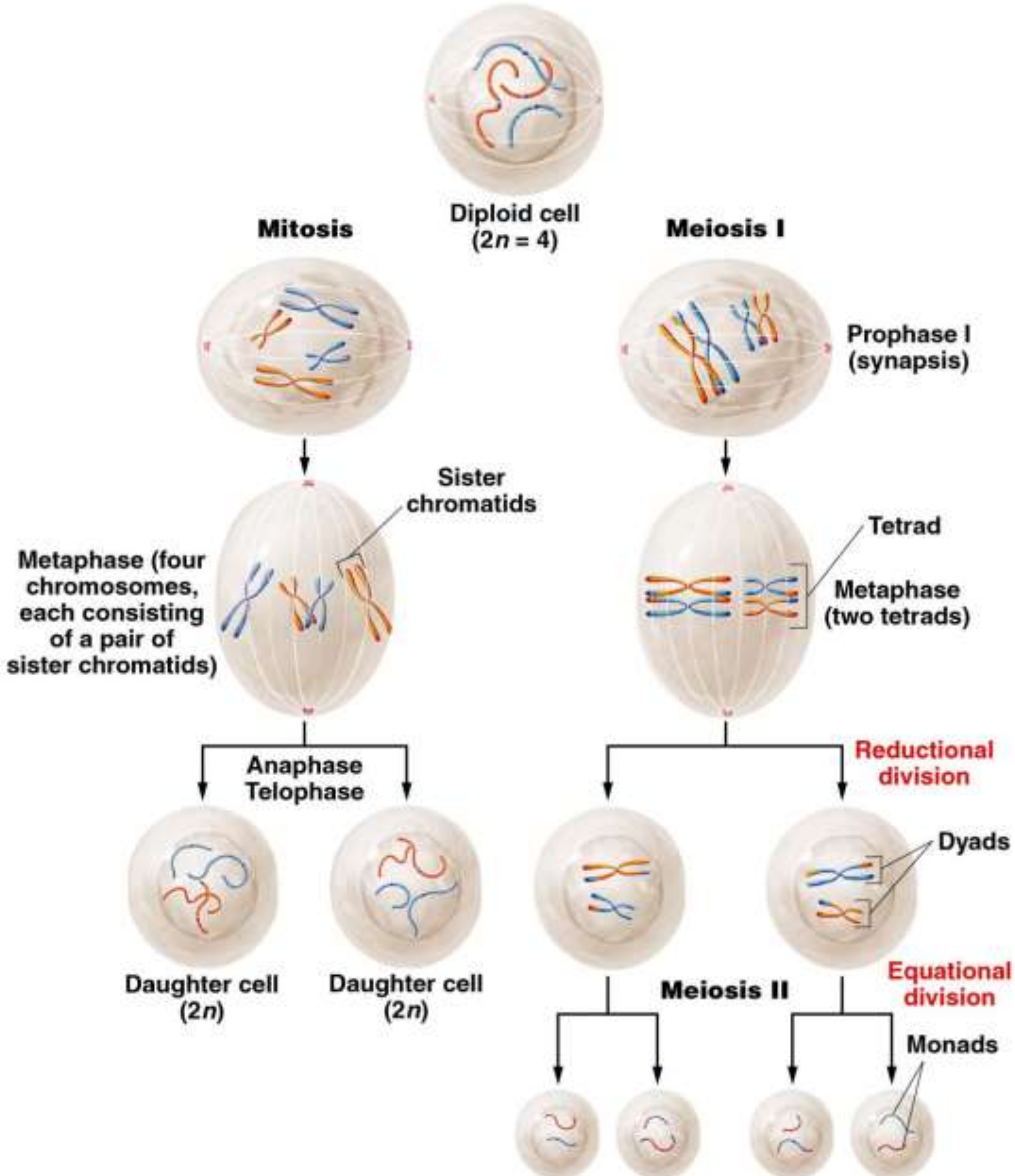
Diploid cell
(2n = 4)
Mitosis
Meiosis I
Prophase I
(synapsis)
Sister
chromatids
Tetrad
Metaphase (four
chromosomes,
each consisting
of a pair of
sister chromatids)
Metaphase
(two tetrads)
Anaphase
Telophase
Reductional
division
Dyads
Daughter cell
(2n)
Daughter cell
(2n)
Meiosis II
Equational
division
Monads

Figure 2.8

Section 2.4

- Meiosis I and II each have prophase, metaphase, anaphase, and telophase stages (**Figure 2.10**).

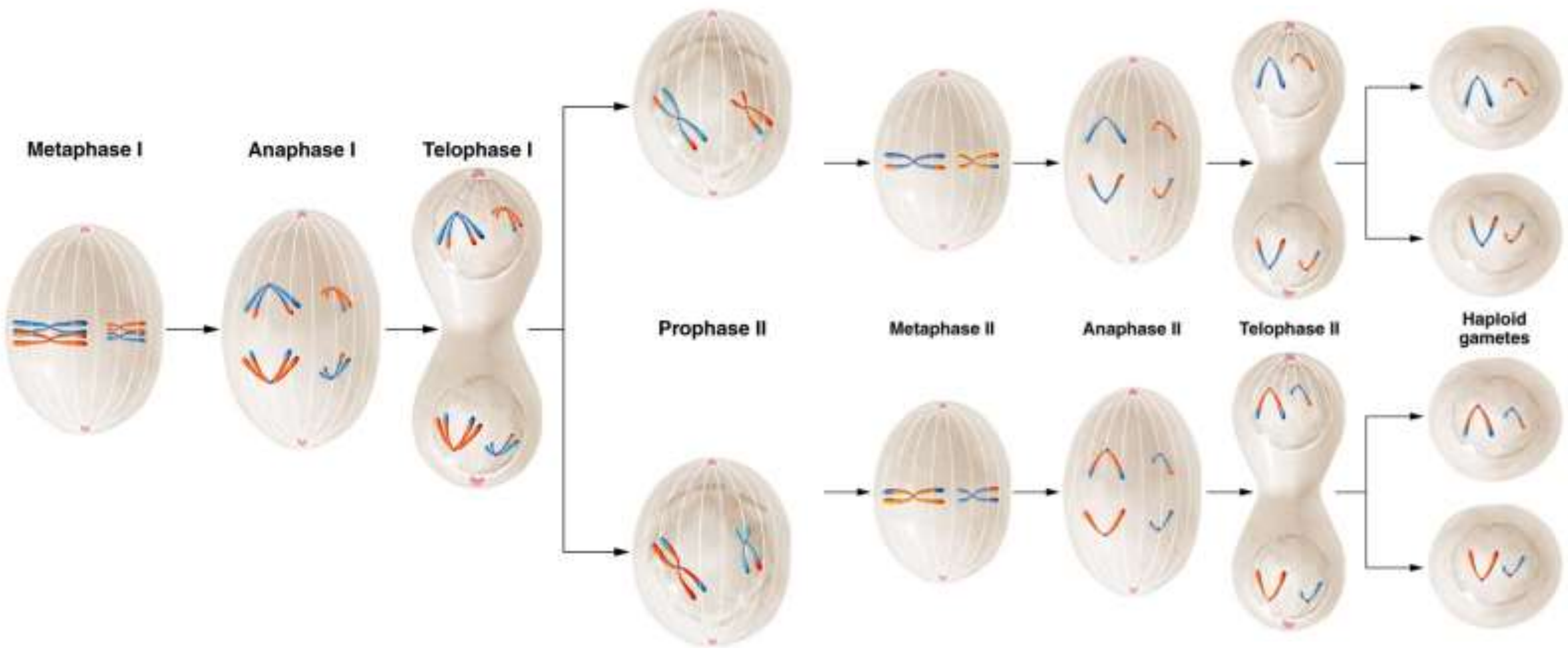
Metaphase I
Anaphase I
Telophase I
Prophase II
Metaphase II
Anaphase II
Telophase II
Haploid gametes

Figure 2.10

Section 2.4

- Prophase I has five substages, each including specific events (see **Figure 2.9**):
  - leptonema
  - zygonema
  - pachynema
  - diplonema
  - diakinesis
- At the completion of prophase I, the centromeres of each tetrad structure are present on the equatorial plate.

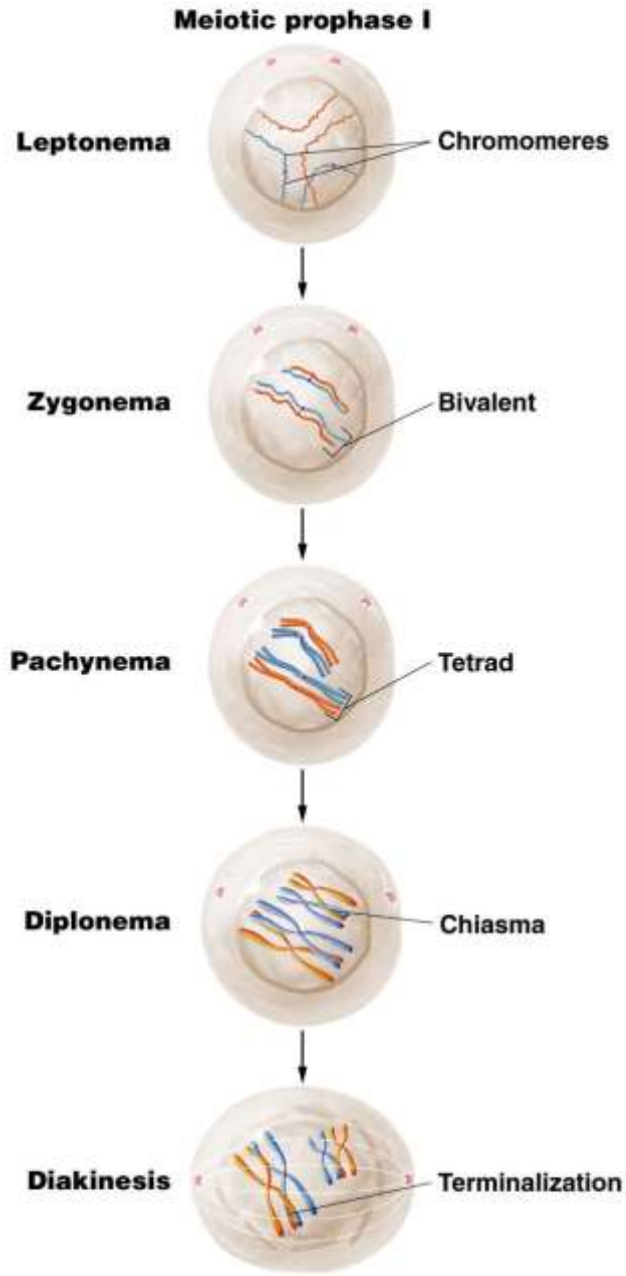
Meiotic prophase I
Leptonema
Chromomeres
Zygonema
Bivalent
Pachynema
Tetrad
Diplonema
Chiasma
Diakinesis
Terminalization

Figure 2.9

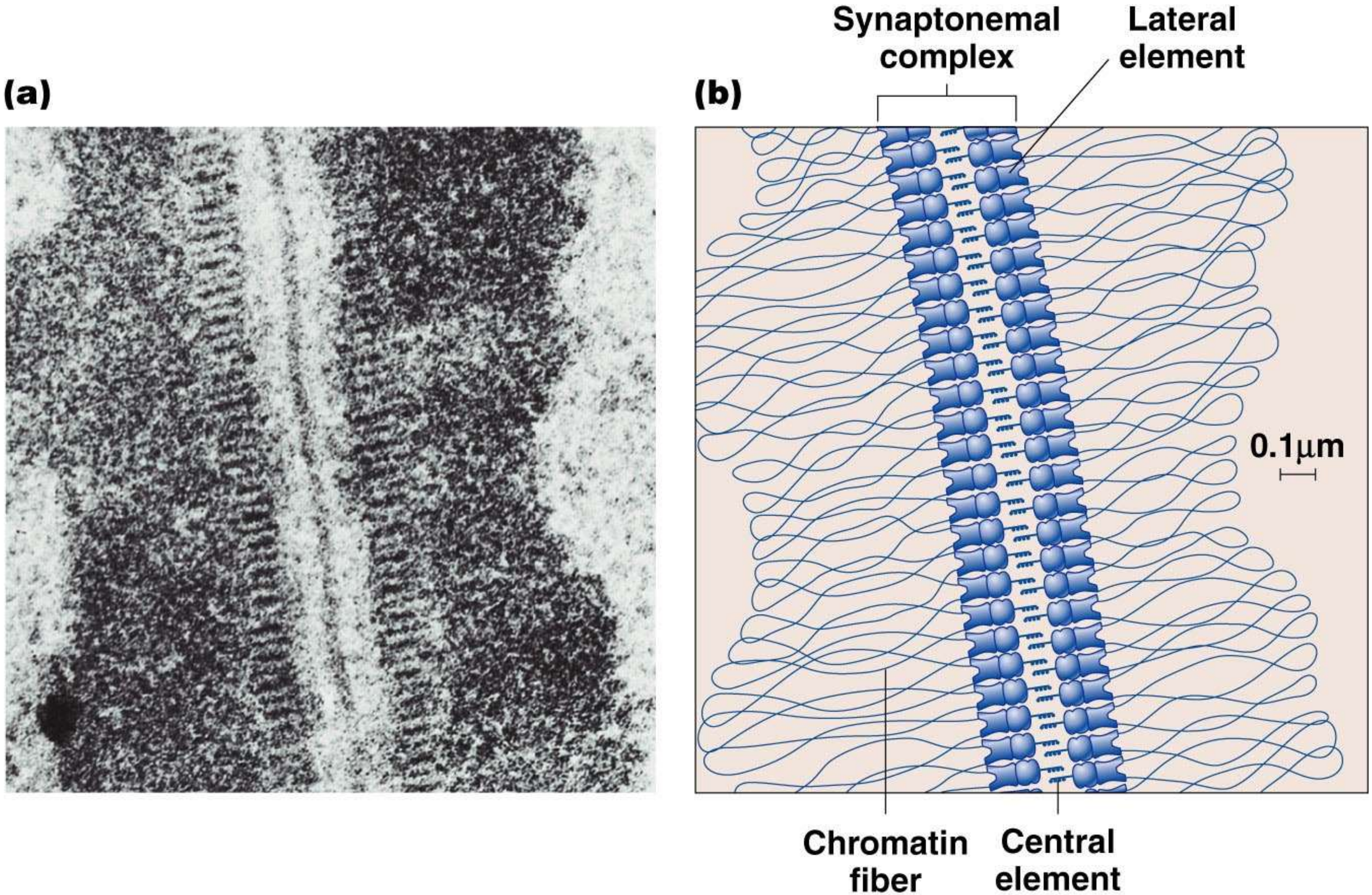
(a)
(b)
Synaptonemal complex
Lateral element
0.1μm
Chromatin fiber
Central element

Figure 2.14

Section 2.4

- Metaphase I, anaphase I, and telophase I are similar to those of mitosis.

Section 2.4

- During meiosis I, the centromeres holding each pair of sister chromatids together do not divide.
- One pair of each tetrad is pulled toward each pole.

Section 2.4

- During **meiosis II**, the sister chromatids in each dyad are separated to opposite poles.
- Each haploid daughter cell from meiosis II has one member of each pair of homologous chromosomes.

Section 2.4

- Meiosis significantly increases the level of genetic variation due to **crossing over** during meiosis I.

Section 2.4

- **Nondisjunction** during meiosis I or II leads to gametes with abnormal numbers of chromosomes and can lead to abnormal offspring.

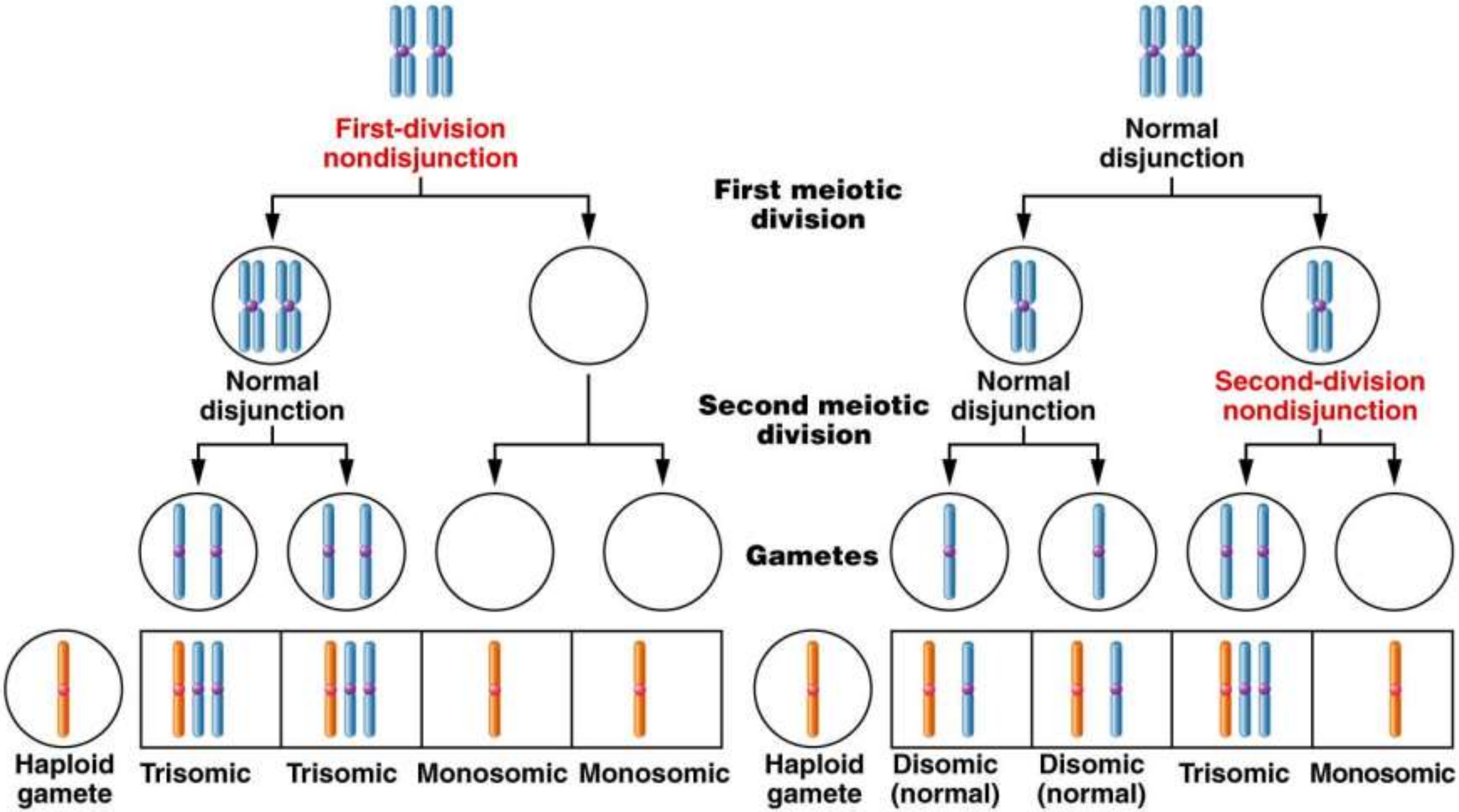
First-division nondisjunction
Normal disjunction
First meiotic division
Normal disjunction
Second meiotic division
Normal disjunction
Second-division nondisjunction
Gametes
Haploid gamete
Trisomic
Trisomic
Monosomic
Monosomic
Haploid gamete
Disomic (normal)
Disomic (normal)
Trisomic
Monosomic

Figure 8.1

2.5 The Development of Gametes Varies in Spermatogenesis Compared to Oogenesis

Section 2.5

- Male gametes are produced by **spermatogenesis** in the testes (**Figure 2.11**).
- Female gametes are produced by **oogenesis** in the ovary.

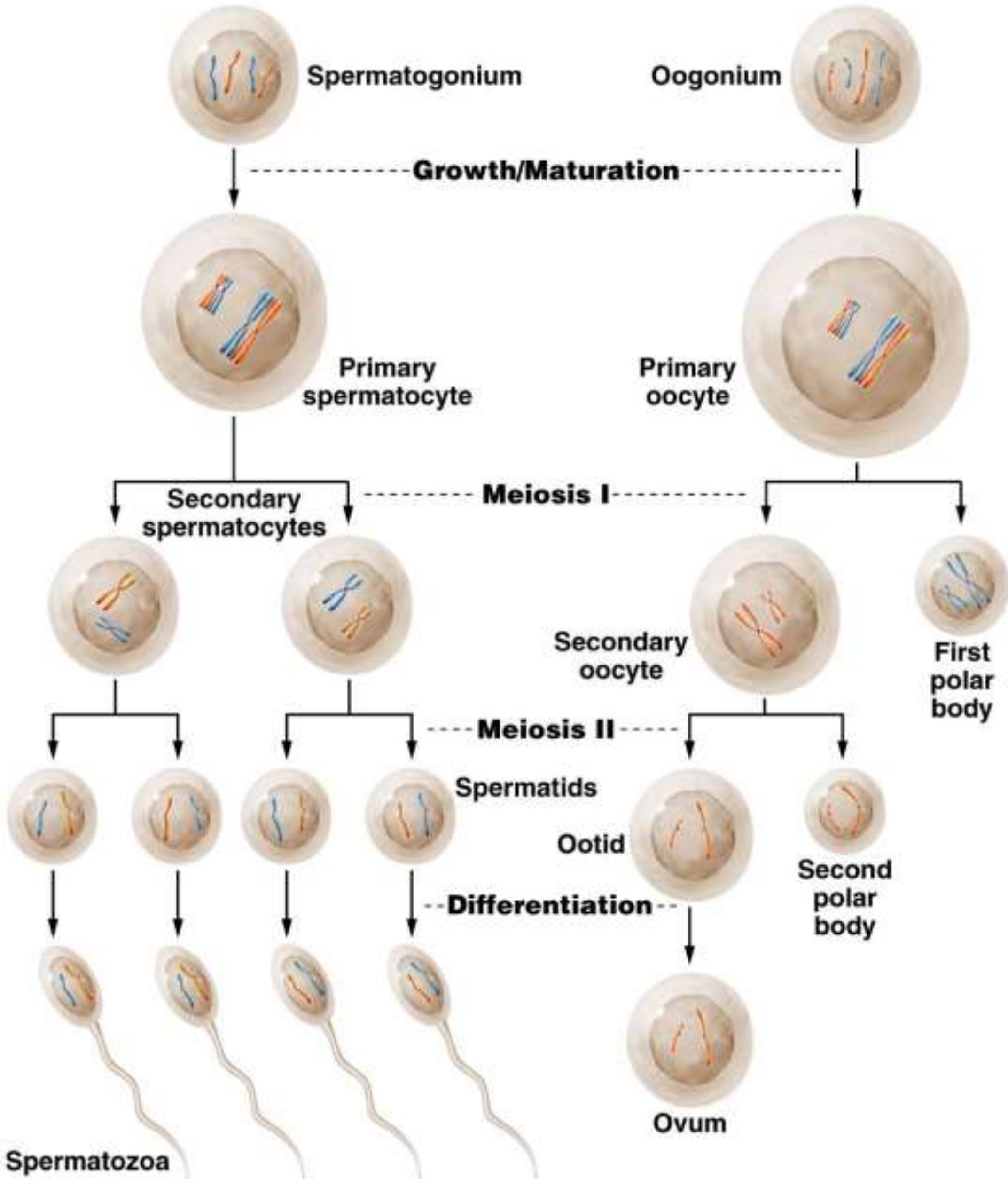
Spermatogonium
Oogonium
Growth/Maturation
Primary spermatocyte
Primary oocyte
Secondary spermatocytes
Meiosis I
Secondary oocyte
First polar body
Meiosis II
Spermatids
Ootid
Second polar body
Differentiation
Ovum
Spermatozoa

Figure 2.11

Section 2.5

- The primary spermatocyte undergoes meiosis I to produce two secondary spermatocytes, which undergo meiosis II to produce a total of four haploid spermatids.

Section 2.5

- During oogenesis, the four daughter cells do not receive equal cytoplasm.
- The cell that receives the most cytoplasm undergoes both meiosis I and II and develops into the ovum.
- The cytoplasm-deficient polar bodies produced at meiosis I and II do not undergo further division.

2.6 Meiosis Is Critical to the Successful Sexual Reproduction of All Diploid Organisms

Section 2.6

- The mechanism of meiosis is the basis for the production of extensive genetic variation.
- Gametes receive either the maternal or the paternal chromosome from each homologous pair of chromosomes.
- An organism can produce 2^n (where *n* represents the haploid number) combinations of chromosomes in gametes.

Section 2.6

- Crossing over adds further genetic variation because chromosomes become a mixture of maternally and paternally derived DNA.

Section 2.6

- In many fungi, the predominant stage of the life cycle is haploid.
- The life cycle in multicellular plants alternates between a diploid sporophyte stage and a haploid gametophyte stage (**Figure 2.12**).
- Meiosis and fertilization are the bridge between these two stages.

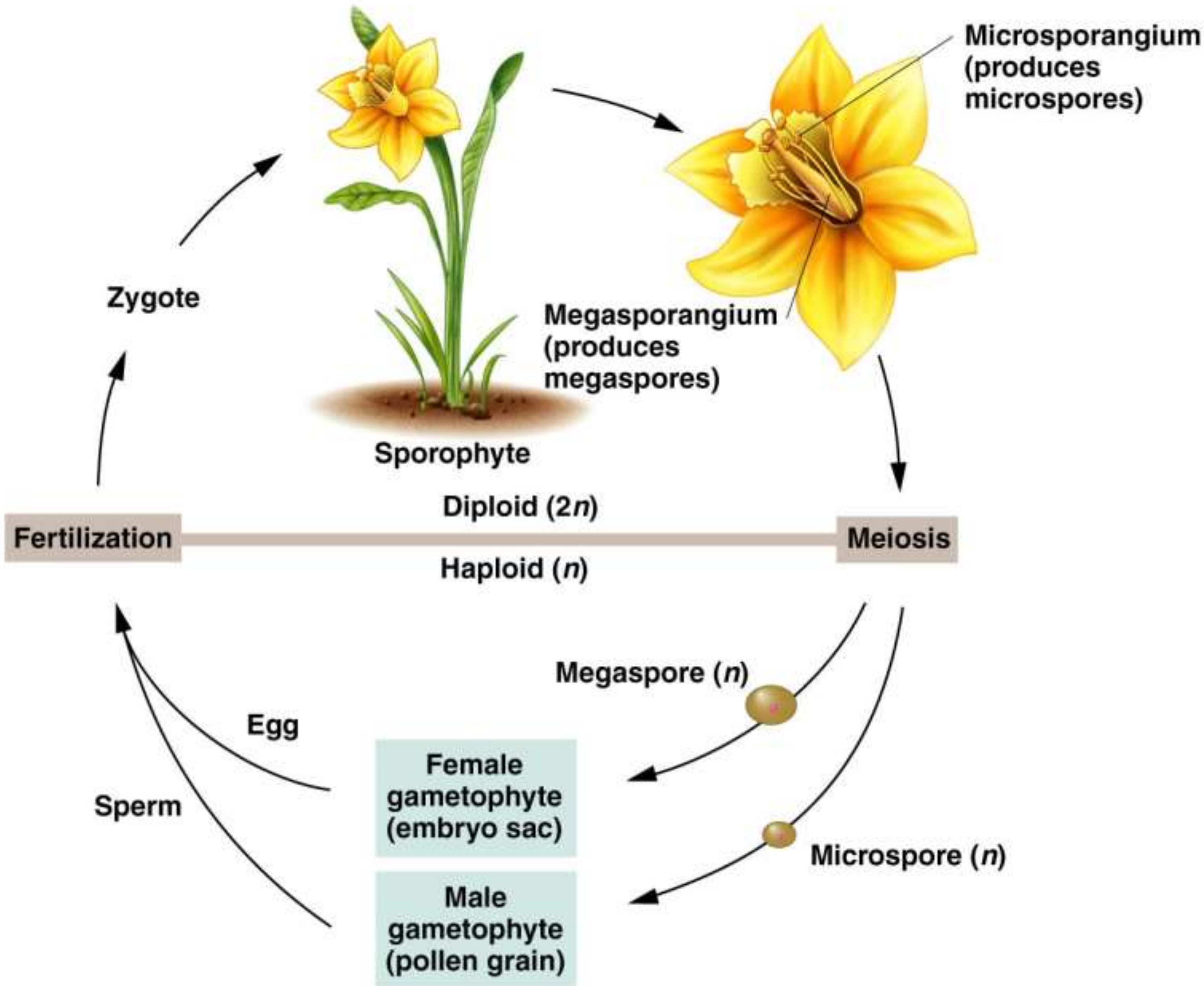
Microsporangium
(produces
microspores)
Zygote
Megasporangium
(produces
megaspores)
Sporophyte
Diploid (2*n*)
Fertilization
Meiosis
Haploid (*n*)
Megaspore (*n*)
Egg
Female
gametophyte
(embryo sac)
Sperm
Microspore (*n*)
Male
gametophyte
(pollen grain)

Figure 2.12

2.7 Electron Microscopy Has Revealed the Physical Nature of Mitotic and Meiotic Chromosomes

Section 2.7

- Chromosomes are visible only during mitosis and meiosis because the chromatin fibers that make up chromosomes coil and condense in these stages (**Figure 2.13**).

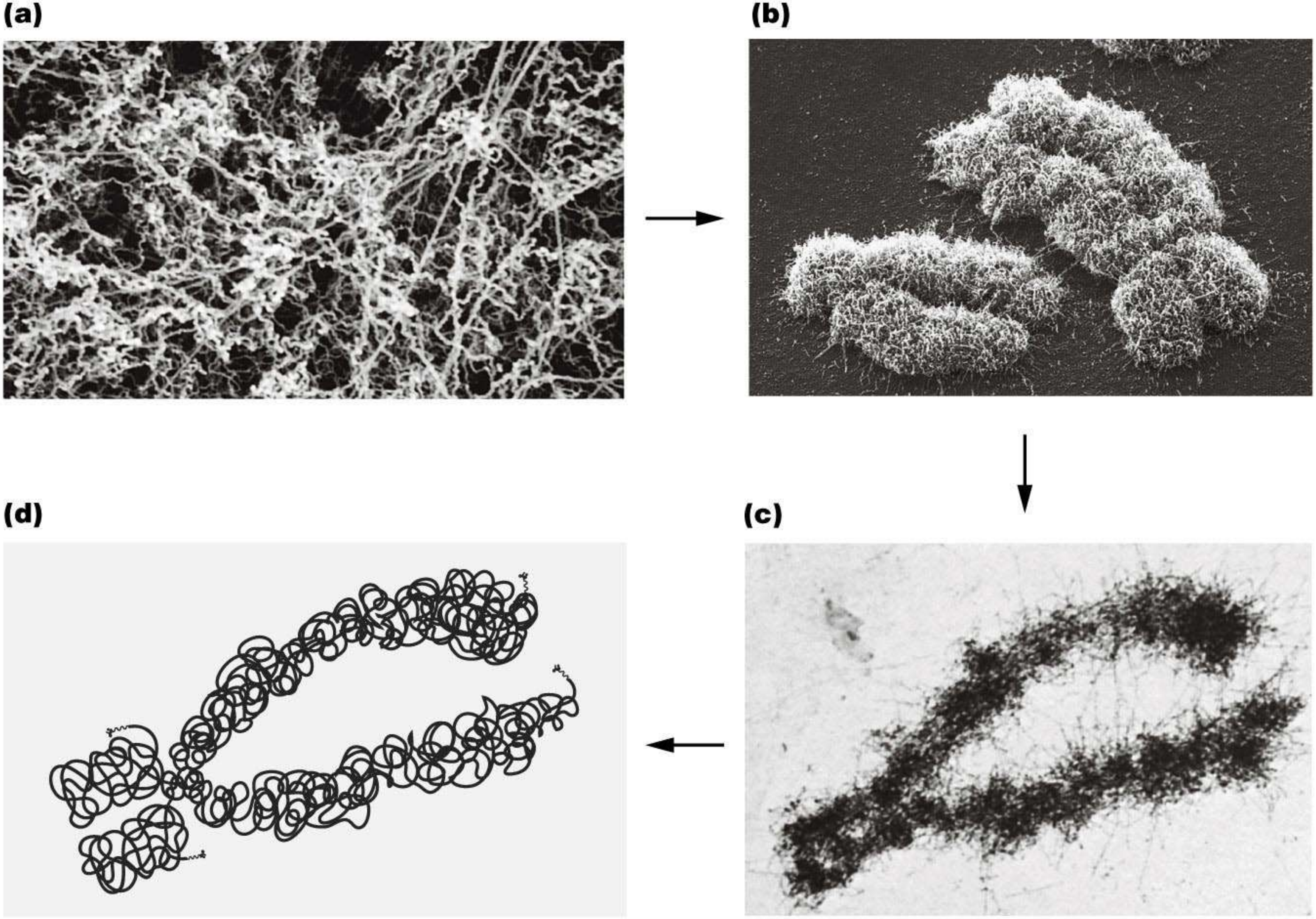

Figure 2.13

Section 2.7

- Electron microscopic observations of mitotic chromosomes in varying states of coiling led to postulation of the folded-fiber model (**Figure 2.13d**).

(d)

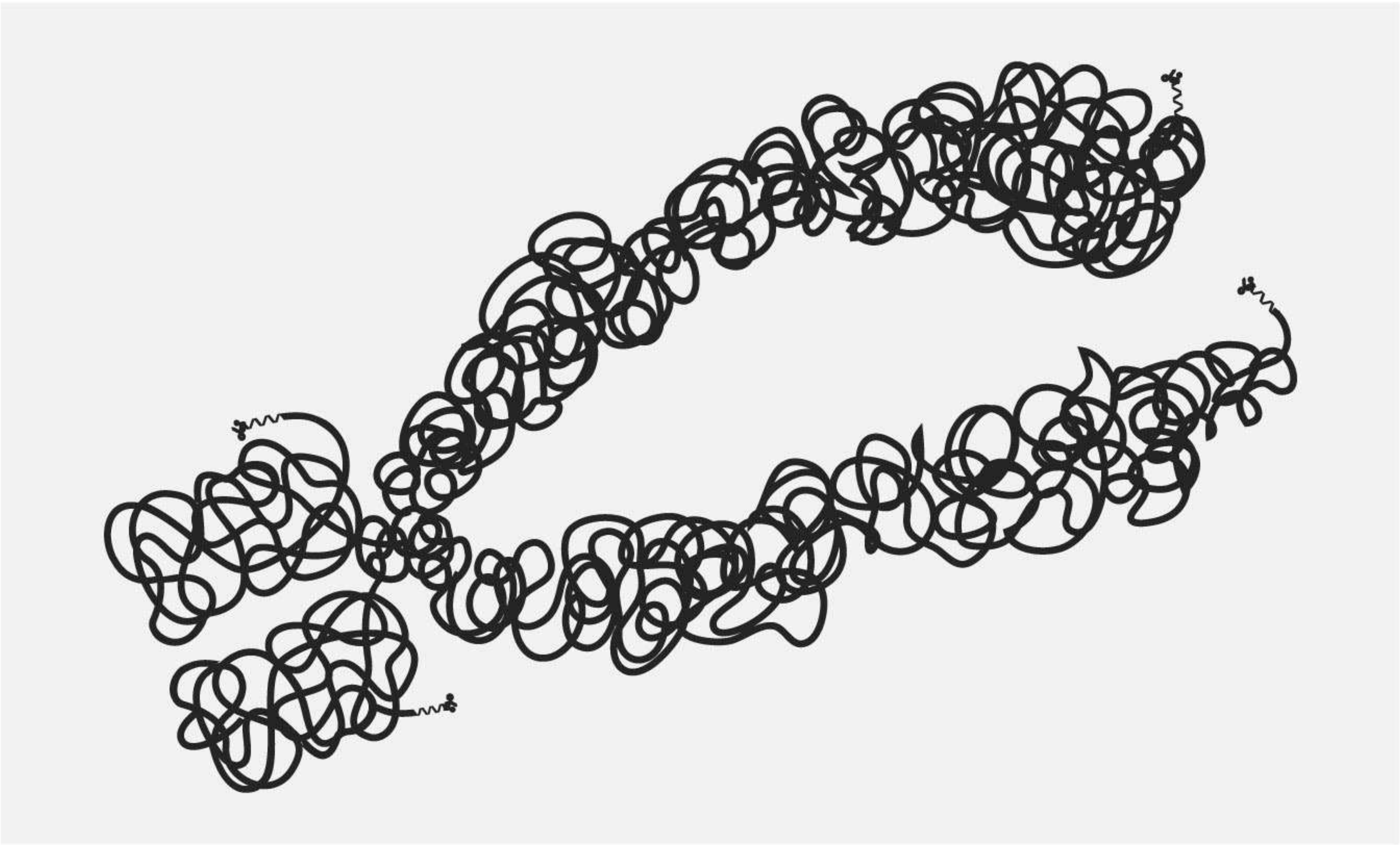

Figure 2.13d

Section 2.7

- The **synaptonemal complex** is found only in chromosomes of cells undergoing meiosis (**Figure 2.14**).
- It is the vehicle for pairing of homologs and their segregation during meiosis.

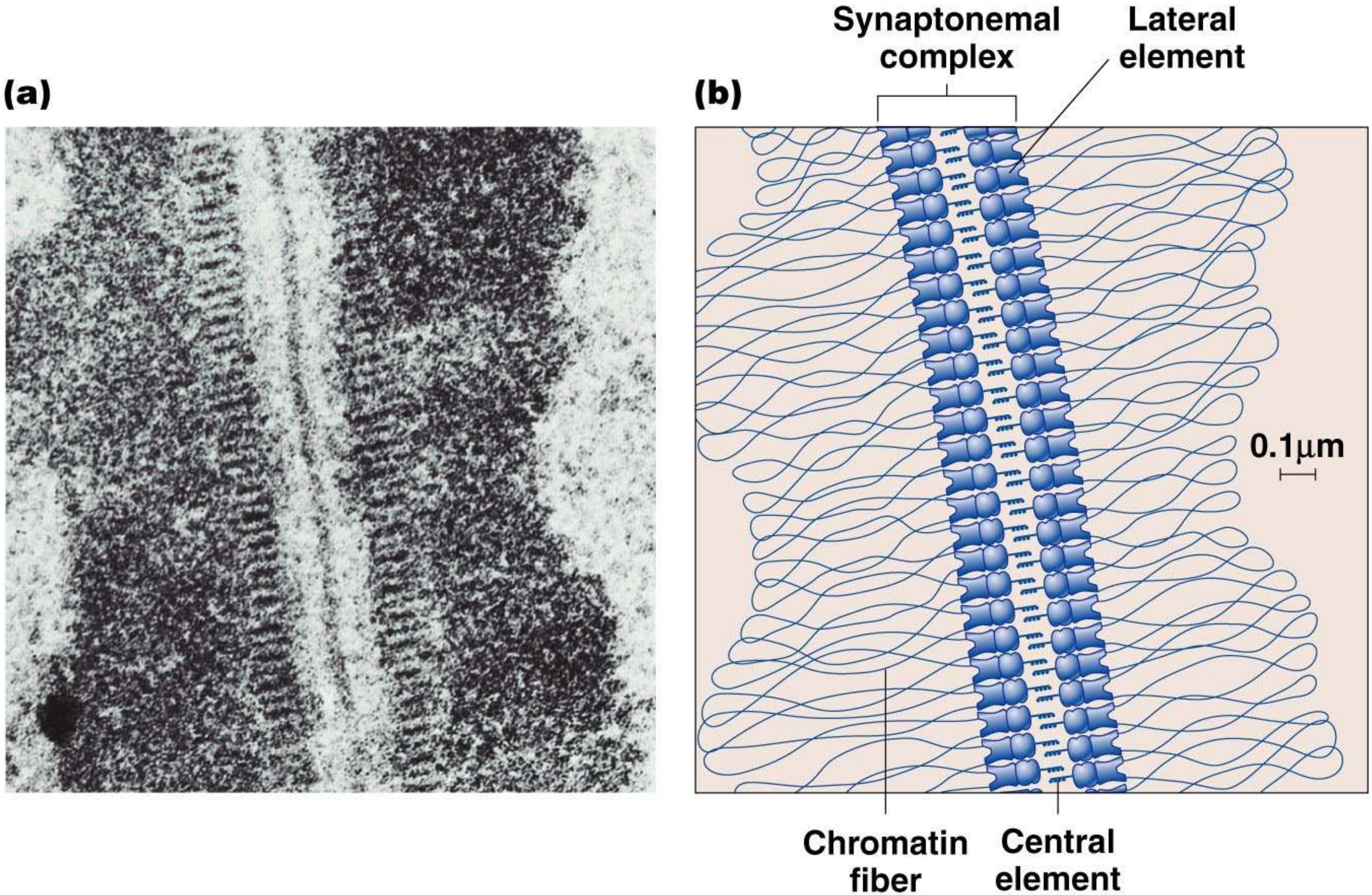
(a)
(b)
Synaptonemal complex
Lateral element
0.1μm
Chromatin fiber
Central element

Figure 2.14