Cell division

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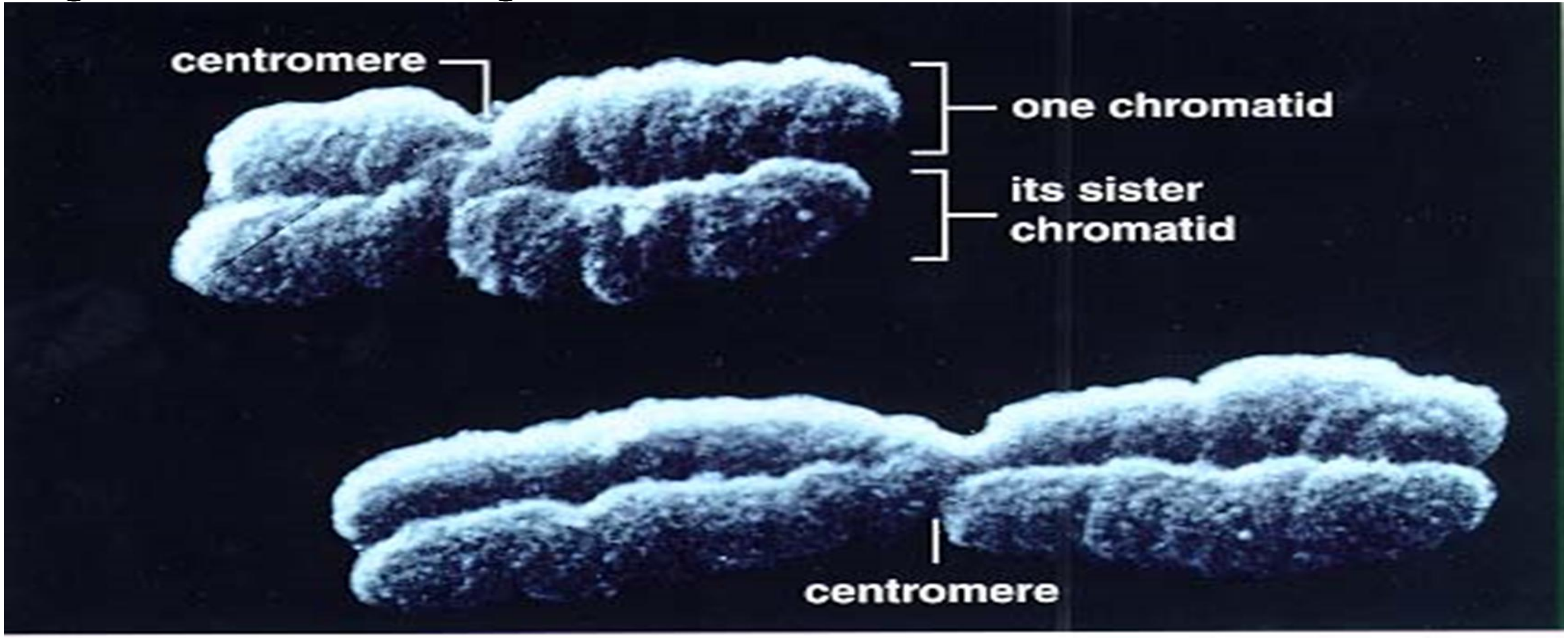
- **cell division**
- process by which cells reproduce themselves
- 2 types of cell division—
- **somatic cell division & reproductive cell division**
- **somatic cell -** any cell of the body other than a germ cell
- **germ cell -** a gamete (sperm or oocyte) or any precursor cell destined to become a gamete
- **somatic cells -** essential for growth, development, regeneration & maintenance of various tissues of the body
- **germ cells -** essential for the production of gametes

- **somatic cell division**
- a cell undergoes a nuclear division called **mitosis** & a cytoplasmic division called **cytokinesis**
- produce 2 genetically identical cells, each with the same number & kind of chromosomes as the original cell
- **Reproductive cell division**
- mechanism that produces gametes, the cells needed to form the next generation of sexually reproducing organisms
- process consists of a special two step division called **meiosis** , in which the number of chromosomes in the nucleus is reduced by half

- Human cells contain 23 pairs of chromosomes, for a total of 46
- One member of each pair is inherited from each parent
- 22 pairs of these chromosomes are called **autosomes**
- 23rd pair is called **sex chromosomes**
- When a cell reproduces, it must replicate (duplicate) all its chromosomes to pass its genes to the next generation of cells



When the cell divides, the sister chromatids separate from each other and are called chromosomes again

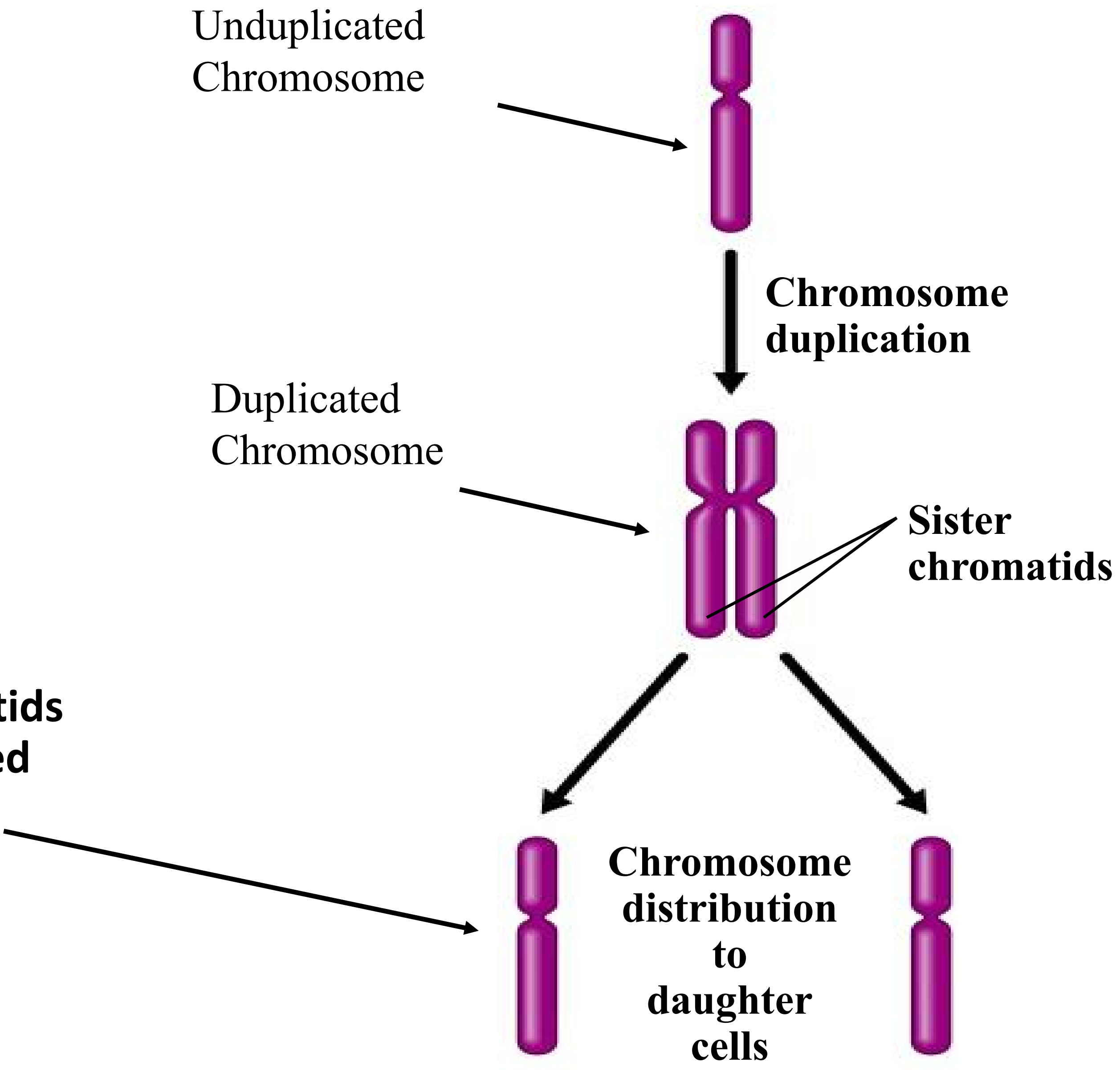


Figure 8.5

Somatic Cell Division

Objectives

After this lecture students should be able to

Describe the cycle of the cell

Interphase and the phases

The stages of mitosis and describe the events that occur in each one stage

Discuss the significance of mitosis

The differences between mitosis and meiosis

- **THE CELL CYCLE**
- is an orderly sequence of events in which a somatic cell duplicates its contents & divides in two
- OR
- a series of changes that a cell undergoes from the time it is formed until it has completed a division & reproduced it self.

Divided into **2** major periods:

- **Interphase-** cell is not dividing, long period of time, cell increases in size & content & replicates its genetic material
- **Mitotic phase-**short period of time, cell divides its nucleus & cytoplasm, giving rise to 2 daughter cells

TWO PHASES OF THE CELL CYCLE

Interphase

- Cell growth and replication of DNA

Mitotic phase

- Cell divides

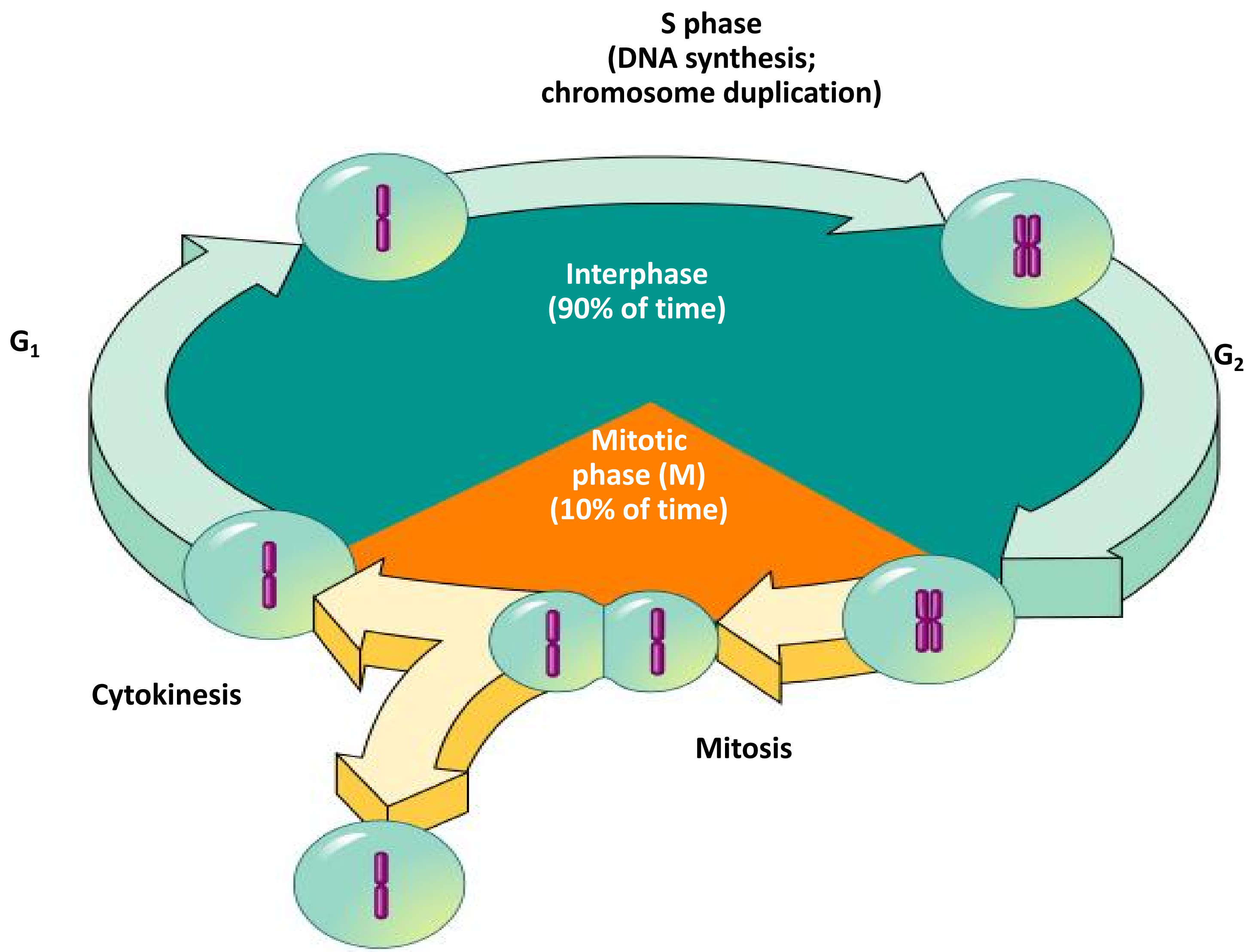
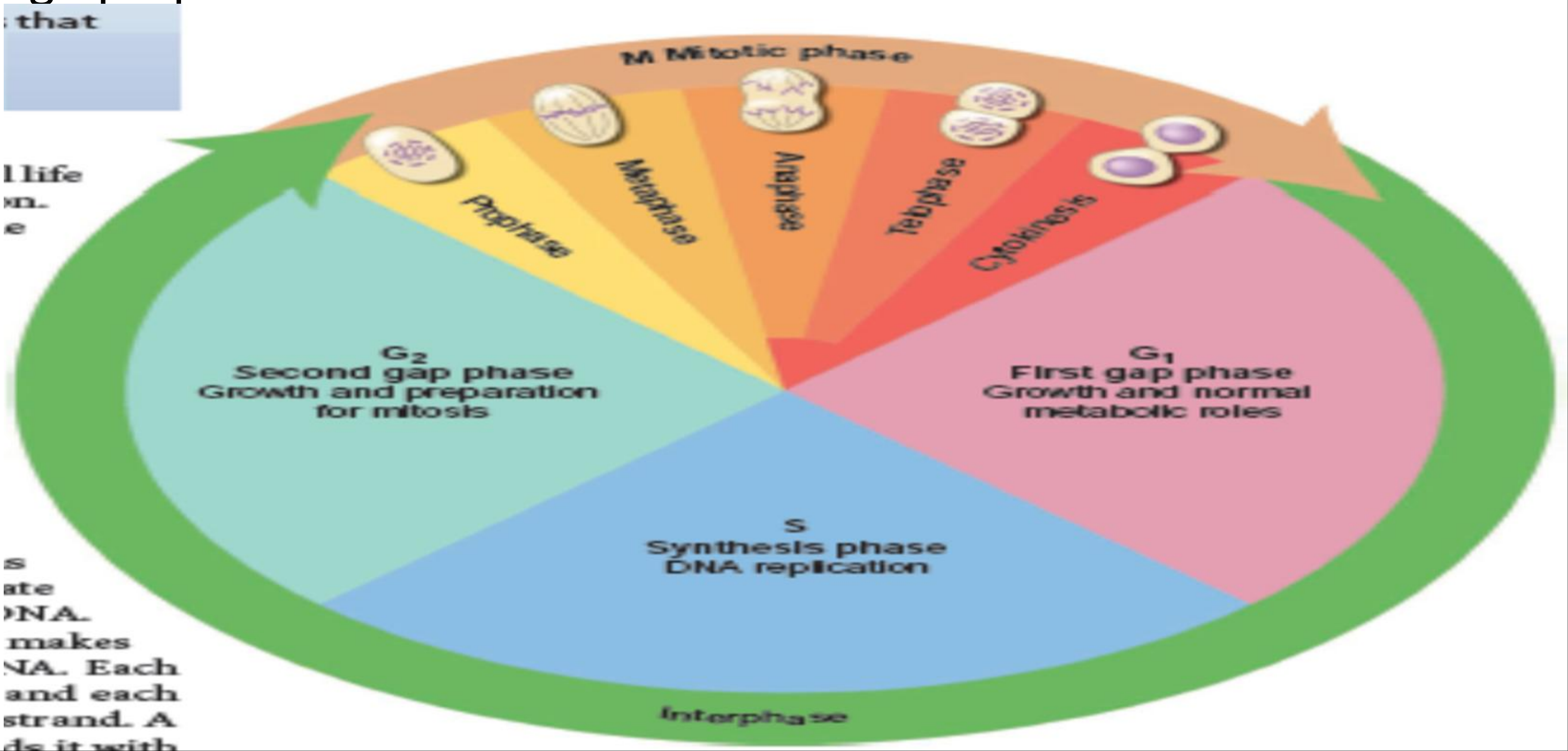
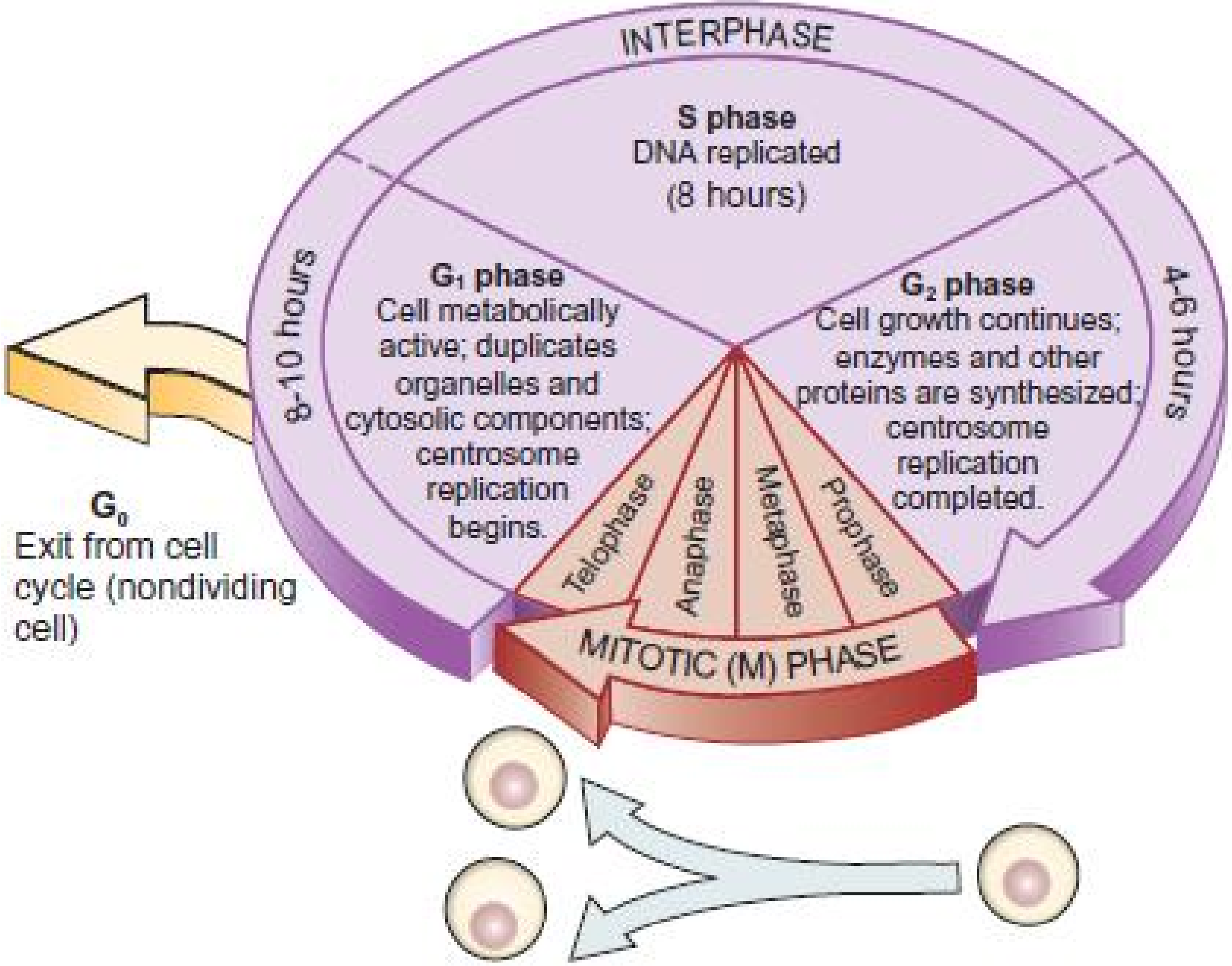


Figure 8.6

Interphase –is subdivided into 3 phases

- **G1**: synthesis of macromolecules essential for DNA duplication
- **S phase**: period of DNA duplication
- **G2**: Cell undergo preparations for mitosis
- Check points





? During which phase of the cell cycle does DNA replication occur?

Interphase

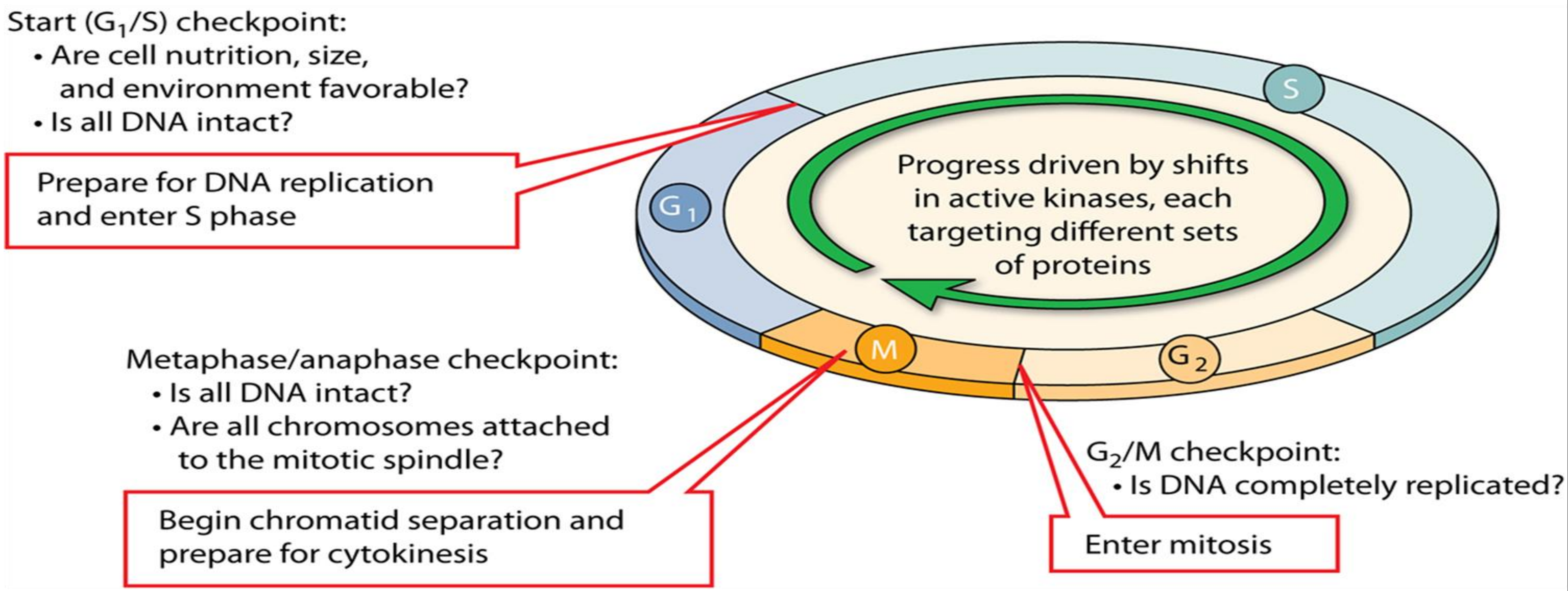
G1-PHASE

- Nucleoli reestablished
- Cell volume restored to normal
- Active RNA and protein synthesis for DNA & enzymes necessary to carry out these synthetic activities.
- Replication of centrosomes/Centrioles begin to duplicate & organelle duplication
- G1 lasts 8 to 10 hour

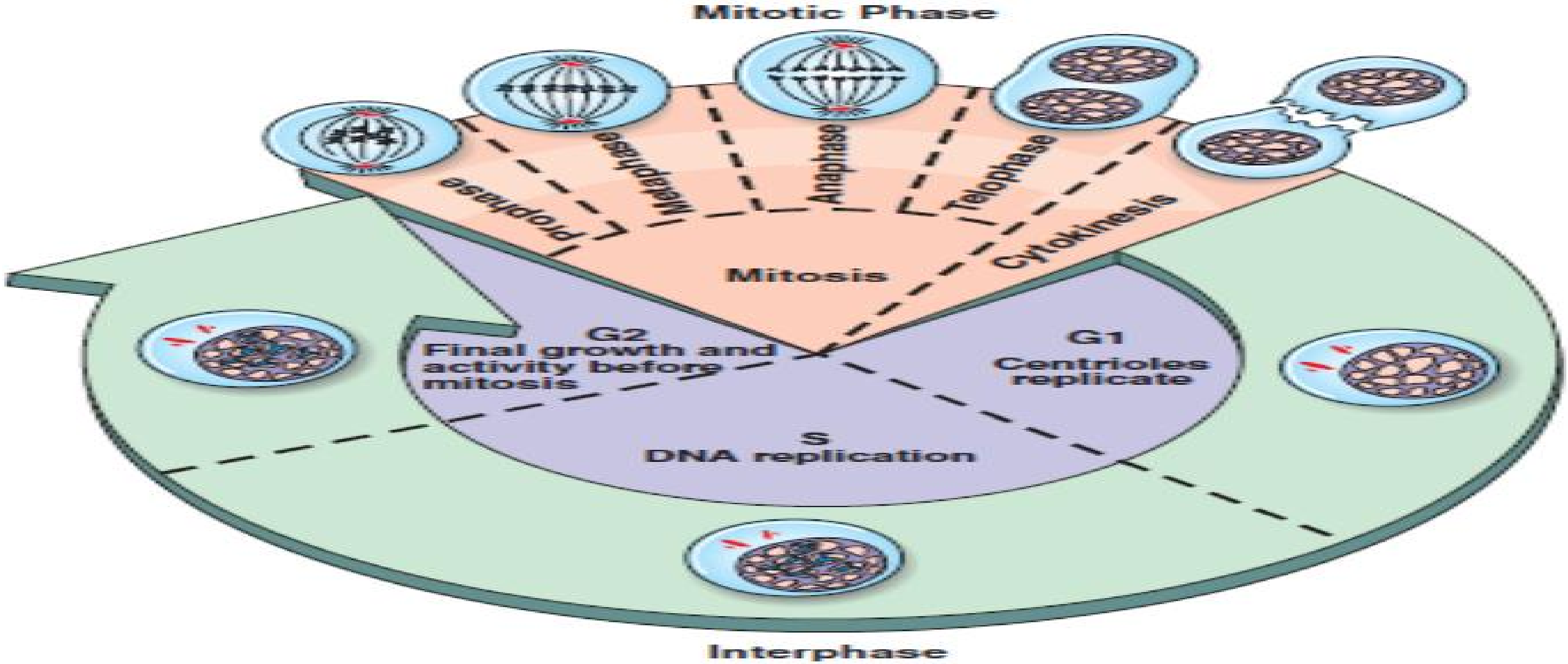
S-PHASE

- Genome duplication
- enzymes and other proteins are synthesized in preparation for cell division
- replication of centrosomes is completed
- lasts 8 hours

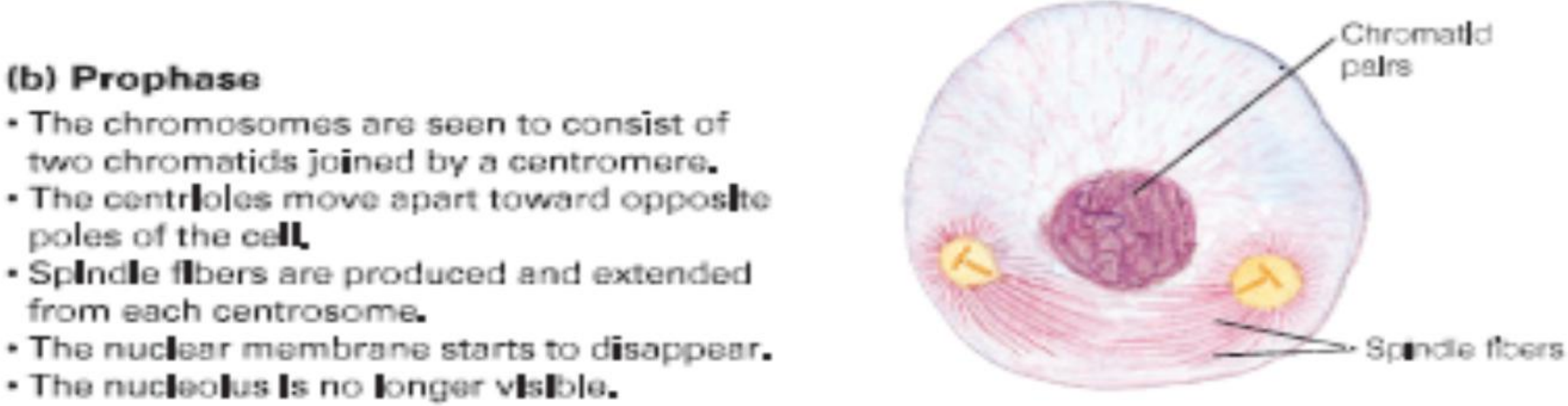
- **<u>G2-PHASE</u>**
- Synthesis of RNA and protein required for cell division done
- Energy for mitosis stored
- Tubulin synthesized for assembly into the microtubules
- DNA replication checked for errors and corrected
- 4-6hours

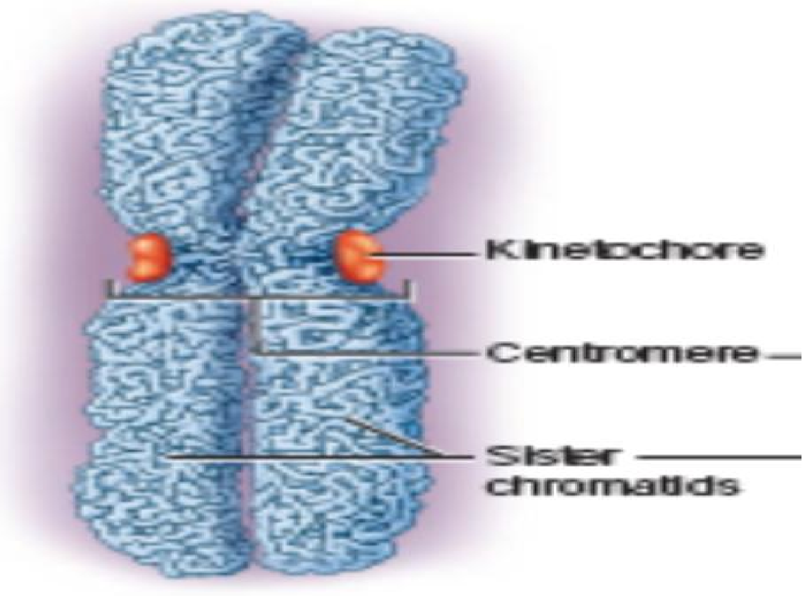


- **MITOTIC PHASE**
- **mitotic (M) phase** of the cell cycle, which results in the formation of 2 identical cells, consists of a nuclear division (mitosis) & a cytoplasmic division (cytokinesis)
- **NUCLEAR DIVISION: MITOSIS** , is the distribution of 2 sets of chromosomes into 2 separate nuclei.
- The process results in the *exact* partitioning of genetic information
- Comprises 5 stages:- prophase, metaphase, anaphase and telophase

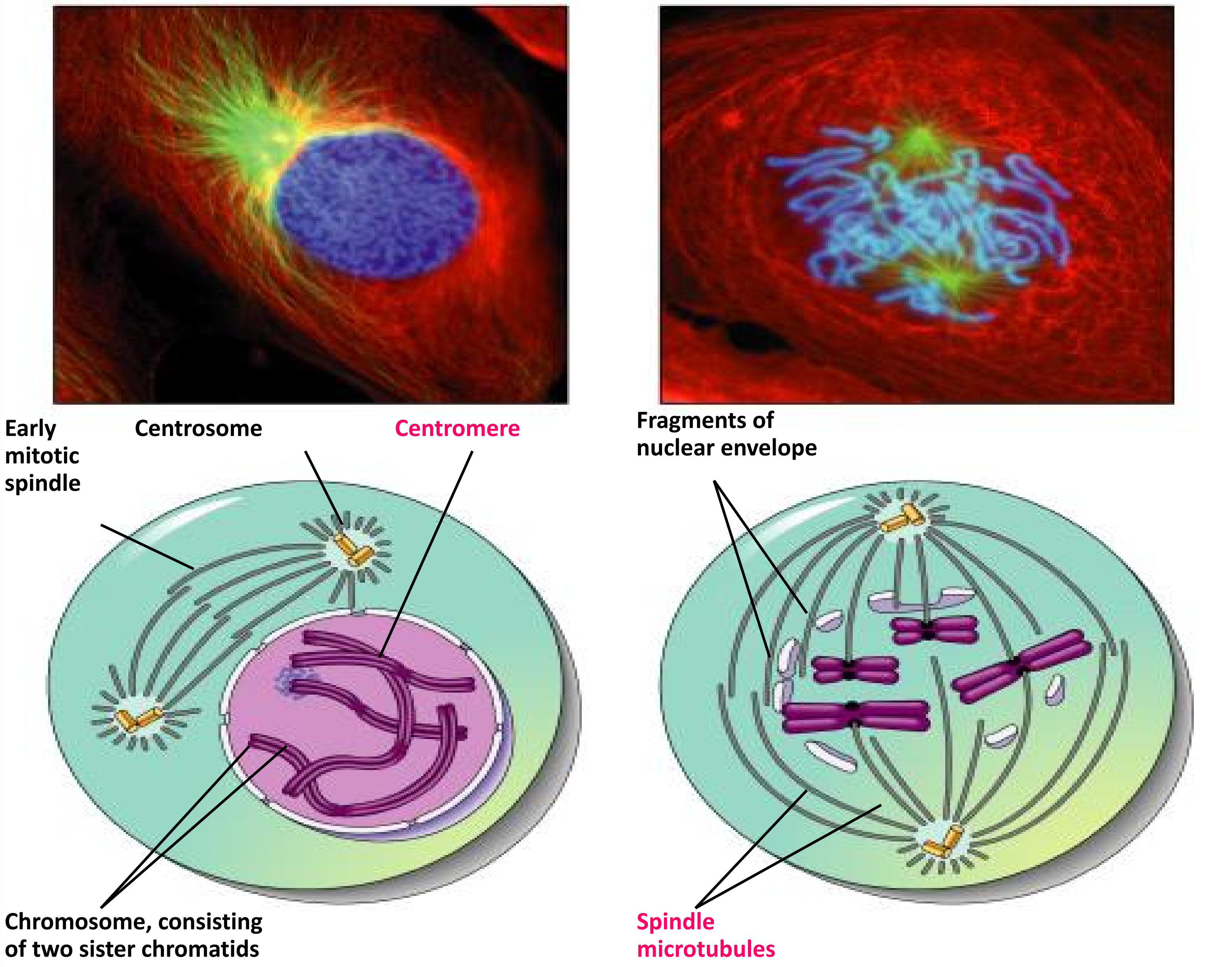


- **PROPHASE**
- chromatin fibers condense & shorten into chromosomes that are visible under the light microscope
- Each chromosome consists of a pair of identical strands called **chromatids**
- **centromere** is constricted region holds the chromatid pair together
- **kinetochore is** a protein complex outside of each centromere
- tubulins in the pericentriolar material of the centrosomes start to form the **mitotic spindle**
- a football-shaped assembly of microtubules that attach to the kinetochore
- microtubules lengthen, push centrosomes to the poles (opposite ends) of the cell so that the spindle extends from pole to pole
- nucleolus disappears and the nuclear envelope breaks down

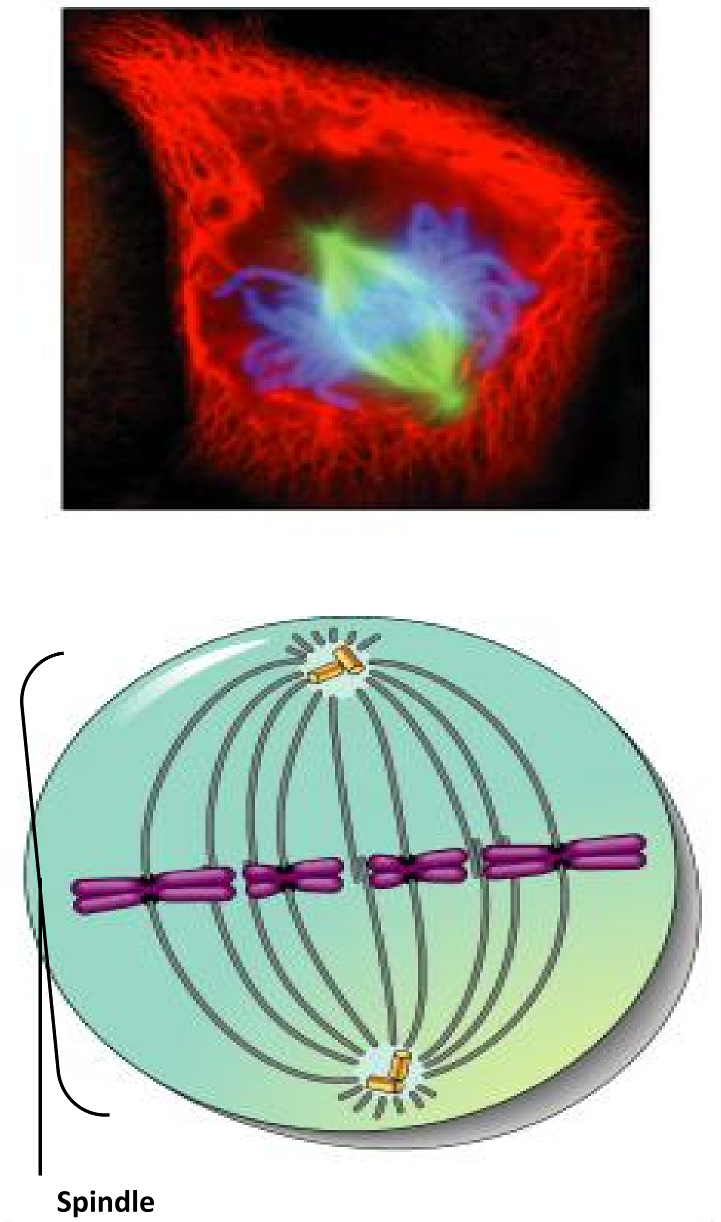




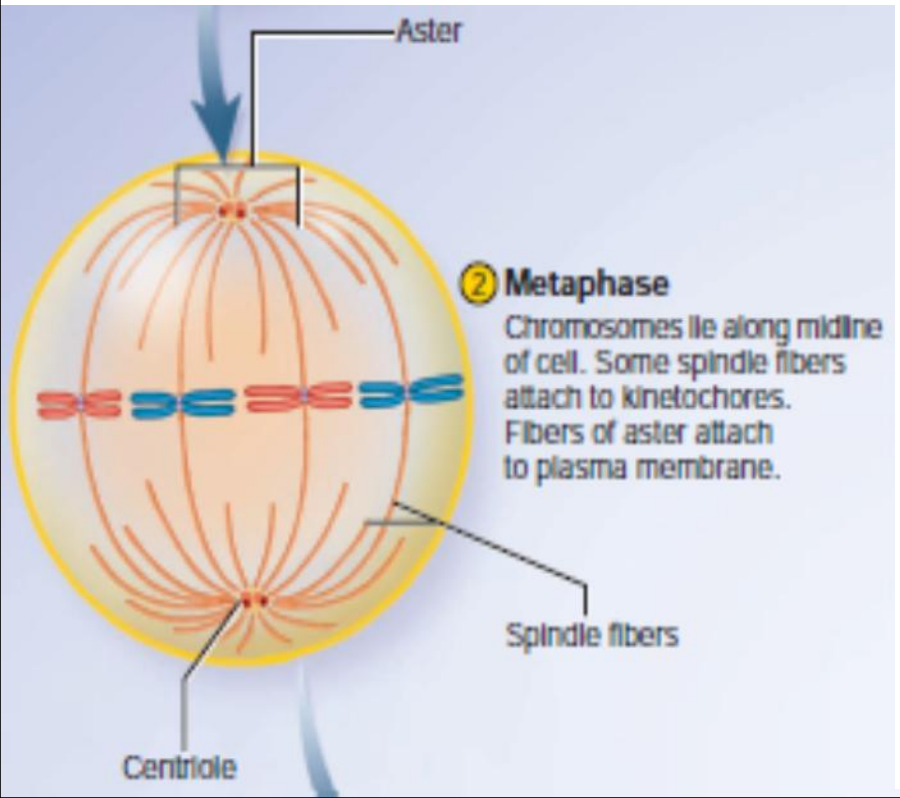
Prophase



Metaphase

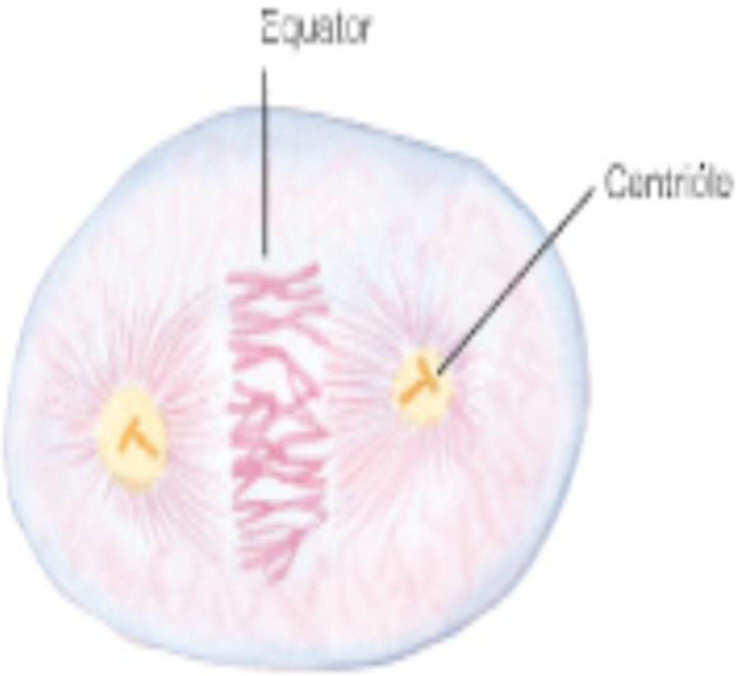


- **Metaphase**
- Chromosomes attach to spindles at kinetochore
- Chromosomes align at the equator at metaphase plate
- Spindle fibres form a football-shaped array mitotic spindle
- Long microtubules reaching out from each centriole to the chromosomes
- Shorter microtubules forming a star like aster



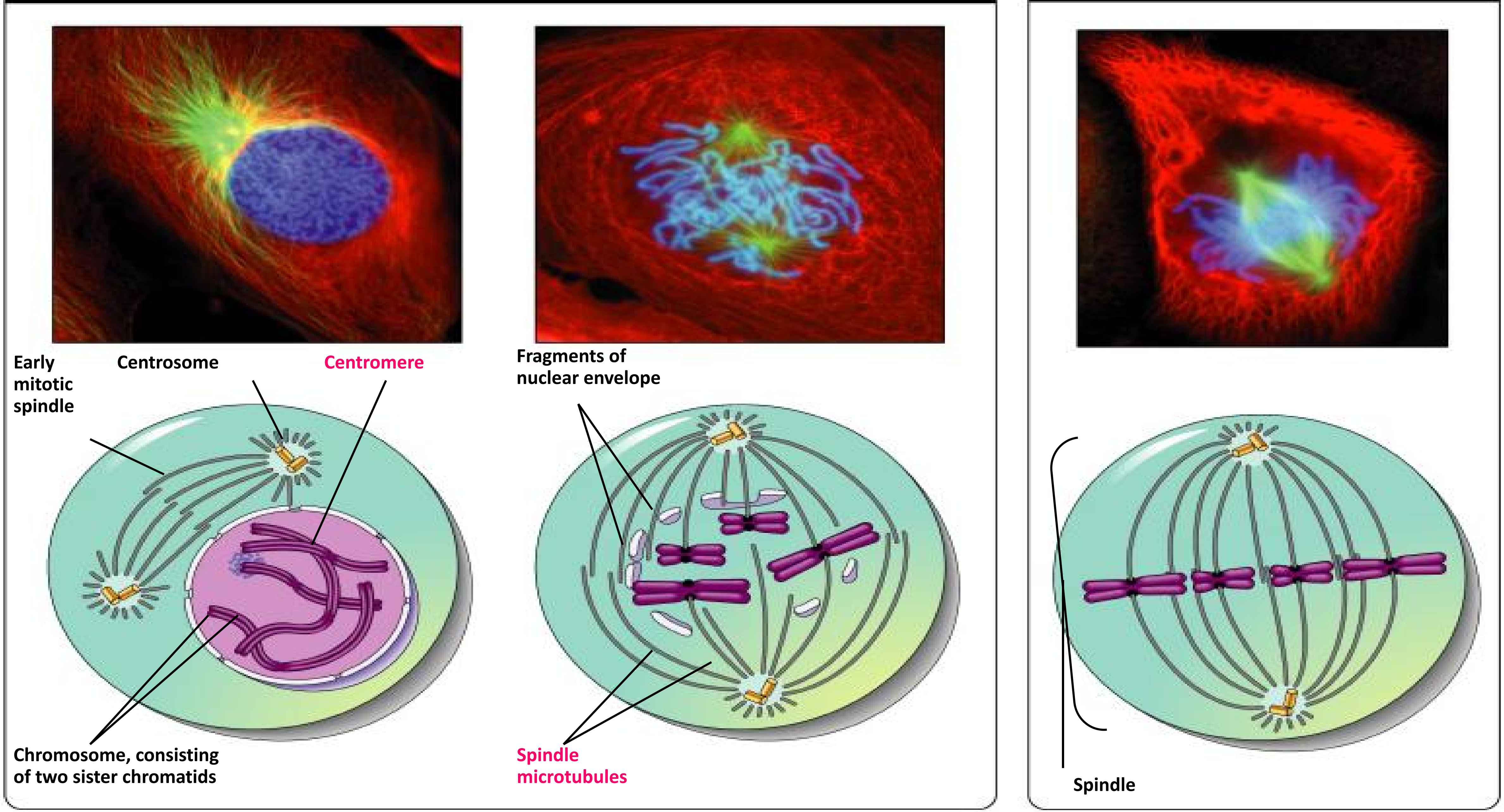
(c) Metaphase

- The chromosomes are lined up at the equator of the cell.
- The spindle fibers from each centriole are attached to the centromeres of the chromosomes.
- The nuclear membrane has disappeared.

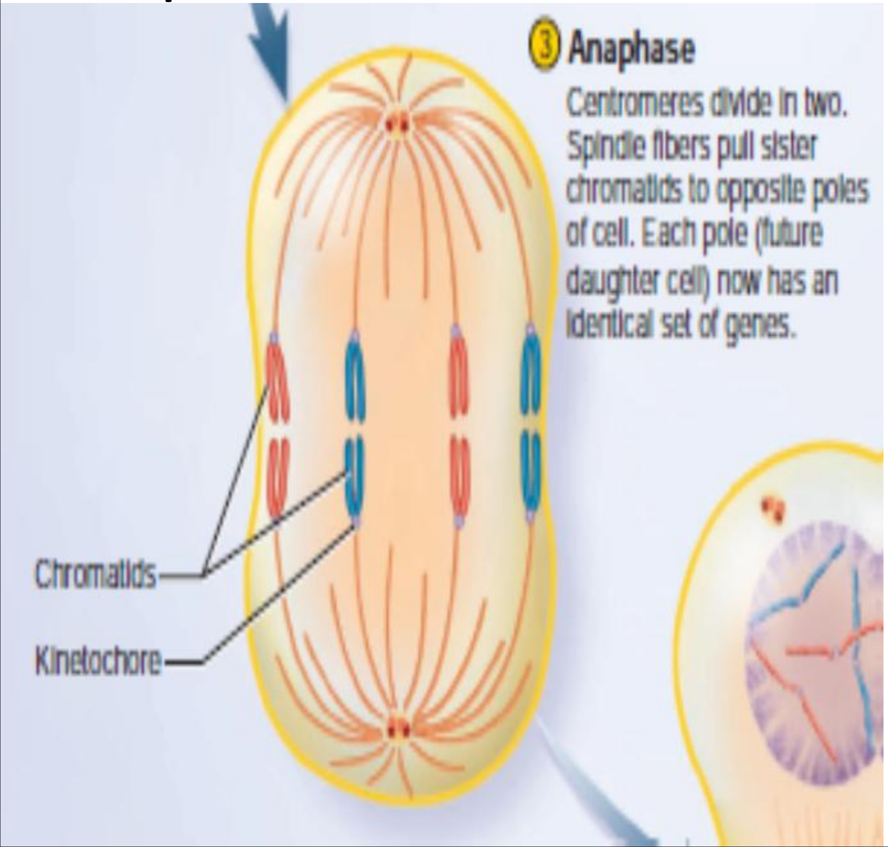


Prophase

Metaphase



- **Anaphase**
- centromeres split, separating the 2 members of each chromatid pair, which move toward opposite poles of the cell
- Chromosome separate
- Sister chromatids become chromosomes
- 46 pairs of chromosomes



(d) Anaphase

- The centromeres split, and the sister chromatids separate as each is pulled to an opposite pole.

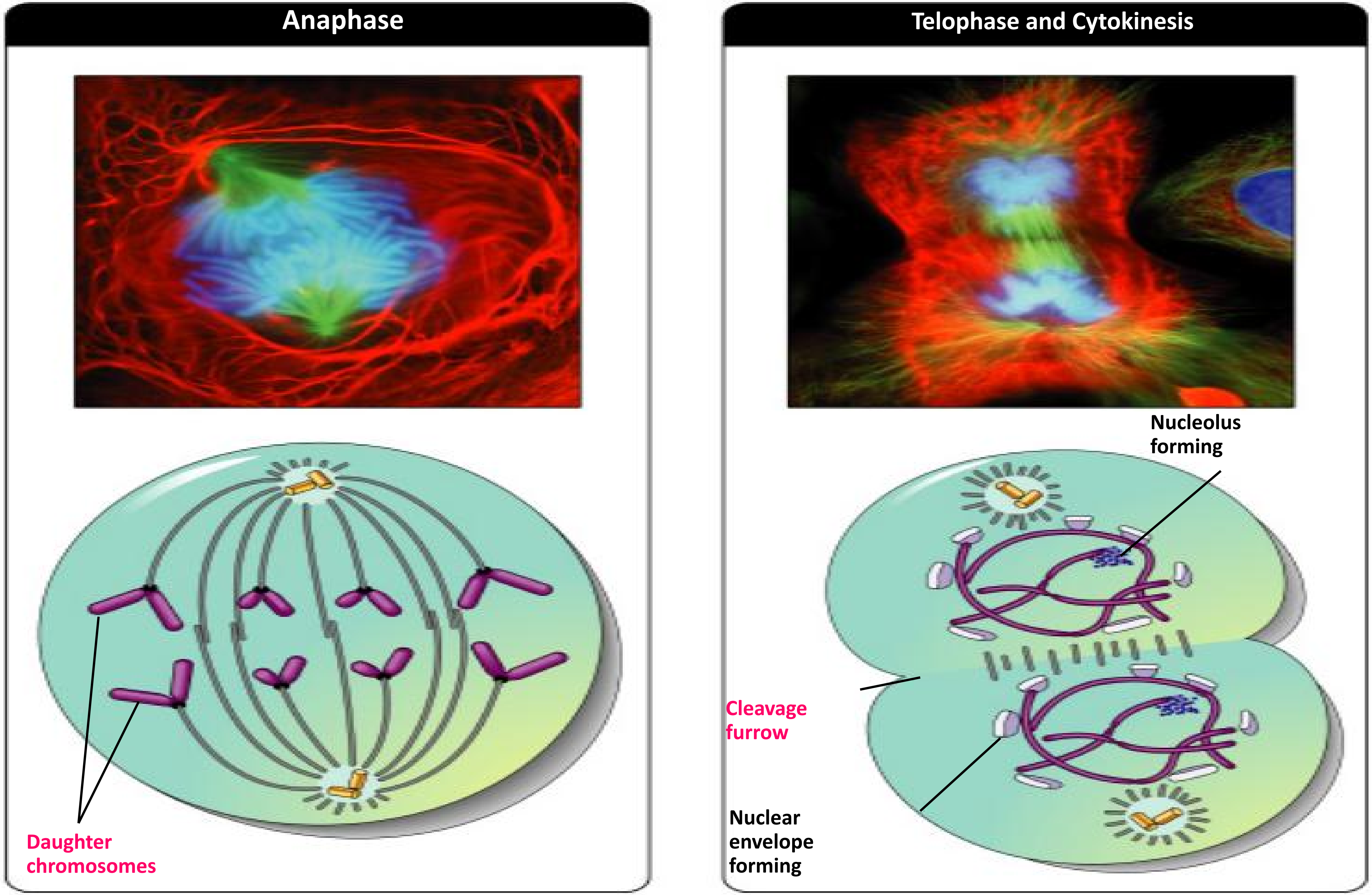
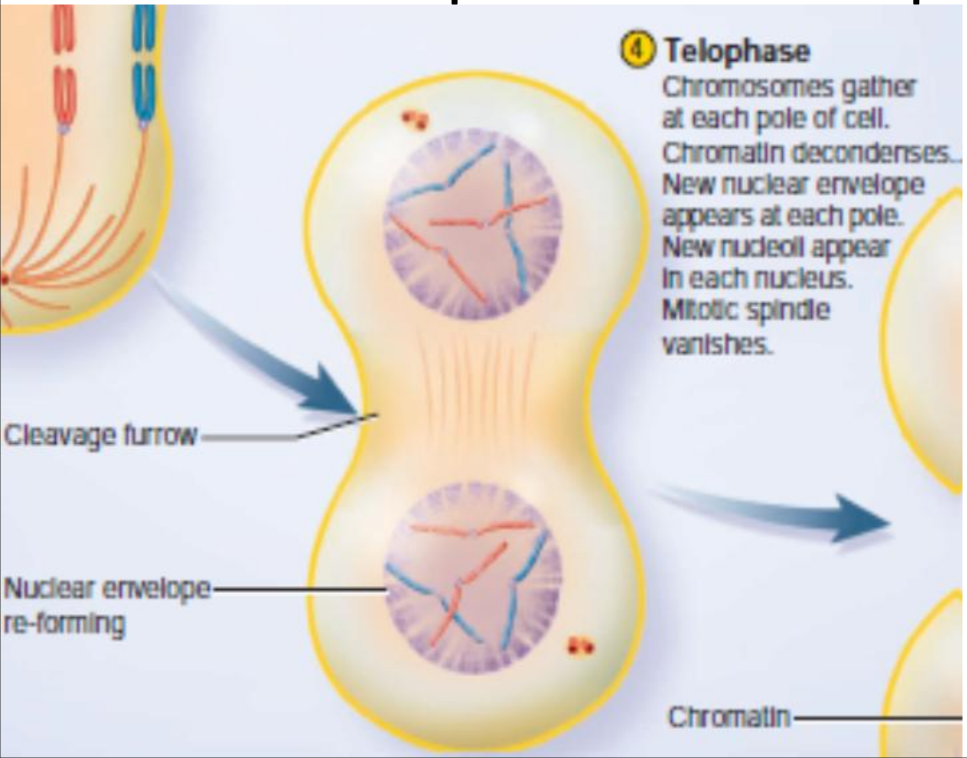
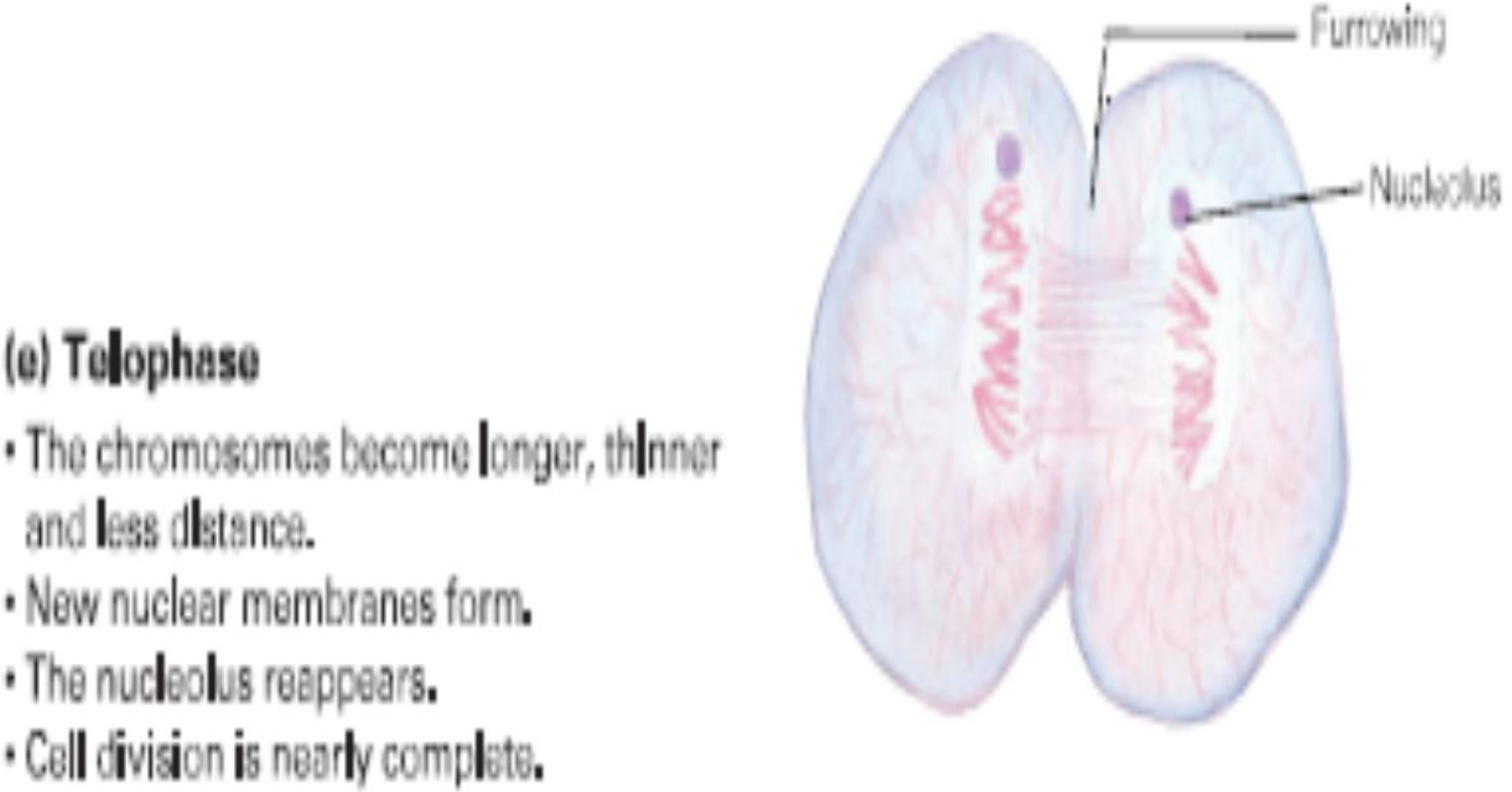

Anaphase
Daughter chromosomes
Telophase and Cytokinesis
Nucleolus forming
Cleavage furrow
Nuclear envelope forming

Figure 8.7.3

- **Telophase**
- begins after chromosomal movement stops
- identical sets of chromosomes, now at opposite poles of the cell, uncoil and revert to the threadlike chromatin form
- Nuclear envelope forms around each chromatin mass, nucleoli reappear in the identical nuclei
- the mitotic spindle breaks up





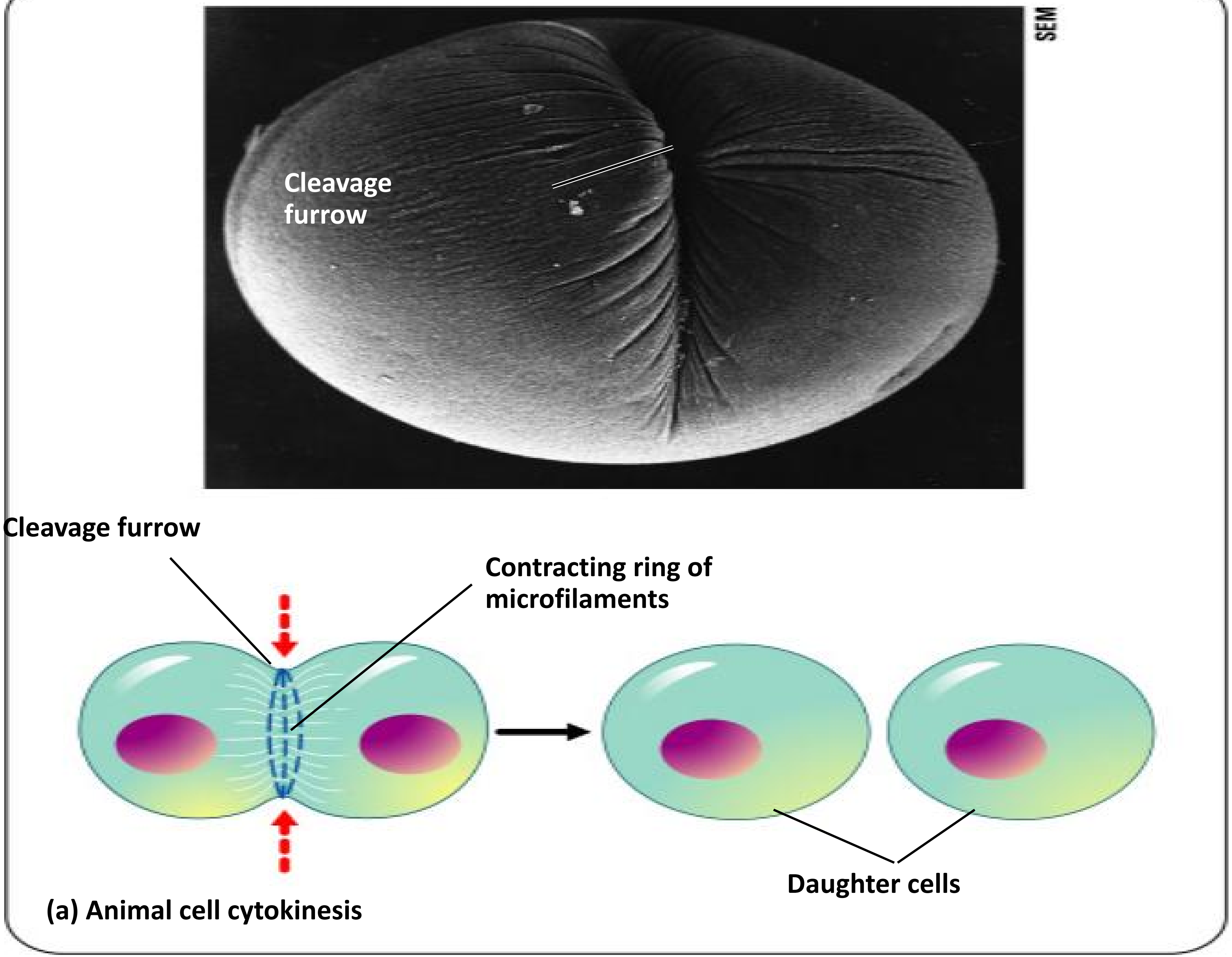
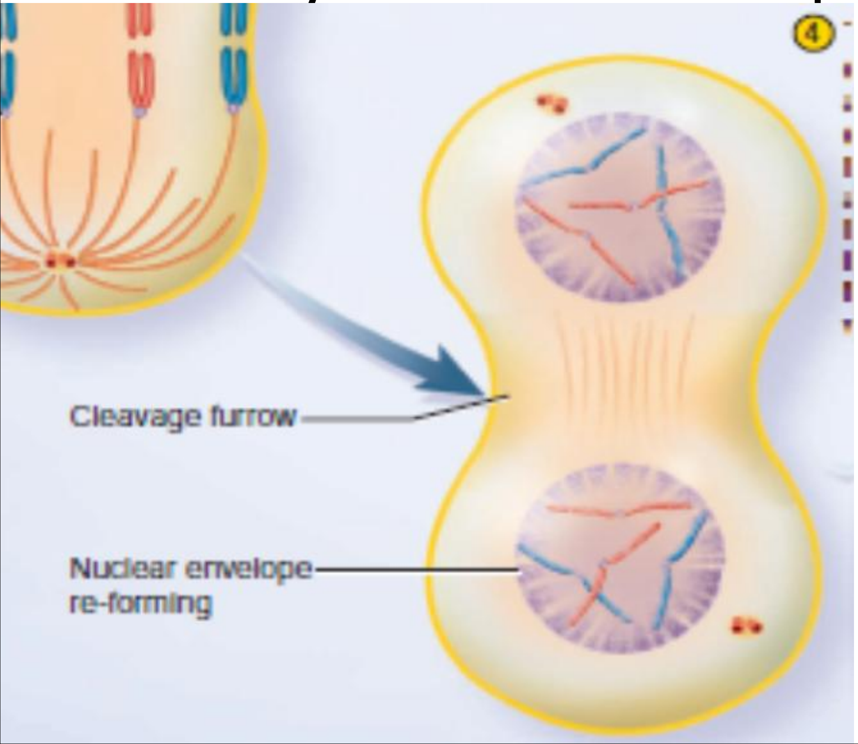
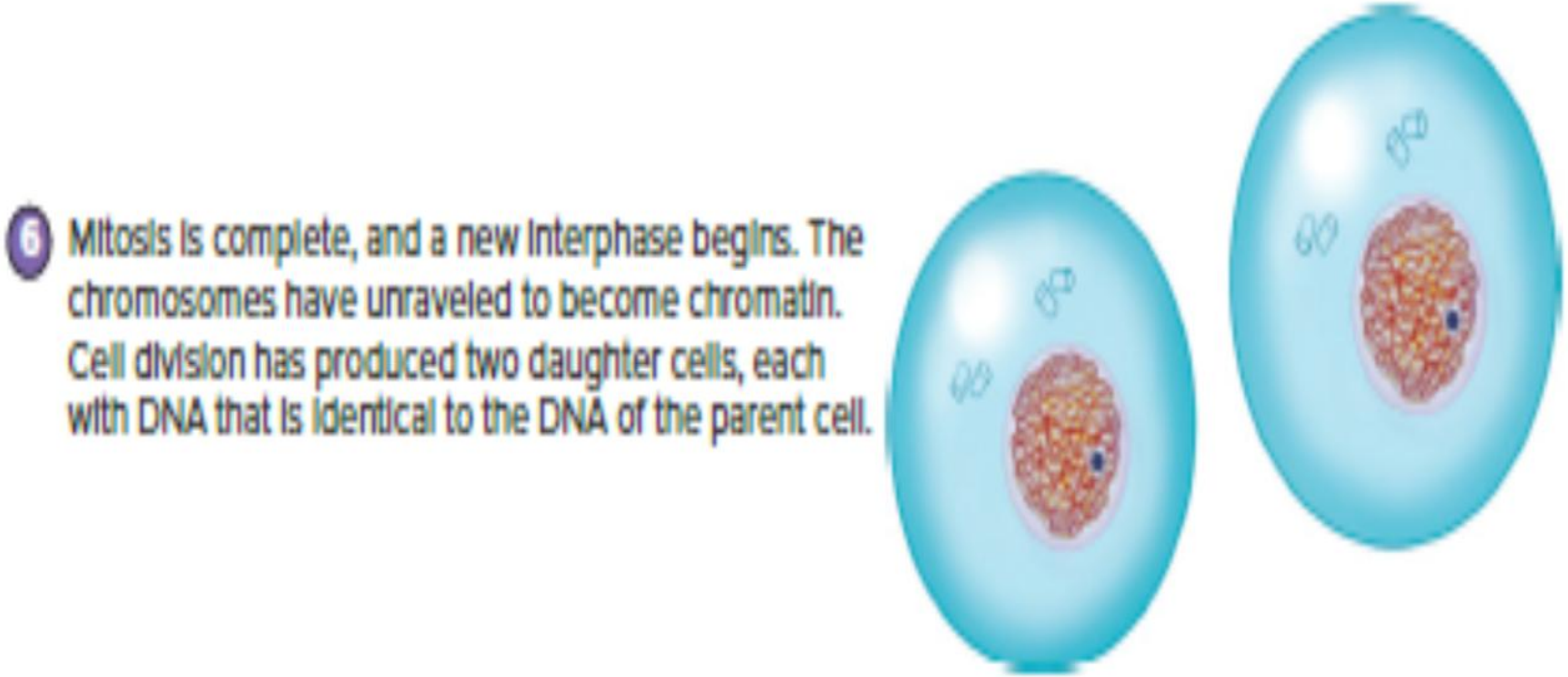

SEM
Cleavage furrow
Cleavage furrow
Contracting ring of microfilaments
Daughter cells
(a) Animal cell cytokinesis

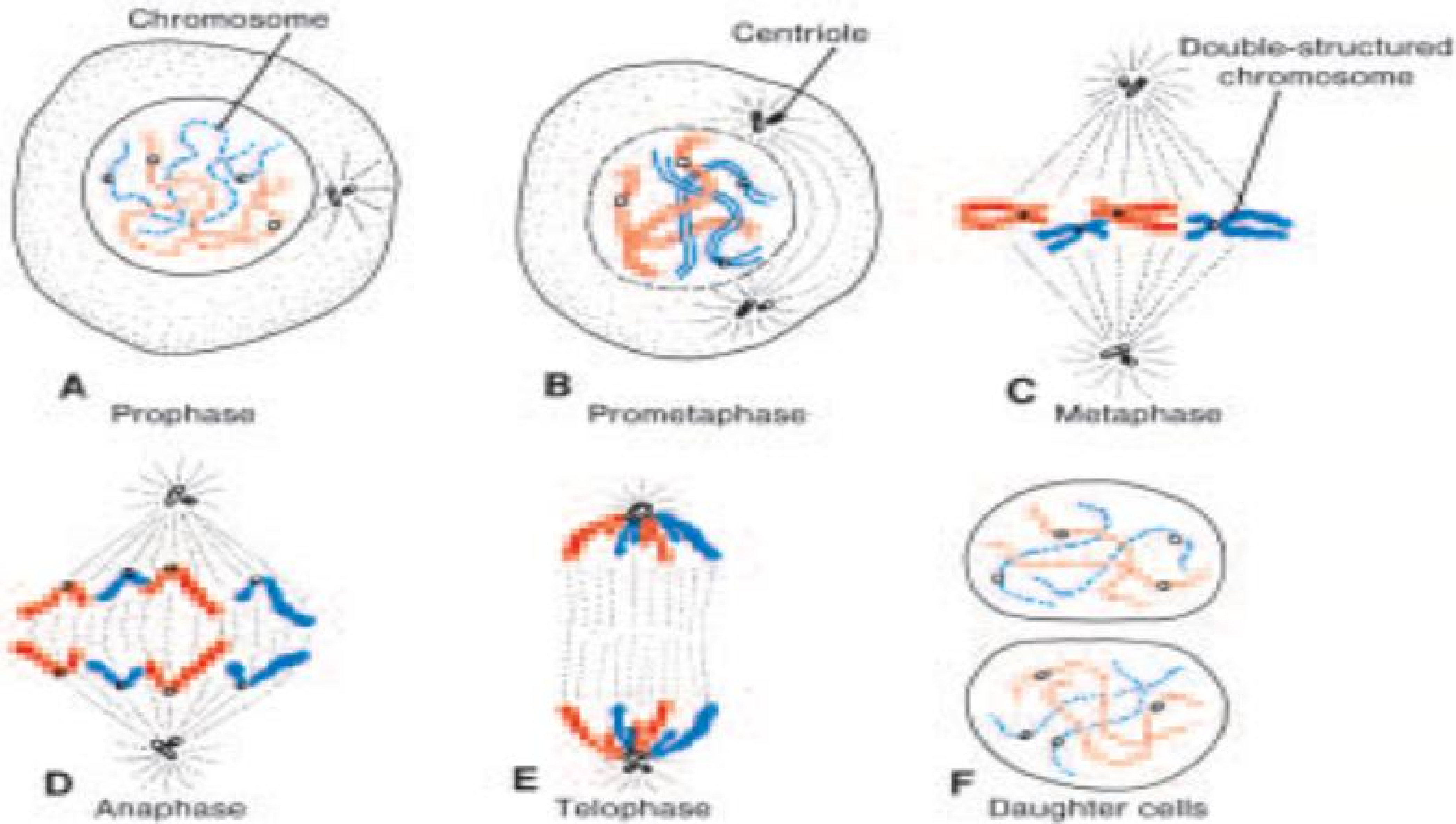
Figure 8.8a

- **CYTOPLASMIC DIVISION: CYTOKINESIS**
- division of a cell’s cytoplasm & organelles into 2 identical cells
- process usually begins in late anaphase with the formation of a **cleavage furrow**
- a slight indentation of the plasma membrane & is completed after telophase
- Actin microfilaments that lie just inside the plasma membrane form a *contractile ring* that pulls the plasma membrane progressively inward
- When cytokinesis is complete, interphase begins





- **Purpose of cell division**
- Why cell division?
- Growth of an organism
- Repair
- Repletion of cells lost
- Reproduction
- formation of a multicellular embryo from a fertilized egg;


Chromosome
Centriole
Double-structured chromosome
A
Prophase
B
Prometaphase
C
Metaphase
D
Anaphase
E
Telophase
F
Daughter cells

- **Clinical Application**
- Cancer
- Proper tissue development depends on a balance between cell division and cell death
- A tumour (neoplasm) is a mass of tissue produced when the rate of cell division exceeds the rate of cell death
- **Benign tumors** are surrounded by a connective tissue capsule, grow slowly, and do not spread to other organs
- **Malignant tumors**(cancer) are unencapsulated, fast-growing, and spread easily to other organs by way of the blood or lymph

Meiosis

Special type of cell division **resulting** in the formation of gametes (spermatozoa and ova)whose chromosome number has been reduced from diploid(2n) to haploid (1n) number.

Divided into separate events:

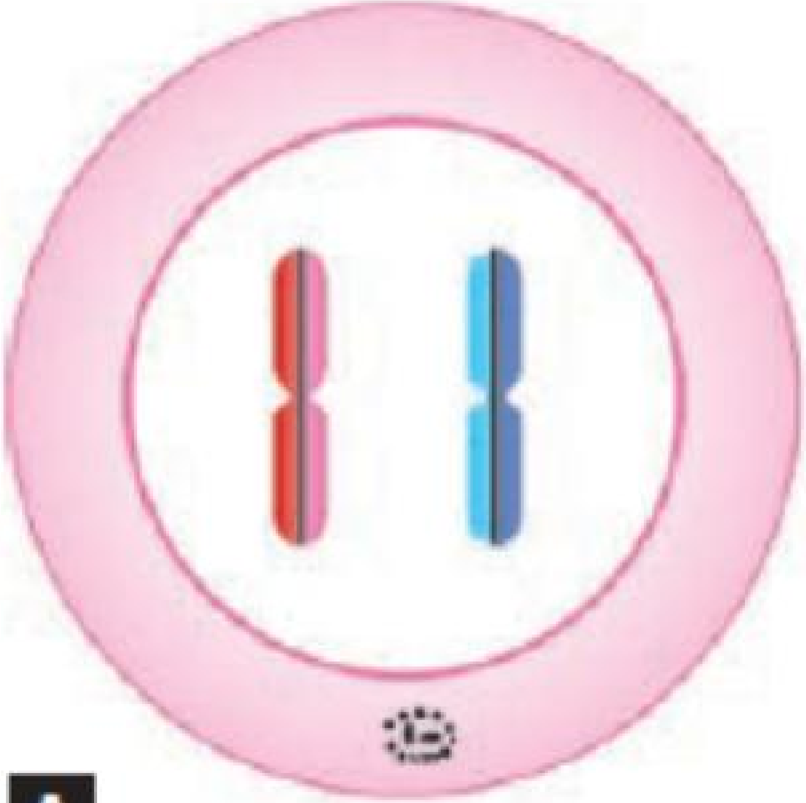
Meiosis 1 and 2

- Meiosis consists of 2 successive divisions-1st & 2nd meiotic division
- During the interphase preceding the 1st meiotic division duplication of DNA content of the chromosome takes place as in mitosis
- As a result, another chromatid identical to the original one is formed.
- Each chromosome is now made up of 2 chromatids

First Meiotic Division

PROPHASE I

- is prolonged and divided into a number of stages:-
- **Leptotene**
- Chromosome become visible
- One end of the thread attached to the nuclear membrane
- Thicker and shorter



A

1. Chromosomes become visible. Each chromosome is made up of two chromatids (but these cannot be made out separately)

- **Zygotene**
- 2 chromosomes of each pair lie parallel to each other closely opposed
- Pairing known as **synapsis** or **conjugation**
- 2 chromosomes together constitute a **bivalent**

- **Pachytene**
- 2 chromatid of each chromosome become distinct
- The bivalent has 4 chromatids in it called **tetrad**
- The 2 central chromatids become coiled over each other for crossing at a number of points known as **crossing over**
- Site where the chromatids cross become adherent points known as **chiasmata**

B

2. Two homologous chromosomes come to lie side by side forming a bivalent

C

3. Four chromatids are now distinct and form a tetrad

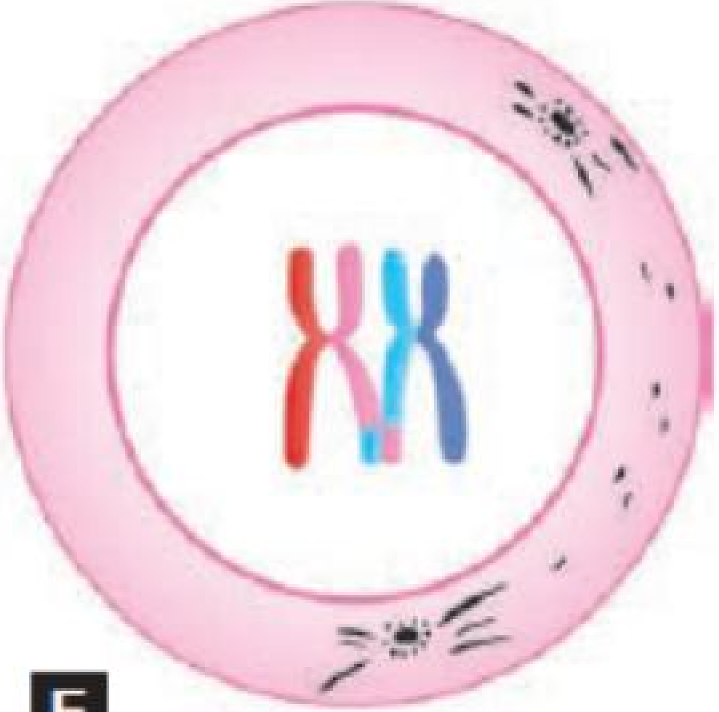
- **Diplotene**
- 2 chromosomes of a bivalent start to move apart
- Chromatids break at points of crossings and loose pieces become attached to the opposite chromatid
- Results in exchange of genetic material between chromatids
- **Diakinesis**.
- Chromosomes condense maximally and the nucleolus disappears, as does the nuclear envelope, freeing the chromosomes into the cytoplasm

➢ DNA recombination

➢ Last for 3weeks in spermatogenesis

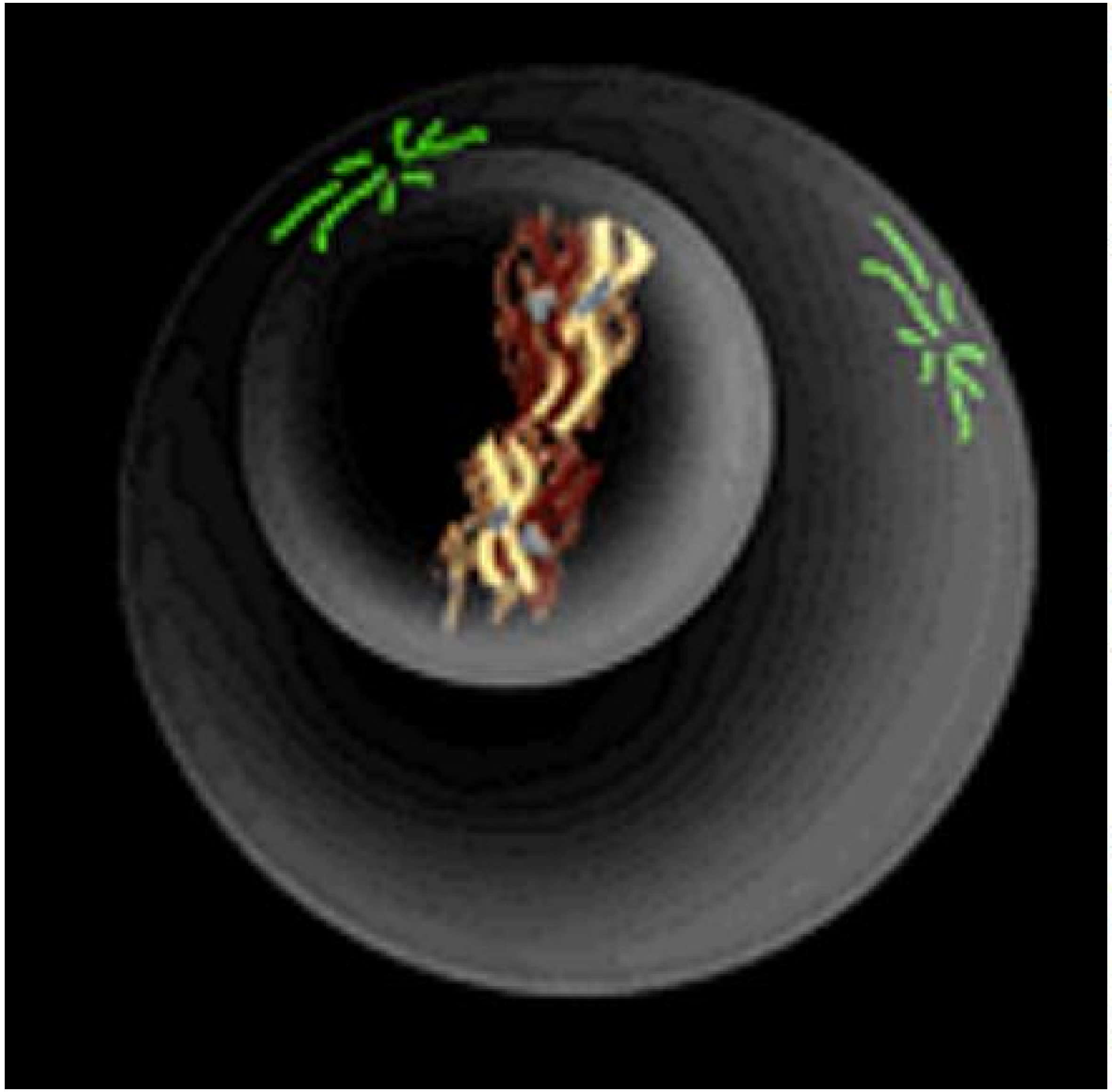
D

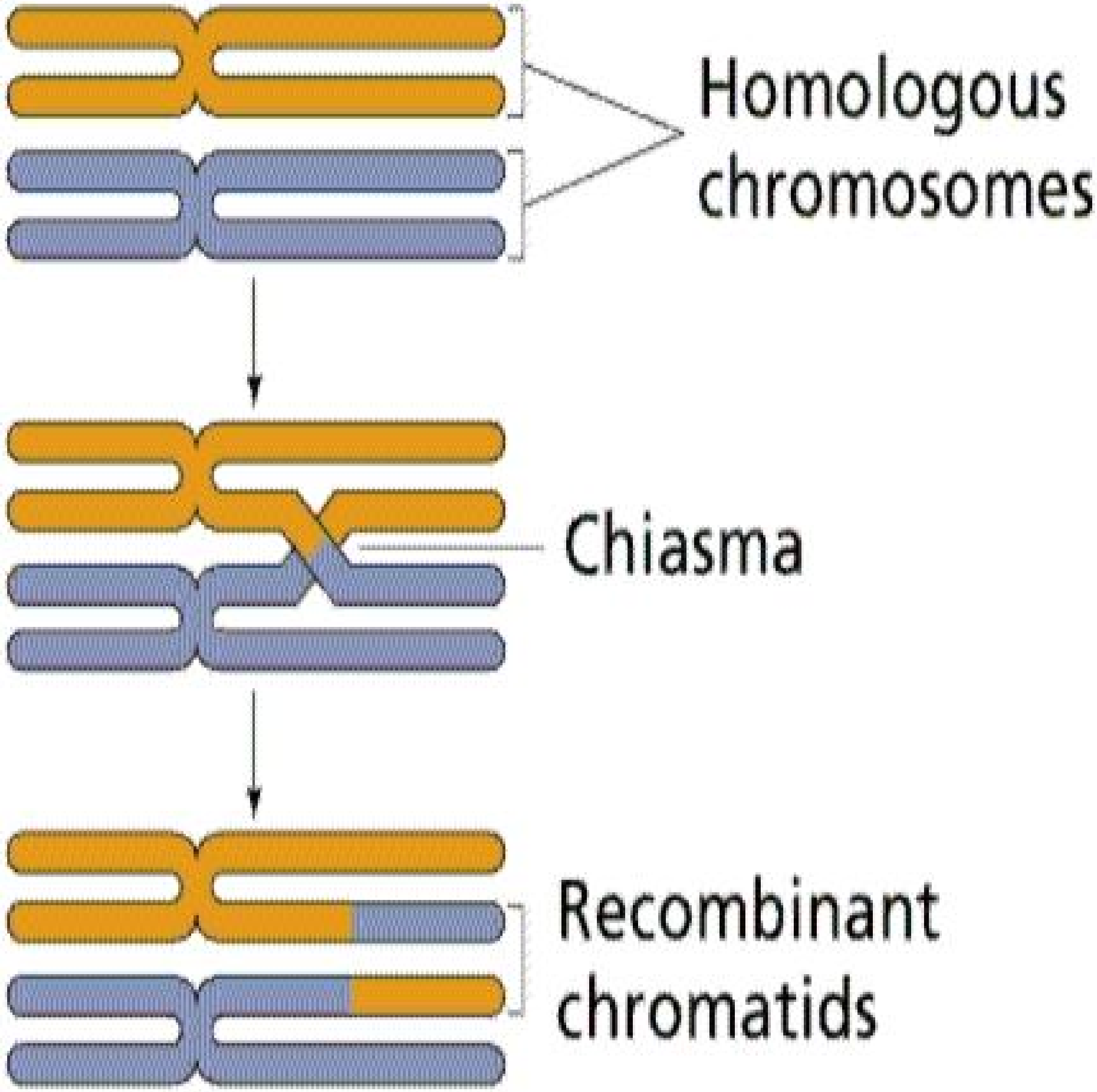
4. The two 'central' chromatids become coiled on each other so that they cross at a number of places. Only one such crossing is shown



E

5. The chromosomes now separate. The 'central' chromatids 'break' at the points of crossing and unite with the opposite chromatid



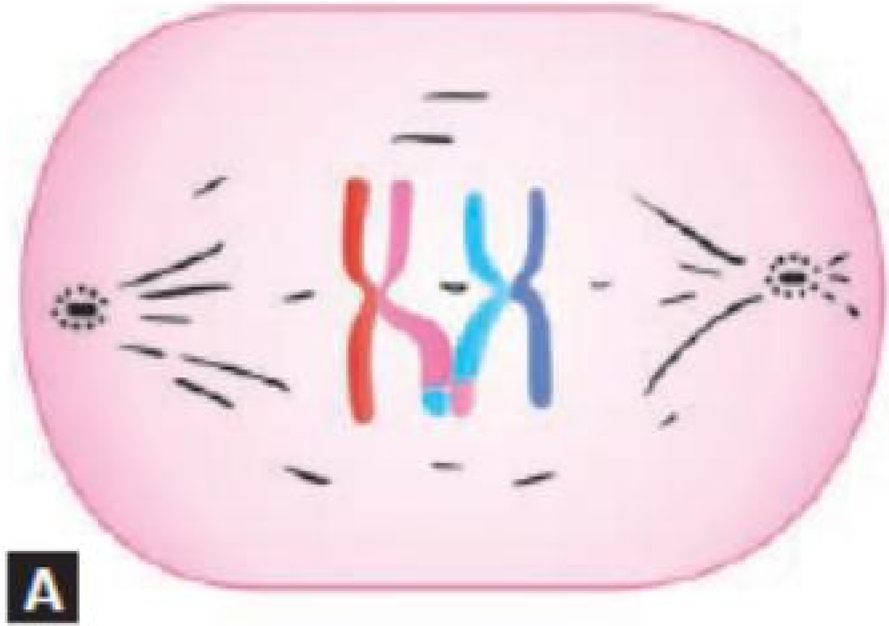

Homologous
chromosomes
Chiasma
Recombinant
chromatids

METAPHASE I

- Chromosomes align at the equator
- Chromosomes attach to the spindles

ANAPHASE I

- The anaphase differs from that in mitosis in that there is no splitting of the centromeres
- One entire chromosome of each pair moves to each pole of the spindle
- daughter cells, therefore, have 23 chromosomes, each made up of two chromatids

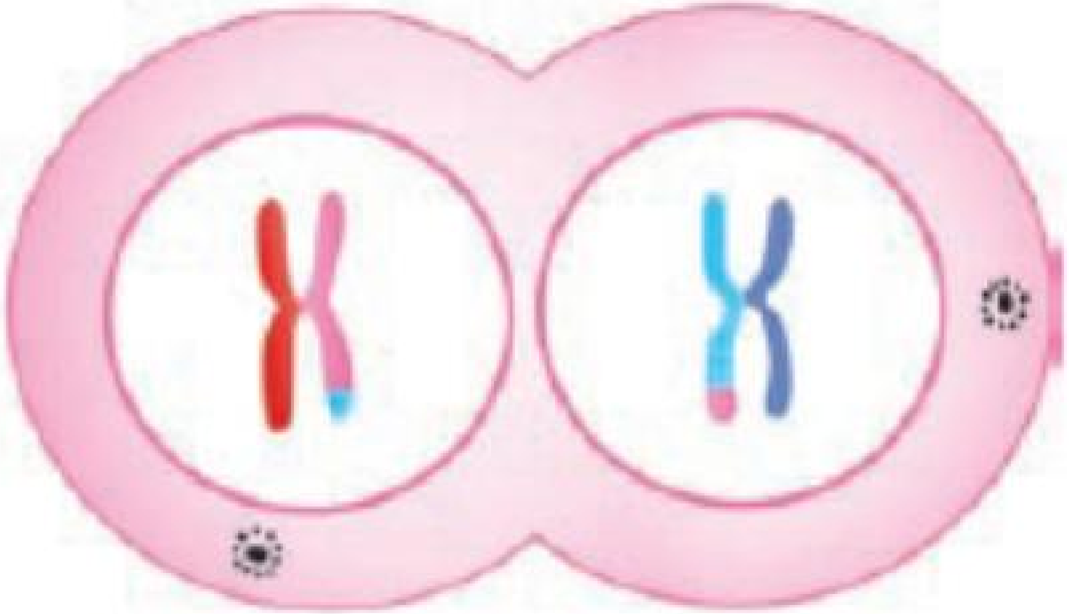


Metaphase
The nuclear membrane disappears. Spindle forms and chromosomes are attached to it by their centromeres.

Anaphase
One entire chromosome of the pair moves to either pole. Note that the centromeres do not divide.

TELOPHASE I

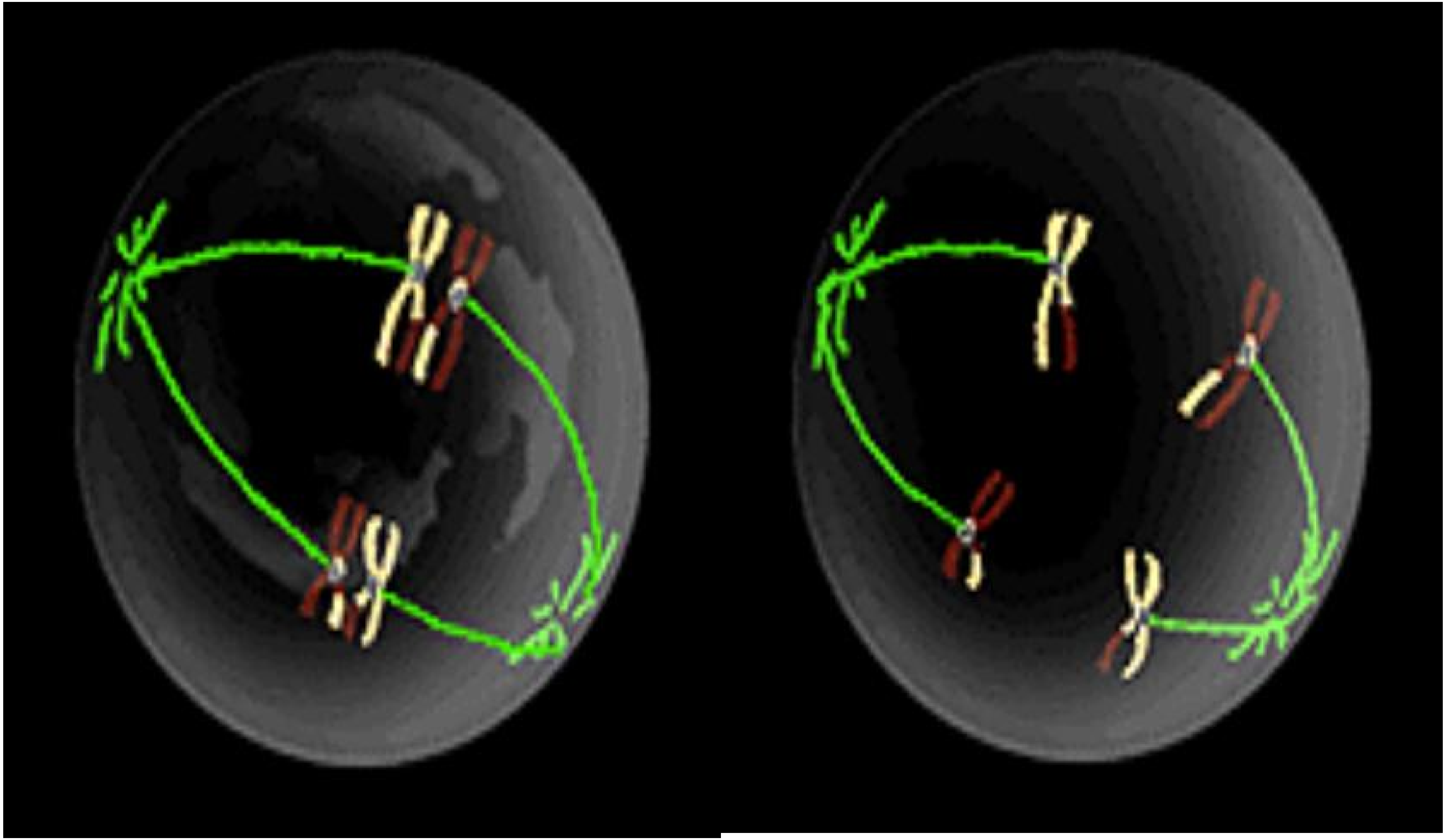
- Cytokinesis
- result in 23 pairs of chromosomes
- Daughter cells are not identical



C

Telophase

Note that the chromosomes in
each cell have been reduced
to the haploid number



Meiosis

<u>**Interphase**</u>

➢No DNA duplication

<u>**MEIOSIS II**</u>

✓similar to mitosis

<u>PROPHASE II</u>

➢Condensation of chromosome

➢Spindle formation

<u>METAPHASE II</u>

➢chromosomes align at the equator

➢spindle fibers attach to the kinetochore

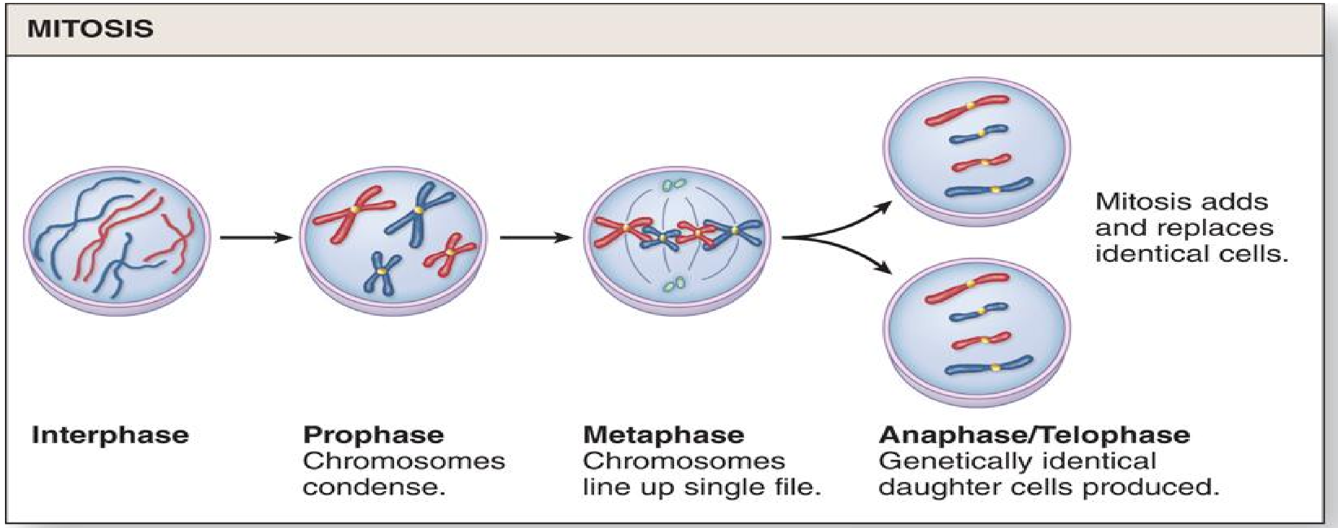
Anaphase II

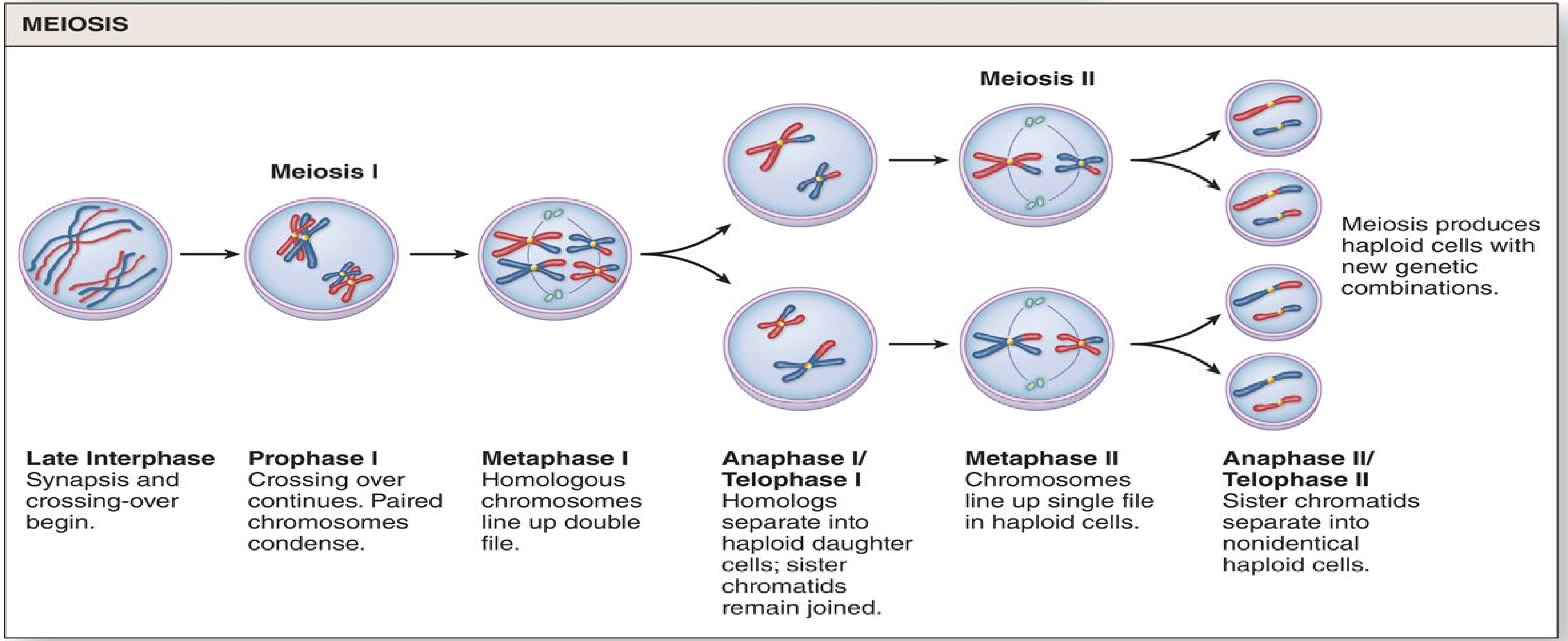
- Sister chromatids pulled to different poles(split at the centromere)

TELOPHASE II

➢Cytokinesis

➢Four different daughter cell produced


MITOSIS
Mitosis adds and replaces identical cells.
Interphase
Prophase
Chromosomes condense.
Metaphase
Chromosomes line up single file.
Anaphase/Telophase
Genetically identical daughter cells produced.


MEIOSIS
Meiosis I
Meiosis II
Meiosis produces haploid cells with new genetic combinations.
Late Interphase
Synapsis and crossing-over begin.
Prophase I
Crossing over continues. Paired chromosomes condense.
Metaphase I
Homologous chromosomes line up double file.
Anaphase I/ Telophase I
Homologs separate into haploid daughter cells; sister chromatids remain joined.
Metaphase II
Chromosomes line up single file in haploid cells.
Anaphase II/ Telophase II
Sister chromatids separate into nonidentical haploid cells.

Importance of meiosis

- Consistency of chromosome number-haploid gametes
- Allow random assortment of maternal and paternal chromosomes
- Shuffles the genes- recombination of genetic material

- ***Significance of Meiosis***
- There is reduction of the number of chromosomes from diploid to haploid.
- At the time of fertilization, the diploid number (46) is restored
- provides consistency of chromosome number from generation to generation

- The 46 chromosomes of a cell consist of 23 pairs, one chromosome of each pair being derived from the mother and one from the father
- During the first meiotic division, the chromosomes are distributed between the daughter cells entirely at random

- the phenomenon of crossing over, results in thorough shuffling of the genetic material so that the cells produced as a result of various meiotic divisions (i.e. ova or spermatozoa); all have a distinctive genetic content

- this process of genetic shuffling takes place at fertilization when there is a combination of randomly selected spermatozoa and ova.
- It is, therefore, not surprising that no two persons (except identical twins) are alike

APOPTOSIS

- Cell suicide
- Release of death promoting factors from MT
- Apoptotic bodies
- Eliminate unneeded cells

IMPORTANCE OF APOPTOSIS

- Death of self antigen T-lymphocytes
- In Ovaries-excess oocytes
- Shaping developing organs

<u>Necrosis</u>

- Cell death due to insults i. e injury

- **Clinical Application**
- **Chromosomal abnormalities**
- May be **numerical** or **structural** causes of birth defects and spontaneous abortions
- Numerical abnormalities
- **Euploid** refers to any exact multiple of *n*, e.g., diploid or triploid
- **Aneuploid** refers to any chromosome number that is not Euploid
- Usually applied when an extra chromosome is present (**trisomy**) or when one is missing (**monosomy**)
- Abnormalities in chromosome number may originate during meiotic or mitotic divisions

- Non disjunction can occur during mitosis in an embryo cell during the earliest cell division
- It produces **mosaicism**
- It is that some cells have abnormal chromosome number and others normal number

- Sometimes a chromosome may break and pieces of one chromosome attach to another

- **TRISOMY 21 (DOWN SYNDROME)**
- usually caused by an extra copy of **chromosome 21 (trisomy 21)**
- Features of children with Down syndrome include:
- growth retardation
- varying degrees of mental retardation
- craniofacial abnormalities
- upward slanting eyes
- epicanthal folds (extra skin folds at the medial corners of the eyes)
- flat facies, and small ears
- cardiac defects; and hypotonia

Figure 1.8 A and **B.** Children with Down syndrome, which is characterized by a flat, broad face, oblique palpebral fissures, epicanthus, and furrowed lower lip. **C.** Another characteristic of Down syndrome is a broad hand with single transverse or simian crease. Many children with Down syndrome are mentally retarded and have congenital heart abnormalities.

- **KLINEFELTER SYNDROME**
- found only in males
- caused by nondisjunction of XX chromosome during gametogenesis
- As a result the chromosomal complement in somatic cells is XXY
- individual is phenotypically a male
- detected at puberty, are sterility, testicular atrophy,
- hyalinization of the seminiferous tubules
- Gynecomastia
- The cells have 47 chromosomes
- with a sex chromosomal complement of the XXY type, and a **sex chromatin body**
- Nondisjunction of the XX homologues is the most common causative event

- **TURNER SYNDROME**
- only monosomy compatible with life
- found only in females
- It occurs due to loss of one X chromosome following nondisjunction of X chromosome during meiosis
- As a result the chromosomal complement in somatic cells is 45XO
- 98% of all fetuses with the syndrome are spontaneously aborted
- The few that survive are mistakenly female in appearance and lack ovaries with a short stature
- Webbed neck, skeletal deformities
- Broad chest with widely spaced nipples
- 80% of these females non disjunction in the male gametes is the cause

(continued from previous page)

Figure 2.12 Patient with Turner syndrome. **A.** At birth. Note the loose skin at the posterior of the neck caused by the remains of a cystic hygroma (fluid-filled cyst), the short neck, malformed ears, and swelling in the hand **B** and the foot **C** caused by lymphedema. **D.** At 6 years of age, the webbed neck is prominent and the nipples are widely spaced

- **Structural Abnormality**
- Involve one or more chromosomes usually result from chromosome breakage
- Breakage may result from environmental factors such as viruses, radiation & drugs
- Sometimes the breakage is lost & will cause abnormality in the affected infant
- Partial depletion of short arm of chromosome 5 causes **cri -du –chat syndrome**
- Affected infants have a cat like cry, microcephaly(small head)
- Intellectual disability and congenital heart disease

- Microdeletion can occur on longarm of chromosome 15
- If the depletion occurs on the maternal chromosome it results in **angelman’s syndrome**
- The children are unable to speak , have intellectual disability, poor motor development , prone to prolonged and unprovoked laughter
- If deletion occurs on the paternal chromosome result is **prader-willi syndrome**
- Affected children have hypotonia , obesity, intellectual disability, hypogonadism and undescended testes

Figure 2.13 Patient with Angelman's syndrome result-