Genetics

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Lecture 2

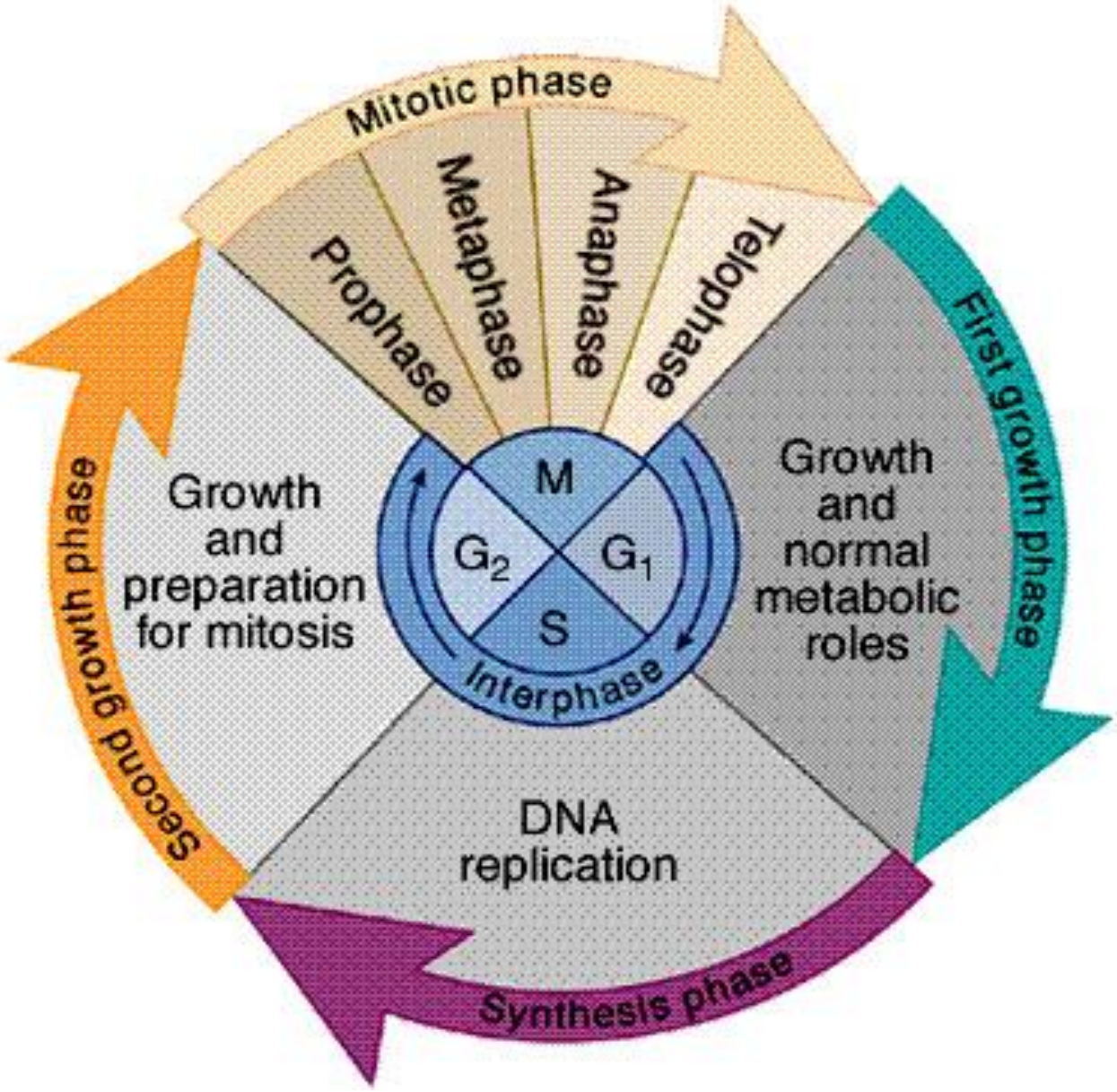
The cell cycle and Cell Division

The cell cycle

- Living cells go through a series of stages known as the cell cycle. They undergo a continuous alternation between division and non-division.
- The period between cell divisions is known as **interphase**. Interphase consists of three phases (**G1** phase, **S** phase, and **G2** phase).
- During interphase, the biochemical activity is devoted to :

  - Cell growth

  - Replication of DNA of each chromosome


Mitotic phase
Prophase
Metaphase
Anaphase
Telophase
First growth phase
Growth and normal metabolic roles
DNA replication
Synthesis phase
Second growth phase
Growth and preparation for mitosis
M
G2
G1
S
Interphase

- Interpahse:

1 - G1 (Gap 1):

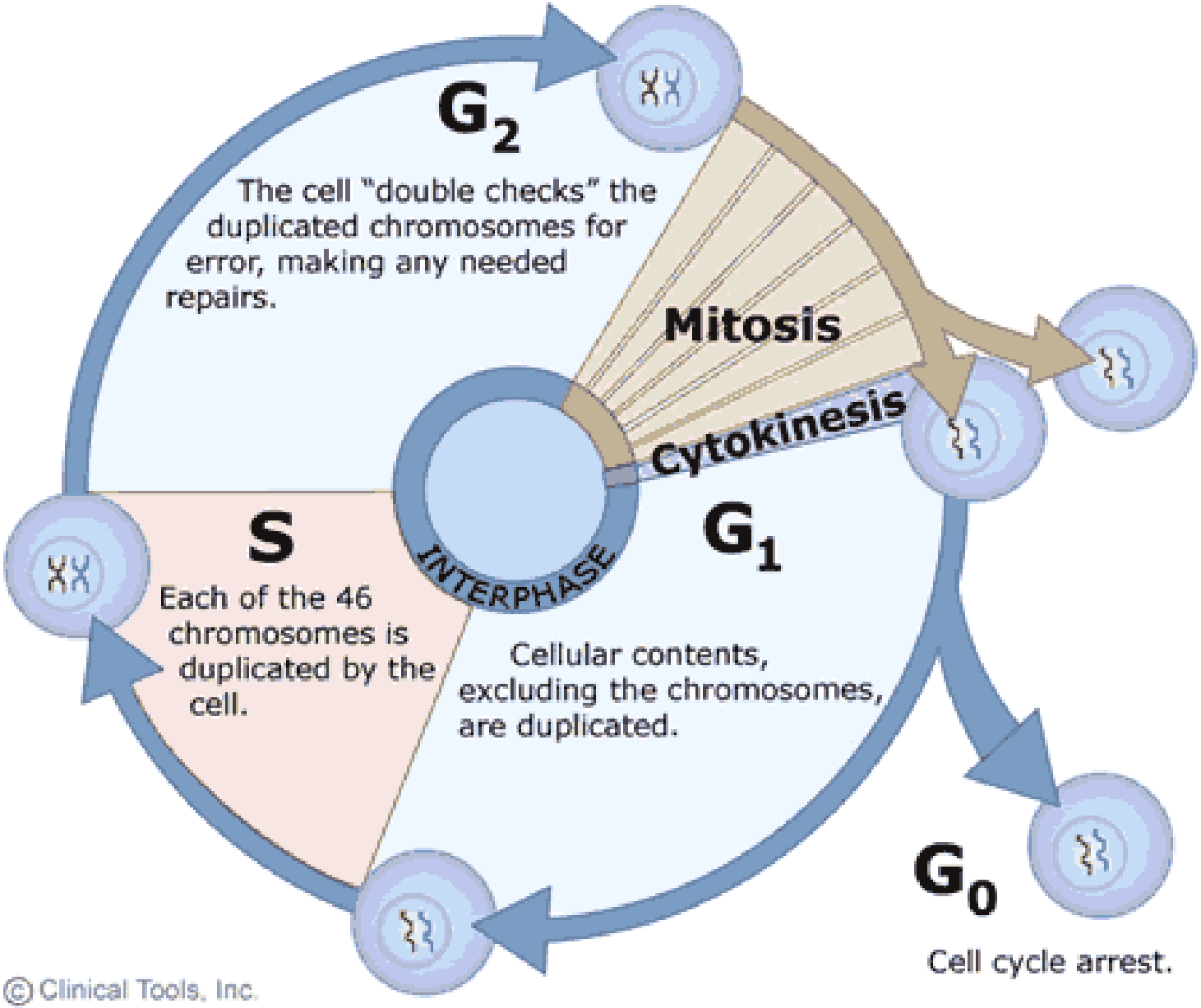
- In this phase the cell grows.
- Synthesis of enzymes necessary in the **S** phase.
- At some point in G1 the cell follows one of two paths: either inter **a resting phase** called **G0** stage (Gap 0) or become committed to initiate DNA synthesis and complete the cycle. The time when this decision is made is called **G1 checkpoint**

2- **S phase:** The period during which DNA is synthesized. The cell makes copies of its chromosomes. Each chromosome now consists of two sister **chromatids**.

3 - G2 (Gap 2):

- Second growth phase.
- The cell checks the duplicated chromosomes and gets ready to divide.
- By the end of **G2** the volume of the cell has roughly doubled, DNA has been replicated and mitosis is initiated.

- M phase (Mitosis): the cell divides into two new cells.


G2
The cell "double checks" the duplicated chromosomes for error, making any needed repairs.
Mitosis
Cytokinesis
INTERPHASE
S
Each of the 46 chromosomes is duplicated by the cell.
G1
Cellular contents, excluding the chromosomes, are duplicated.
G0
Cell cycle arrest.
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Duration of the cell cycle in Human cells (in hours)

It takes about 16 hours

Interphase			Mitosis
G1	S	G2	M
5	7	3	1

Vary among cell types

Consistent among cell types

Duration of phases of Mitosis:

Prophase: 36 minutes

Metaphase: 3 minutes

Anaphase: 3 minutes

Telophase: 18 minutes

Mitosis

- **Mitosis consists of the following stages:**

1. Prophase:

- the centrioles migrate to two opposite sides of the cell.
- spindle fibers start to form
- the nuclear envelope begins to break down and the nucleolus fades.
- Microtubules of the cytoskeleton disassemble.
- The diffuse chromatin (replicated DNA and associated proteins) condenses into chromosomes.
- Each replicated chromosome comprises two chromatids, both with the same genetic information (called sister chromatids).

2. Prometaphase:

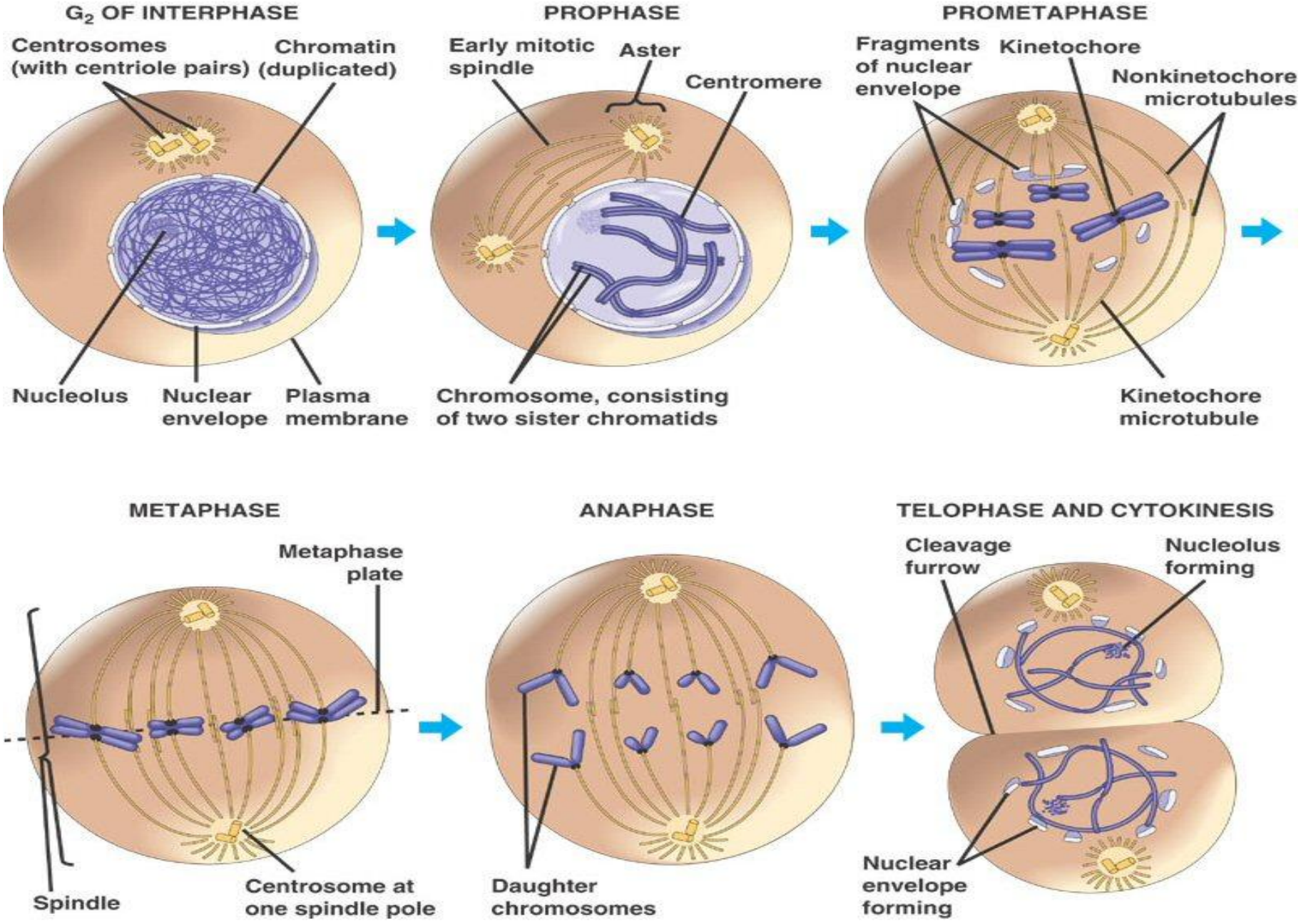
- In this stage the nuclear envelope breaks down so there is no longer a recognizable nucleus.
- Some mitotic spindle fibers (microtubules) elongate from the centrosomes and attach to **kinetochores** (protein bundles at the centromere region on the chromosomes where sister chromatids are joined).
- These microtubules which attach to the kinetochore are called “kinetochore microtubules”.
- Other spindle fibers elongate but instead of attaching to kinetochores, they attach with spindle fibers growing from the other side of the cell. These are called “polar microtubules or non-kinetochore microtubules”.
- the chromosomes start to migrate towards the center of the cell by the kinetochore microtubules

3. Metaphase: all chromosomes align in one plane at the center of the cell called the equatorial plane (also referred to as the metaphase plate).

4. Anaphase: Spindle fibers shorten, the sister chromatids separate (daughter chromosomes), pulled apart towards the opposite cell poles.

5. Telophase :

- The daughter chromosomes arrive at the poles and the spindle fibers that have pulled them apart disappear.
- Cytokinesis of the cytoplasm (division of the cytoplasm) occurs resulting in two identical cells.
- In each new cell, chromosomes begin to uncoil and become diffuse chromatin while a nuclear envelope re-forms arround them.
- The nucleolus gradually re-forms


G2 OF INTERPHASE
Centrosomes (with centriole pairs)
Chromatin (duplicated)
Nucleolus
Nuclear envelope
Plasma membrane
PROPHASE
Early mitotic spindle
Aster
Centromere
Chromosome, consisting of two sister chromatids
PROMETAPHASE
Fragments of nuclear envelope
Kinetochore
Nonkinetochore microtubules
Kinetochore microtubule
METAPHASE
Metaphase plate
Spindle
Centrosome at one spindle pole
ANAPHASE
Daughter chromosomes
TELOPHASE AND CYTOKINESIS
Cleavage furrow
Nucleolus forming
Nuclear envelope forming

Meiosis (reduction division)

- Meiosis produces gametes with only one haploid set of chromosomes (reduction of the number of chromosomes by half)
- Meiosis is divided into two main steps:

1. Meiosis I
2. Meiosis II

Meiosis I

- Prophase I ➔ divided into 5 substages:

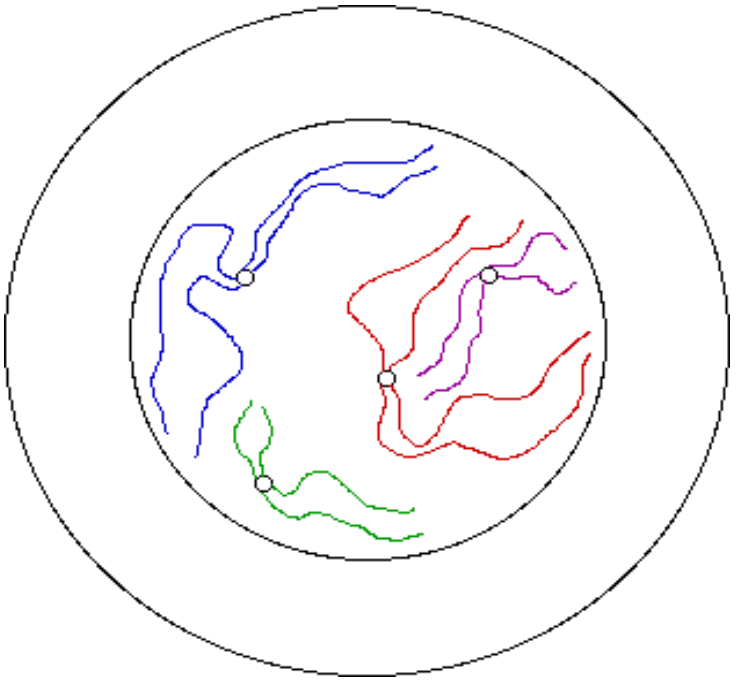
1. Leptonema (Leptotene stage)
2. Zygonema (Zygotene stage)
3. Pachynema (Pachytene stage)
4. Diplonema (Diplotene stage)
5. Diakinesis

- Metaphase I
- Anaphase I
- Telophase I

Prophase 1

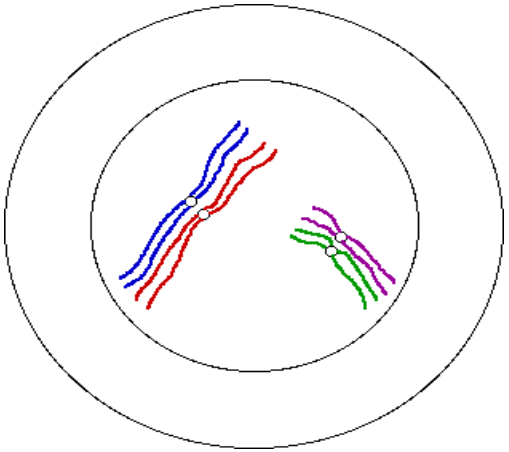
- **Leptonema:** (from Greek words meaning "**thin threads**“)

- Chromtin material begins to condense and the chromosomes become visible
- Each chromosome begins to search its homologue (homology search)



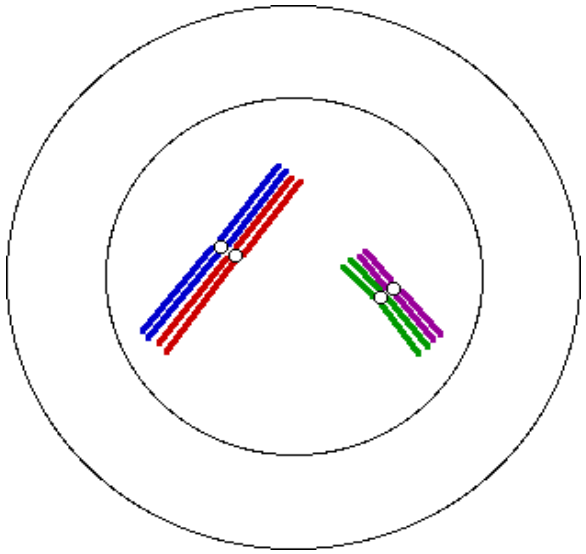
- **Zygonema:** "**paired threads**"

- The chromosomes continue to condense
- Homologous chromosomes find each other and begin to align to each other in a process known as "rough pairing"
- A **synaptonemal complex** starts to form (**synapsis begins**) between the homologs.
- At the completion of zygonema the paired homologs represent structures referred to as "**bivalents**" (also called **tetrads** because each one consists of four chromatids➔ two sister chromatids and two non-sister chromatids)



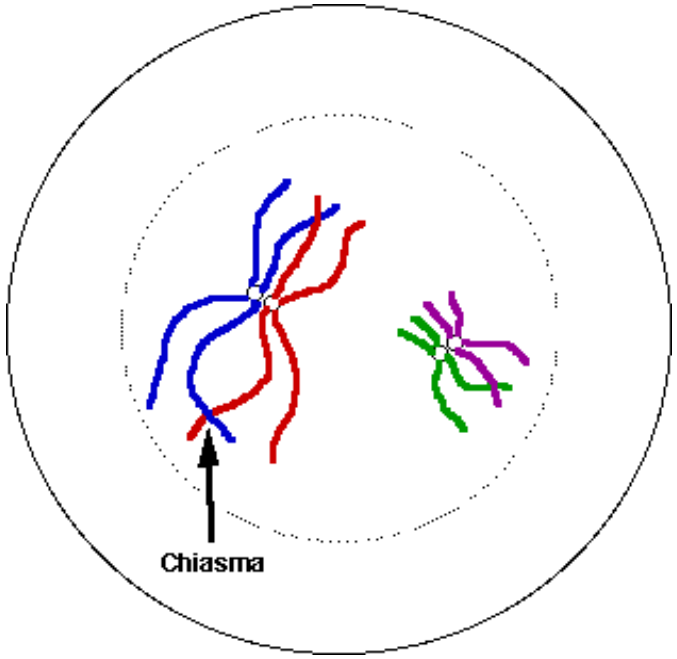
In **pachynema**: "**thick threads**"

- The aligned homologous chromosomes become much more closely associated. This process is known as **synapsis.** (The chromosomes are said to have synapsed)
- The chromosomes continue to condense.
- Crossing-over occurs **(**Exchange of genetic material between non-sister chromatids of homologous chromosomes) between non-sister chromatids but the result of crossing-over is only visible when the chromosomes begin to separate.



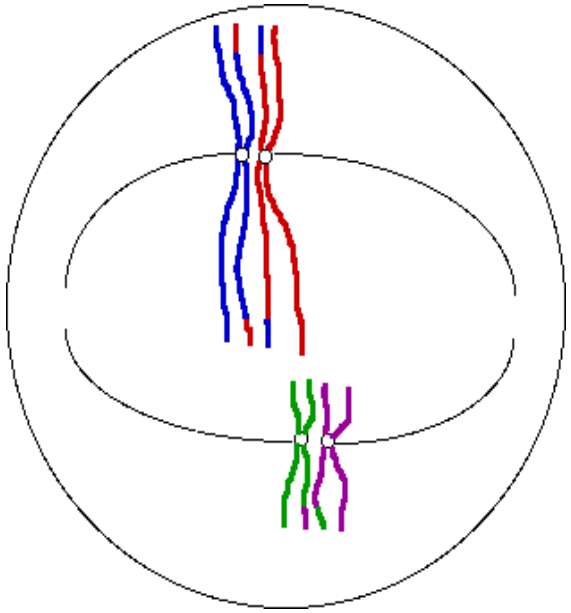
Diplonema: "two threads"

- The homologous chromosomes in each tetrad begin to separate, but they remain connected at points of **crossing over.** Each point of crossing over is known as a **chiasma** (plural: chiasmata).
- Also at this stage, the nuclear envelope begins to break down.



Diakinesis: **"moving through"**

- Is the last stage of prophase I.
- The chiasmata proceed to the end of the chromatids, then separate (terminalization). This leaves chromatids that engaged in crossing over with exchanged genetic material
- The nucleolus and nuclear envelope break down.
- The centromeres of the chromosomes become attached to spindle fibers.



Metaphase I

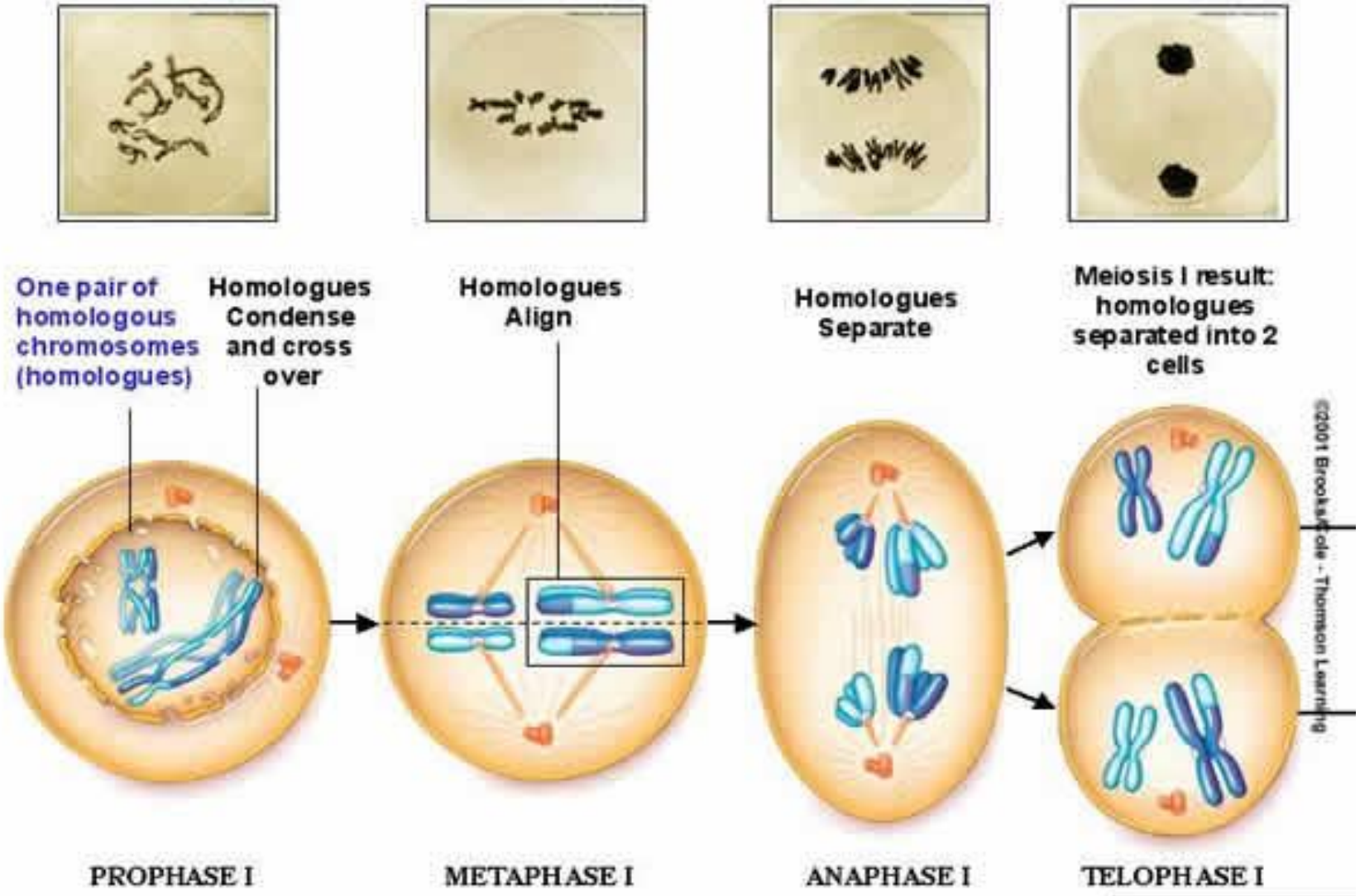
- Chromosomes (bivalents with each one consisting of two chromatids) align at the center of the cell (the metaphase plate)
- A single centromere holds each pair of sister chromatids together.
- The centromere does not divide and the two sister chromatids remain attached (Unlike mitosis where the centromere divides in Anaphase)

Anaphase I

- One-half of each tetrad (one pair of sister chromatids) called a **“dyad”** is pulled towards one pole of the cell **at random**.
- This process is called **disjunction**

Telophase I

- Chromosomes (each consisting of two chromatids) complete their migration to the poles.
- A nuclear membrane forms around each set of dyads.
- Cytokinesis occurs during Telophase I so that two cells are produced each containing half the number of dyads.

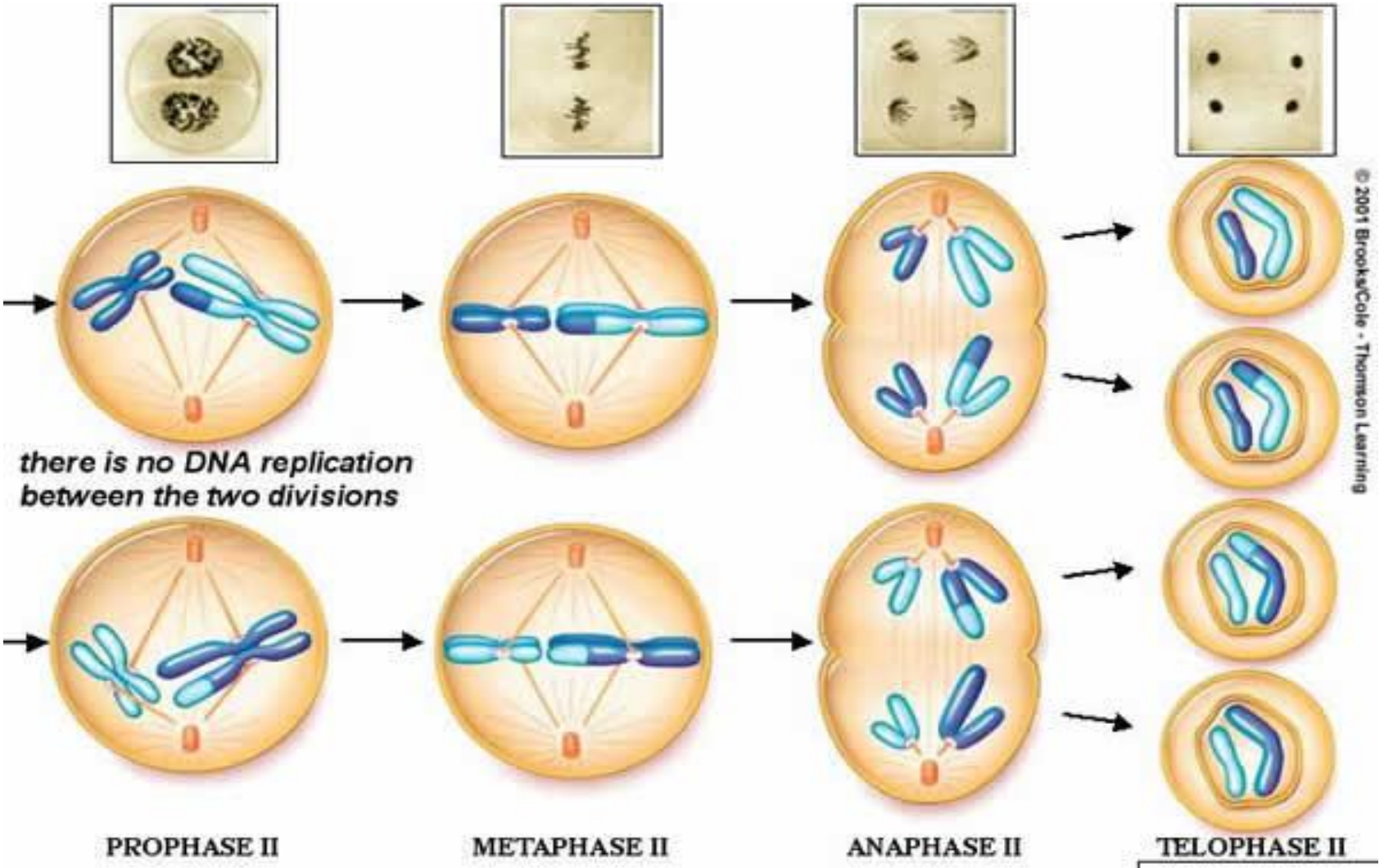


MEIOSIS I: Separate the Homologues

Slide 5

Meiosis II (Similar to mitosis)

- **Prophase II:**
  - each dyad is composed of one pair of sister chromatids attached by one centromere
  - the nuclear membrane that formed during Telophase I breakdown and chromosomes recondense
- **Metaphase II:**
  - the dyads move and align at the center of the cell
  - then the centromere divide
- **Anaphase II:**
  - the sister chromatids of each dyad separate and begin to move towards the opposite poles of each cell
  - each chromatid is now considered a separate chromosome called "**monad**"
- **Telophase II:**
  - nuclear membranes form again and Cytokinesis occurs
  - at the end of Meiosis II, 4 haploid cells are produced from a single cell entering meiosis.



MEIOSIS II: Separate the Sister Chromatids (by mitosis)

Slide 6

Meiosis