The Importance of Cell Division

- **The ability to grow and reproduce are two fundamental qualities of life.**

- During cell division, one cell becomes two new cells.
  - Accomplishes growth and reproduction
  - **Reproduction occurs as binary fission in prokaryotes.**
  - **Growth and some reproduction occurs as mitosis in eukaryotes.**
  - **Reproduction often involves meiosis in eukaryotes.**

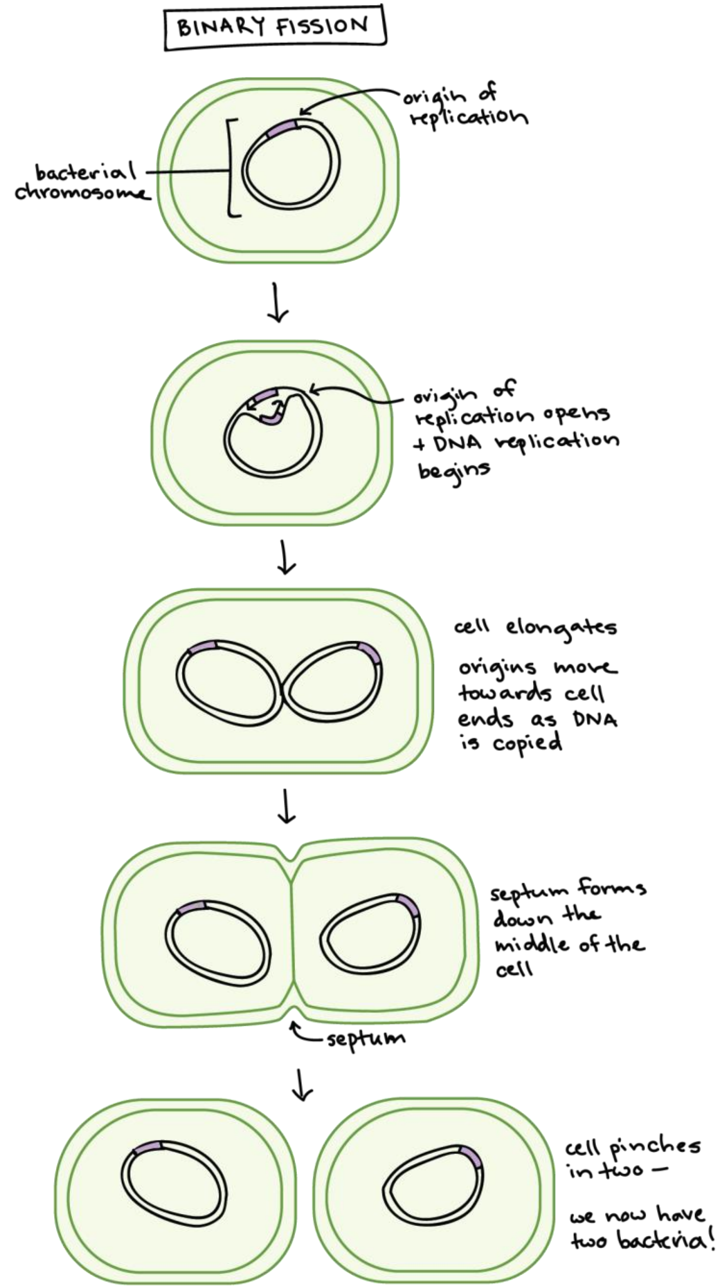
- **All cell division is preceded by DNA replication.**

Uses of Binary Fission and Mitosis

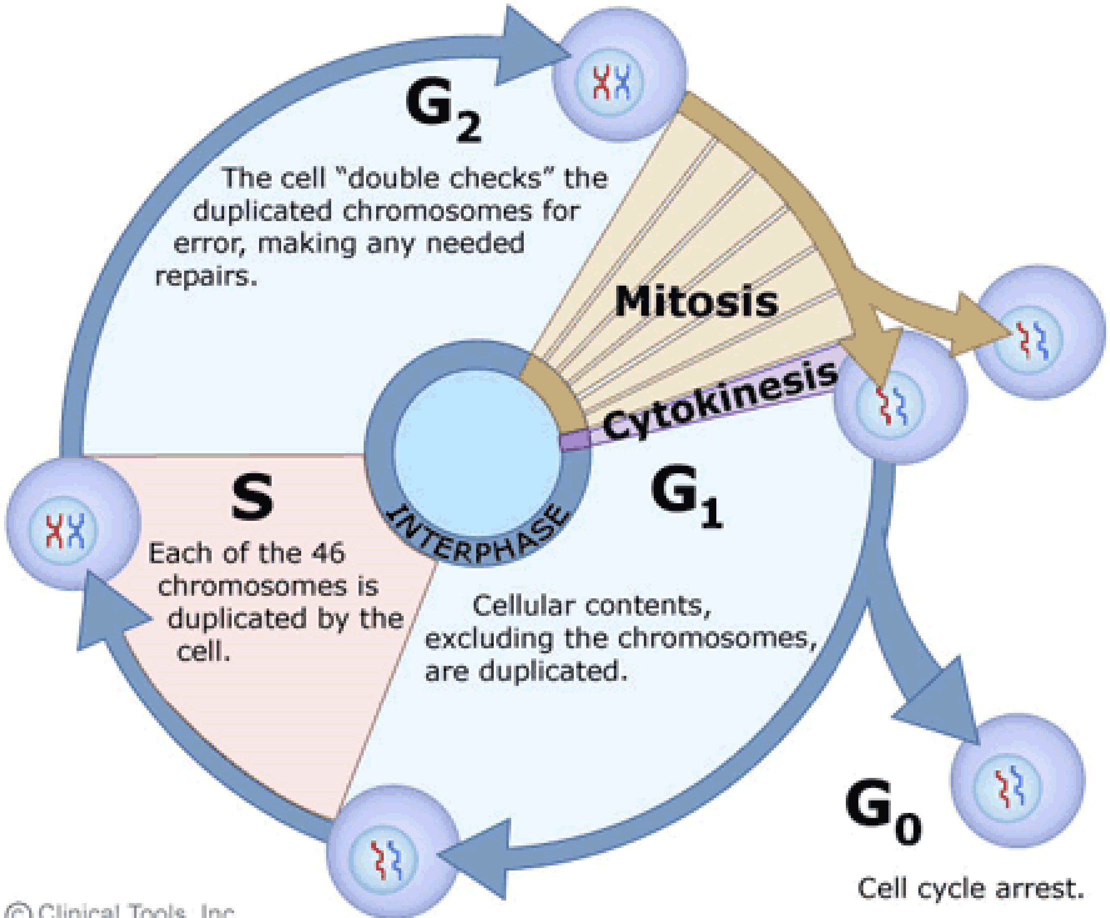
- In **single-celled organisms**
  - **Mitosis and binary fission** are means of **asexual reproduction.**
- In **multi-cellular organisms**

Mitosis:

- Causes **growth by increasing the number of cells**
- **Replaces lost cells**
- **Repairs injuries**



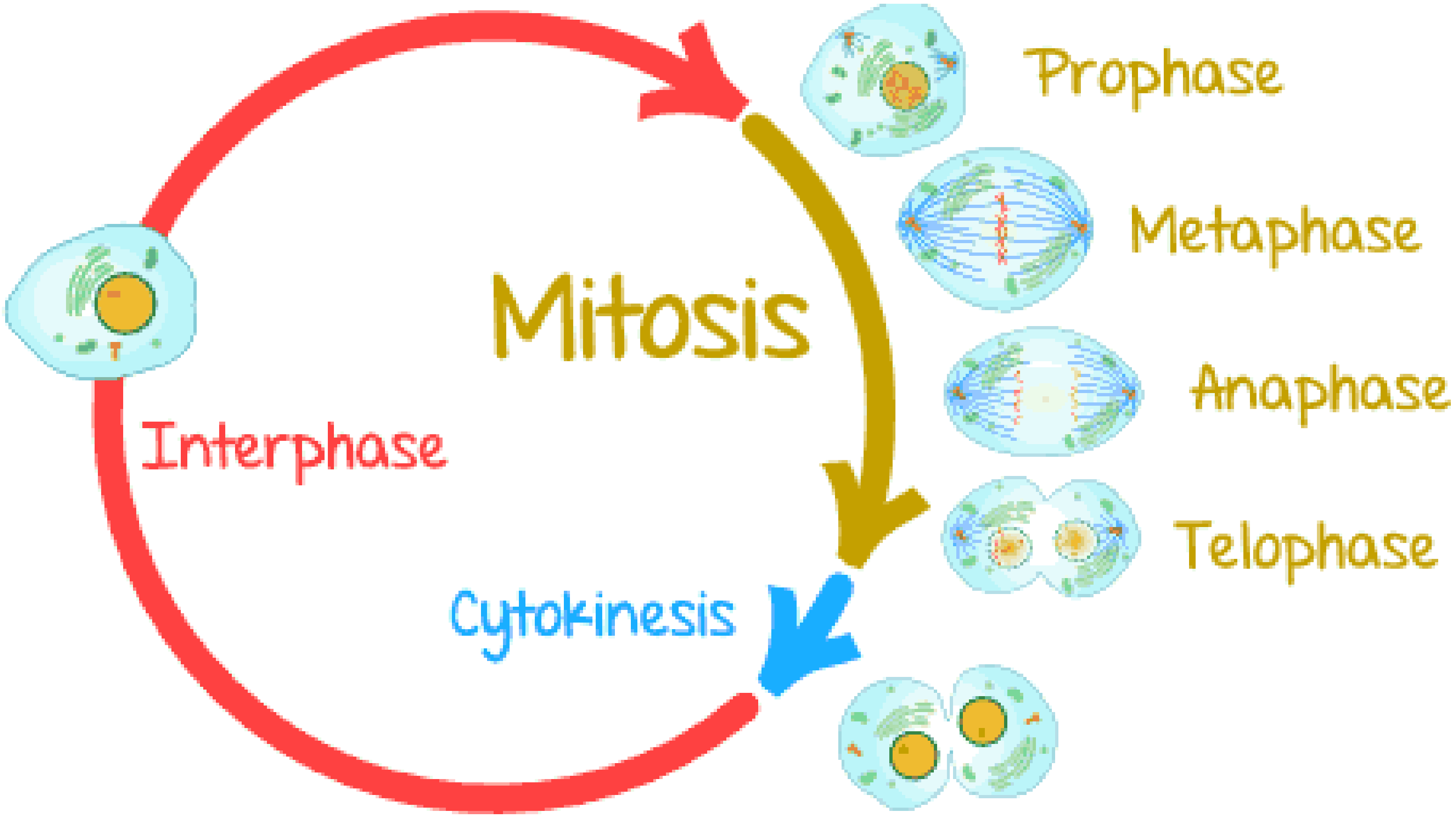
The Cell Cycle



G_0: **(Resting phase)**
Growth to adult size and differentiation. Nerve cells, muscle cells, and some other cells stop dividing.

Eukaryotic cells

- Pass through different stages between the time they are "born" and the time they divide again
- A continuous process
- **Includes interphase and mitosis.**

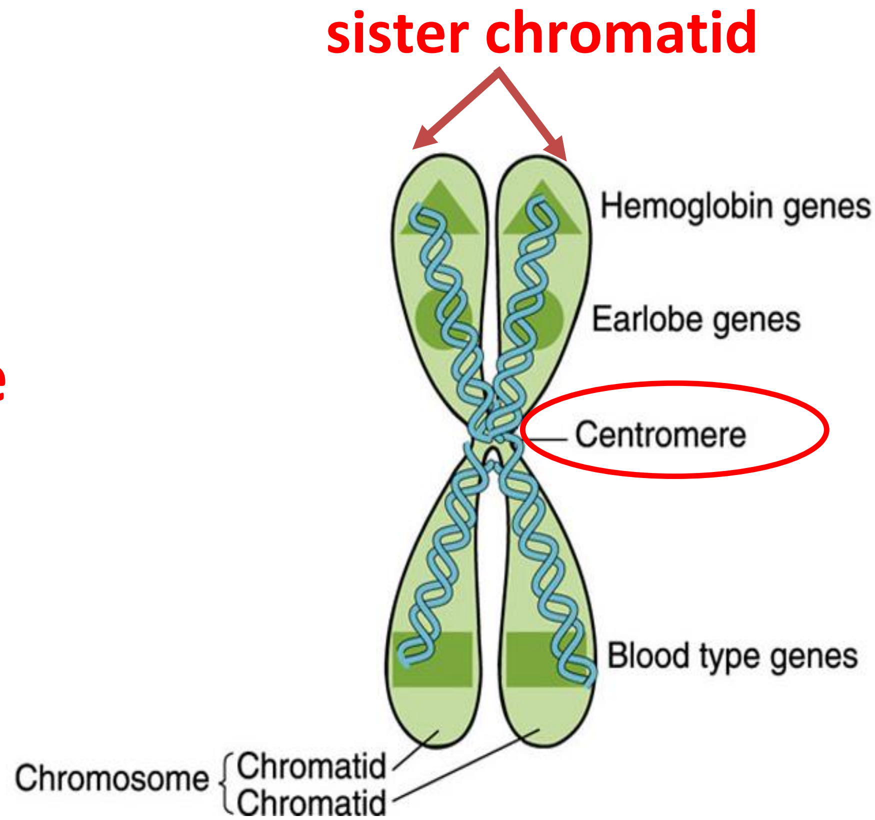

Prophase
Metaphase
Mitosis
Anaphase
Interphase
Telophase
Cytokinesis

Interphase-G_1

- The three phases of interphase
  - **G_1 Phase**
    - The cell **gathers nutrients**, carries out its regular metabolic roles, and performs its normal function.
    - **Cells grow**
    - **Commits to divide**
    - Some cells never divide; they stay in G_1, called **G_o**.
    - **Prepares for DNA replications**

Interphase-S

- **S Phase**
  - DNA replication occurs.
  - When S phase is complete
    - **The identical copies are connected together.**
    - Each is called a **sister chromatid.**
      - Connected at the **centromere**



Interphase-G_2

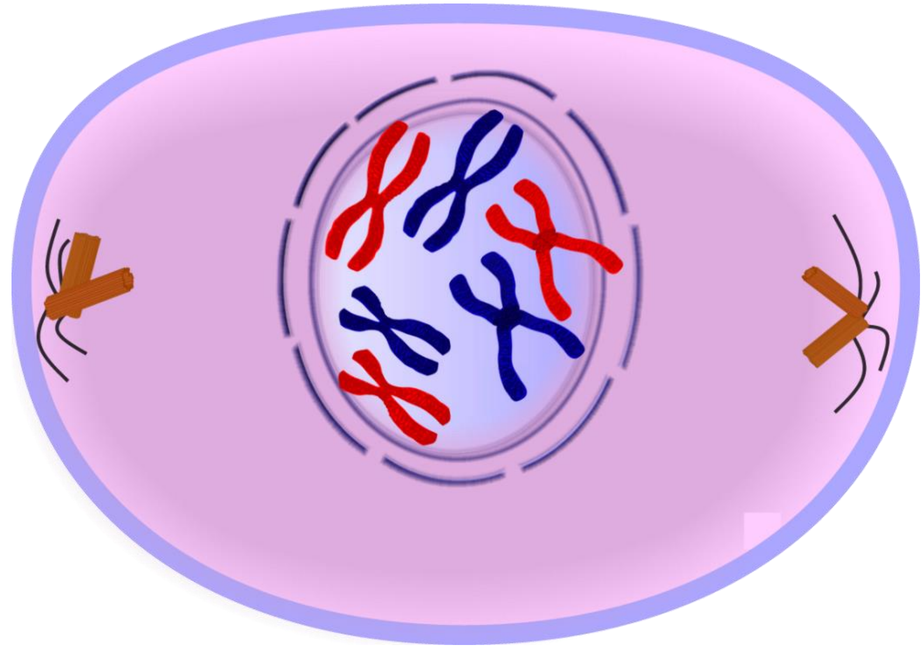
- G_2 Phase
  - Final preparations are made for mitosis.
  - Proteins are made that will be needed in Mitosis.
  - Centrioles are duplicated
  - Repairs errors (if any) of duplicated DNA

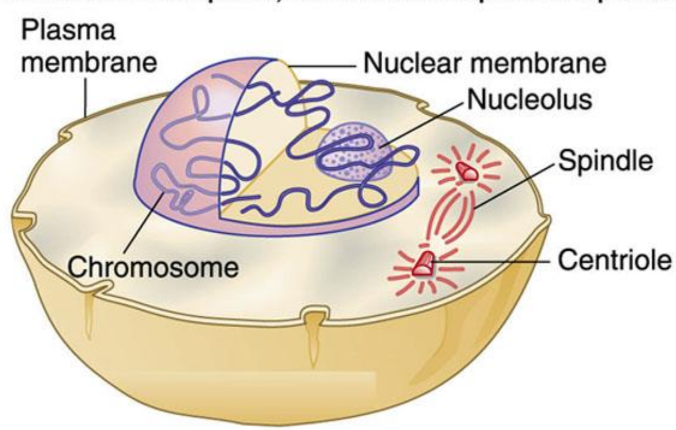
Mitosis

- The **two events of cell division**
  - **Mitosis**
    - **Separating the chromosome copies into two new nuclei**
    - **Occurs in four phases that are continuous with one another**
  - **Cytokinesis**
    - **Dividing the cytoplasm into two new cells that will house the new nuclei**

Prophase

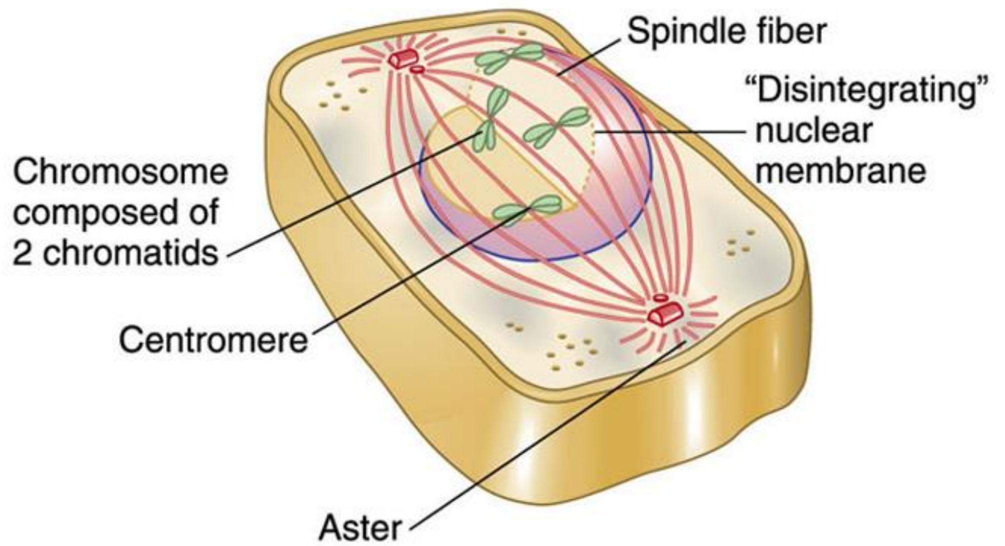
- The thin, tangled chromatin gradually coils and thickens.
  - Becomes visible as separate chromosomes, each with two sister chromatids
- Nucleus disassembles.
- Nucleolus is no longer visible.
- Spindles made of microtubules start to appear from centrioles in animal cells



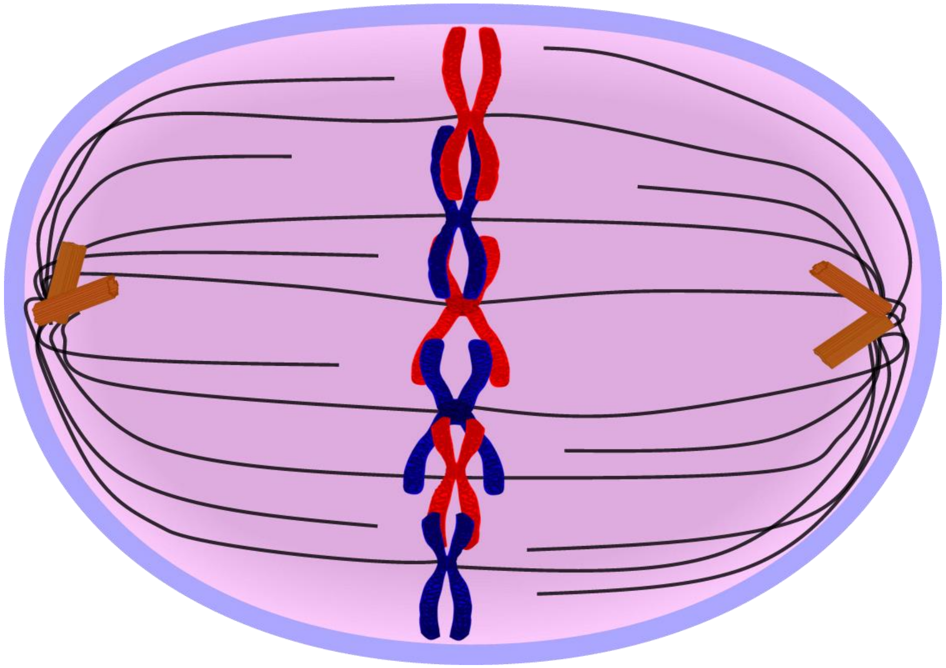


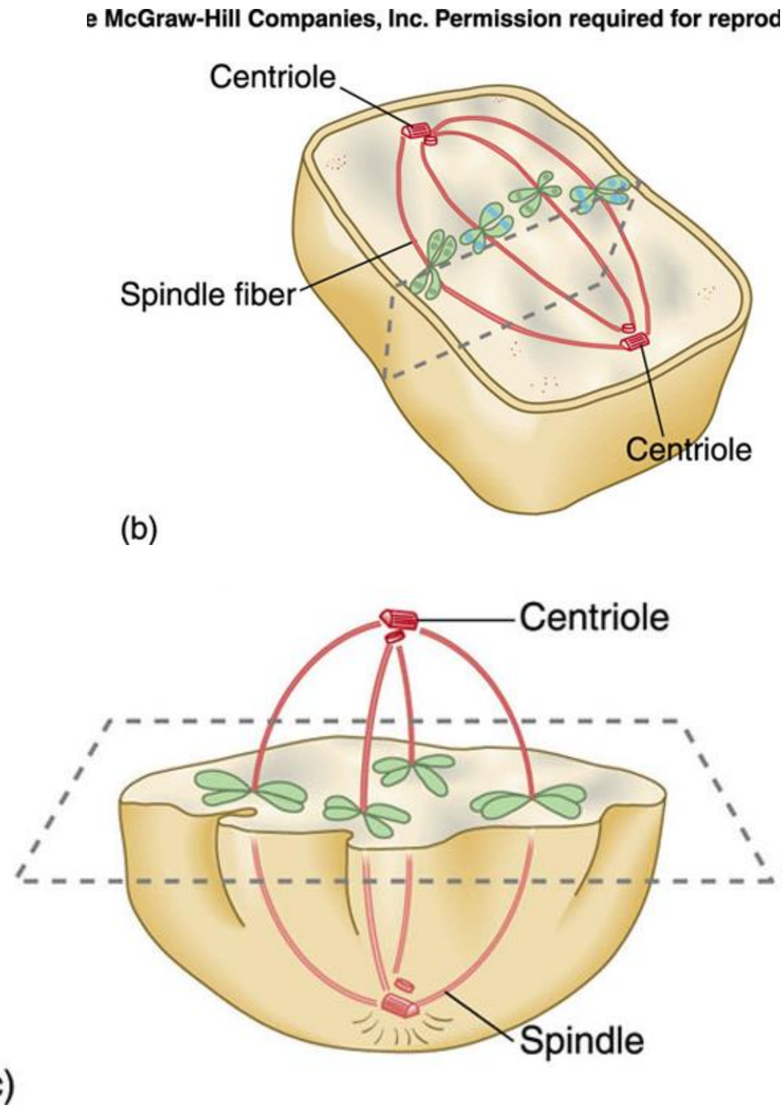
Late Prophase

- **Spindle fibers extend completely across the cell and attach to chromosomes at their centromeres.**
  - Spindles are made of **microtubules**. In animals, they are **formed from the centrioles**.
  - **Asters** (a radial array of microtubules towards the plasma membrane)form only in animal cells.
  - **Spindles move chromosomes around**.



Metaphase

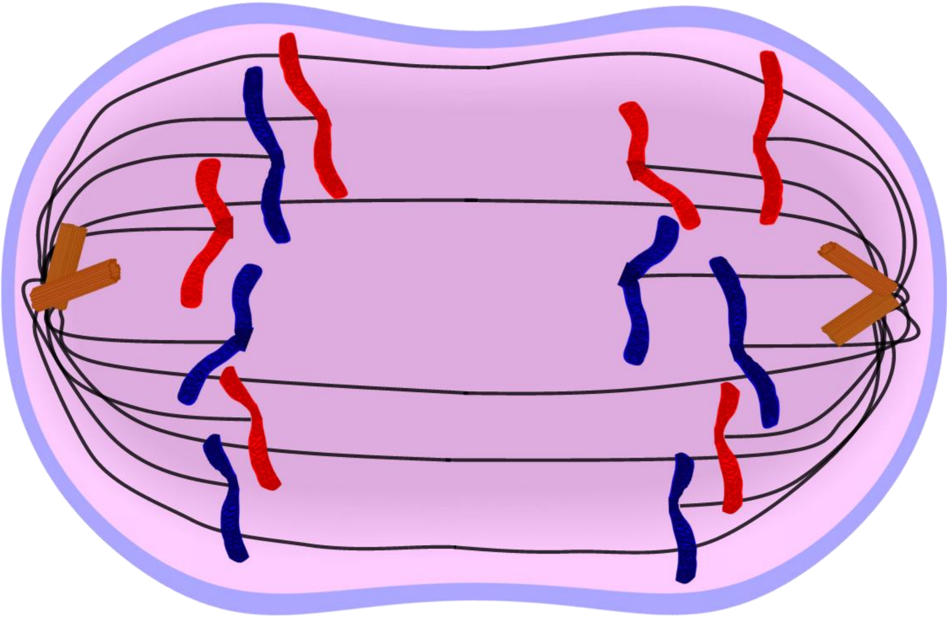


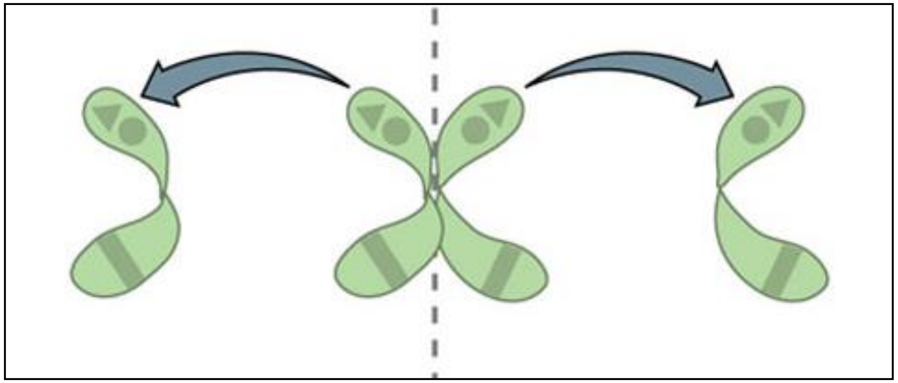


The spindle fibers move the chromosomes so that they are all arranged at the **middle of the cell**, called the **equatorial plate**

Anaphase

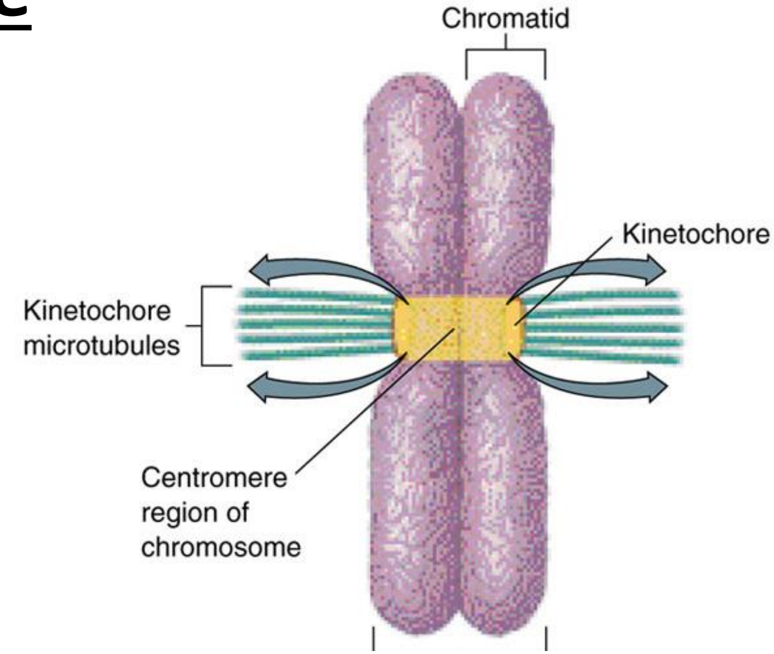
- **Sister chromatids separate and move toward opposite poles.**
  - **Once the sister chromatids are separated, they are known as daughter chromosomes.**

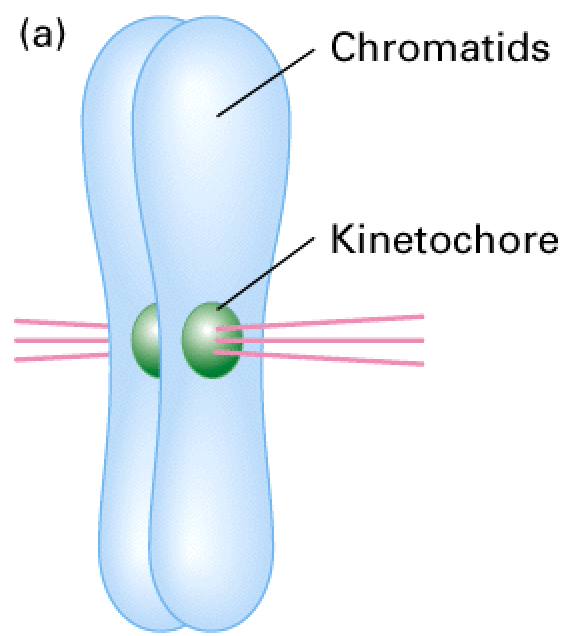




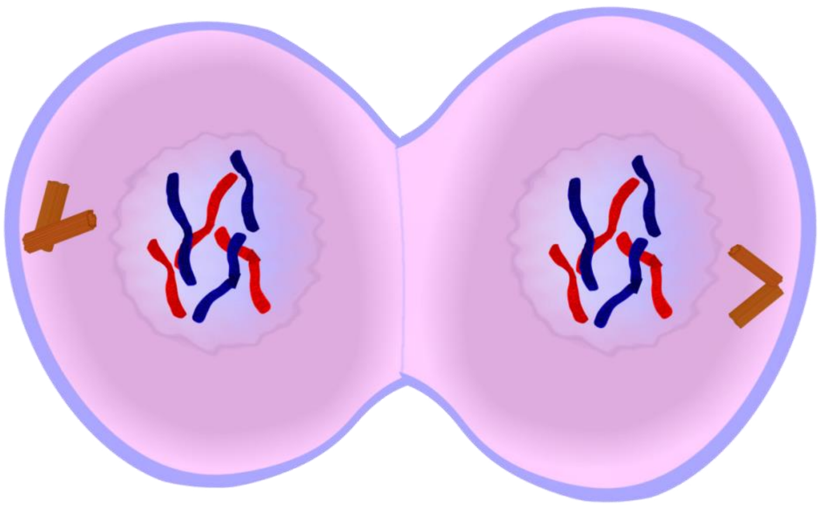
kinetochore

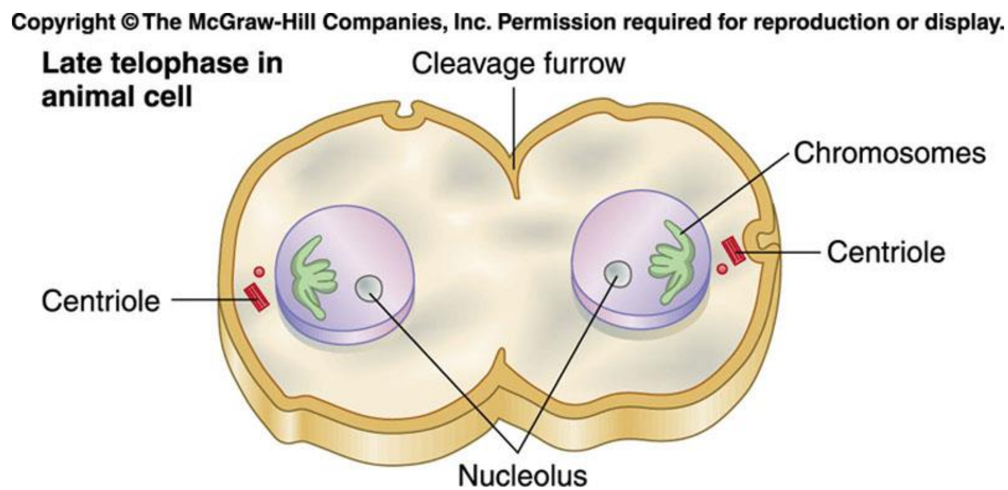
- **What moves the sister chromatids to opposite poles?**
  The poles begin to move farther apart.
  The kinetochore (proteins attached at the centromere) pulls the sister chromatid along the spindle fiber.





Telophase



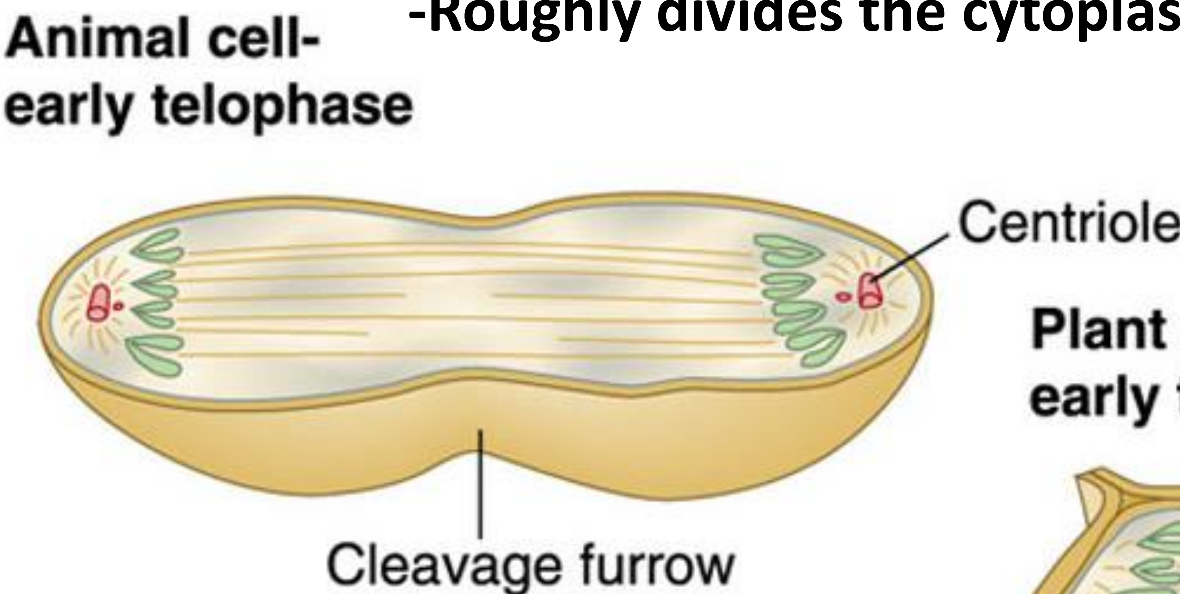


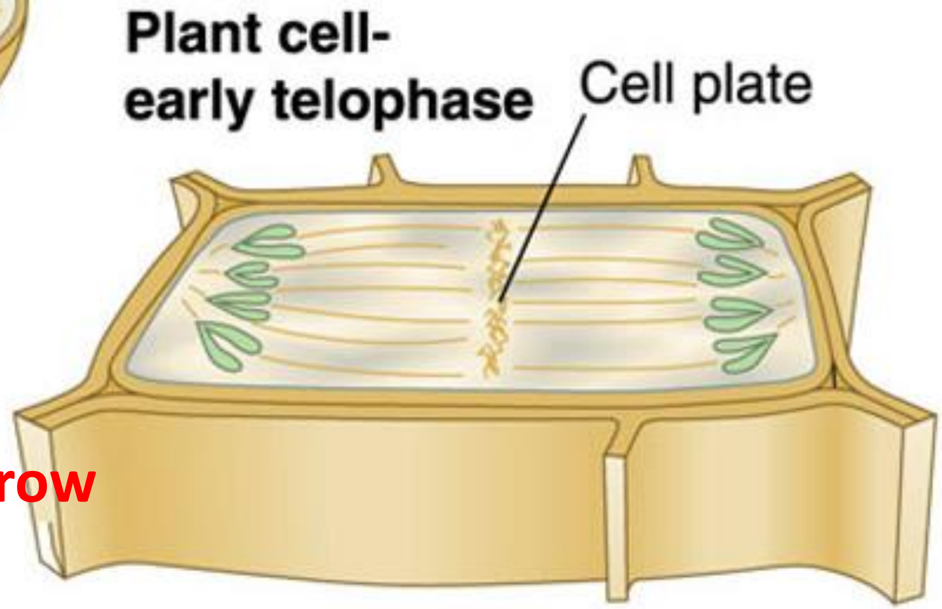
- Spindle fibers disassemble.
- Nuclear membranes form around the two new sets of chromosomes
- Chromatin uncoils.
- Nucleolus reforms.
- Cells begin cytokinesis.

Cytokinesis

-Separates the two new nuclei into new cells

-Roughly divides the cytoplasm and its contents in half





Animal cells

Membrane forms a **cleavage furrow**

Cell pinches into two

Plant cells

Cell plate is formed.

A new **cell wall** is built, separating the nuclei

Genes Regulate the Cell Cycle

- Cells use several **proteins to function as checkpoints.**
- Two classes of genes that code for checkpoint proteins
  - **Proto-oncogenes**
    - Code for proteins that **encourage cell division**
  - **Tumor-suppressor genes**
    - Code for proteins that **discourage cell division**

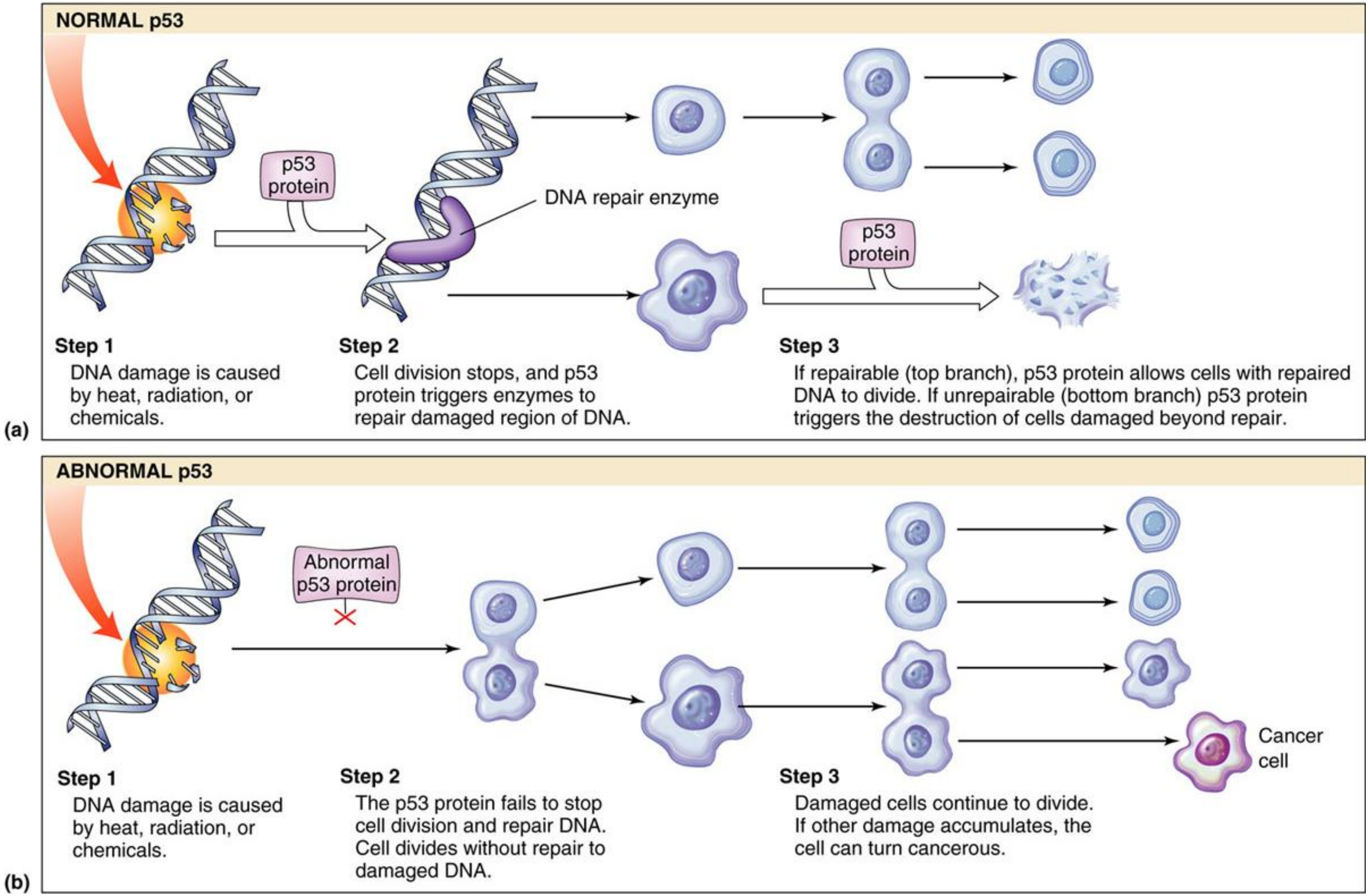
- **The balance of these two types of proteins tells the cell whether or not to proceed with cell division.**

p53, a Tumor-suppressor Gene

- Near the end of G_1, the p53 protein identifies if the cell's DNA is damaged.
  - If the **DNA is healthy, the p53 allows the cell to divide.**
  - If the **DNA is damaged**, p53 activates other proteins that will **repair the DNA.**
    - If the **damage is too severe**, p53 will trigger the events of **apoptosis (cell suicide).**

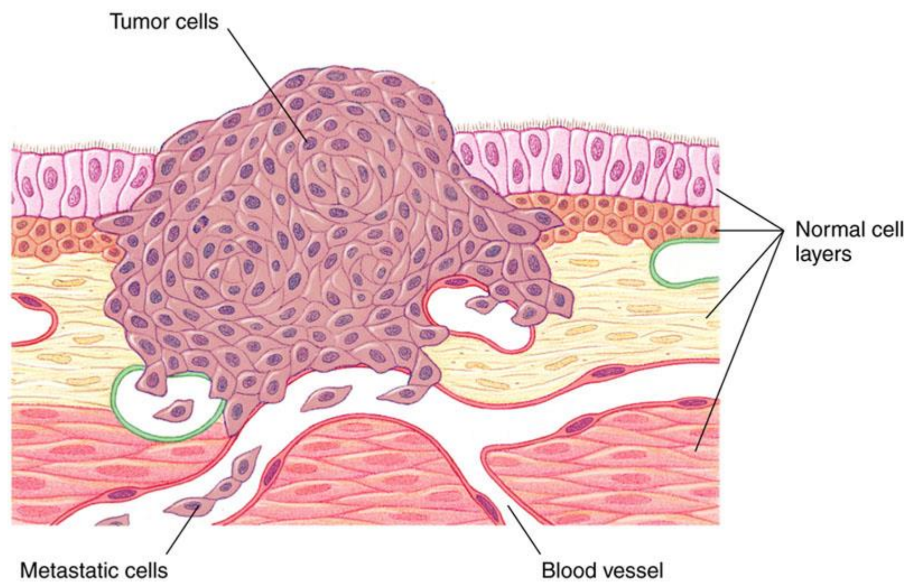
- **Mutations in the p53 gene**
  - **Lead to cells that will proceed through the cell cycle with damaged DNA**
  - Lead to an **accumulation of mutations**
    - **If the mutations occur in proto-oncogenes or tumor-suppressor genes, then cancer will result.**

p53, a Tumor-suppressor Gene



Cancer

- Cancer is caused by a failure to control cell division.
  - Leads to cells that divide too frequently
  - These cell masses are tumors that can interfere with normal body functions.



Benign tumors are cell masses that do not fragment and spread

Malignant tumors are cell masses that fragment, spread and invade other tissues. This process is called **metastasis.**

p53 is mutated in 40% of all cancers. Leads to other mutations that result in cancer

Causes of Cancer:

- Mutagens are agents that damage DNA.
- Carcinogens are mutagens that cause mutations that lead to cancer.
  - Cigarette smoke has been linked directly to p53 mutations

Treatment Strategies – Surgery

- **Surgical removal**
  - Once tumors are identified they can be surgically removed.
  - **Skin cancers and breast cancers are frequently treated this way.**
  - If the cancer is spread diffusely, surgery is not an option.

Treatment Options – Chemotherapy and Radiation Therapy

- Chemotherapy
  - Some **drugs** will target **rapidly dividing cells**.
  - Normal cells that divide rapidly will suffer as well.
    - Weakens the immune system
    - Causes hair loss

- Radiation therapy
  - Uses **x-rays** or **gamma rays directed at the tumor to kill the cancerous cells**
  - **Whole-body radiation** is used to treat **leukemia.**
    - Can lead to radiation sickness
      - Nausea, hair loss, etc.

Uses of Meiosis

- **Sexual reproduction involves the donation of genetic information from two parents.**
  - **Each parent can only donate half of the genome.**

- **Meiosis occurs prior to sexual reproduction.**
  - **Generates gametes (egg and sperm) with half of a genome**
  - **The egg and sperm then join during fertilization to make a unique offspring with a full complement of genetic information.**

Cell Division and Sexual Reproduction

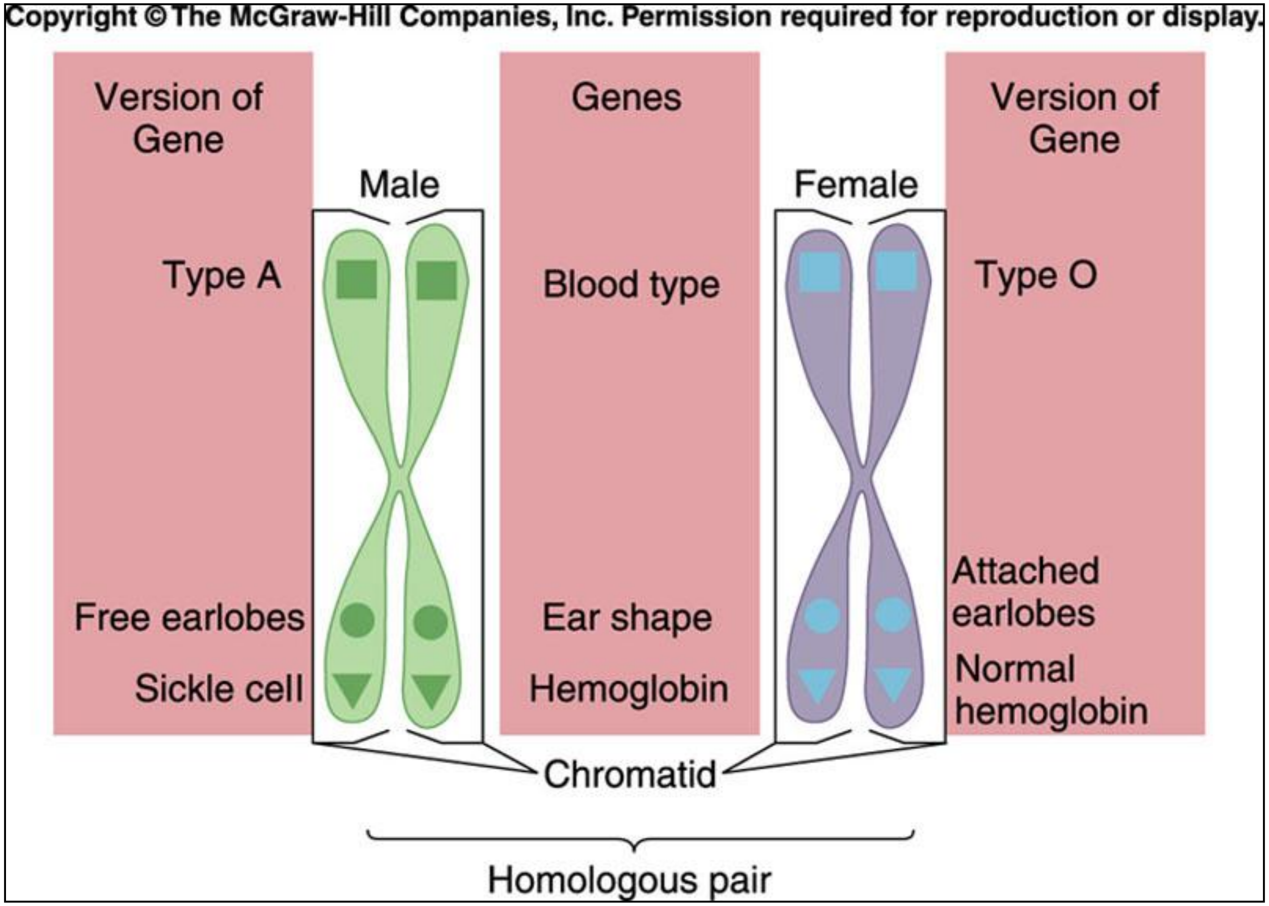
- **Somatic cells** have **two sets of chromosomes**: **Diploid**
- **Gametes** have **one set of chromosomes: Haploid**
- **Meiosis makes haploid gametes.**
  - **Eggs** are made in ovaries (animals) and pistils (plants).
  - **Sperm** are made in testes (animals) and anthers (plants).
  - When **egg and sperm join during fertilization**, the **zygote receives half of its chromosomes from the egg and half from the sperm.**

A Pair of Homologous Chromosomes

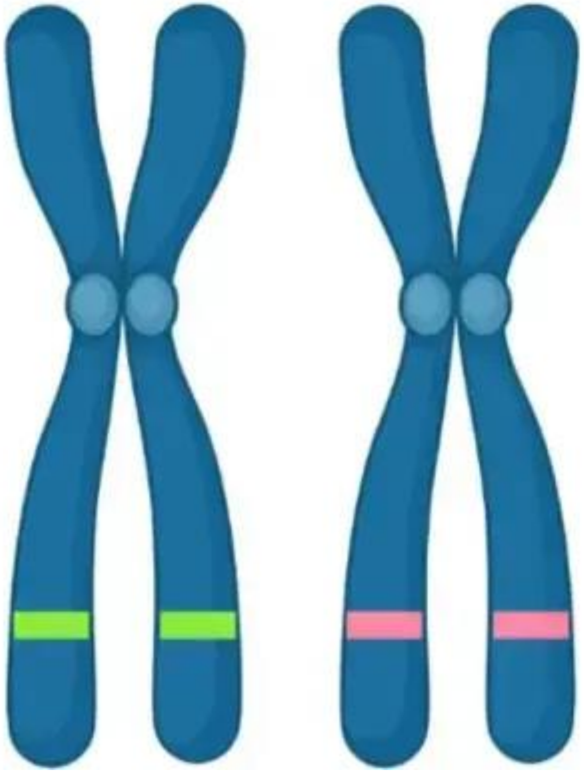
Homologous chromosomes

- Have the same order of genes** along their DNA
- Are of the same size; have the centromere in the same location
- One chromosome in the pair came from mom; the other came from dad.

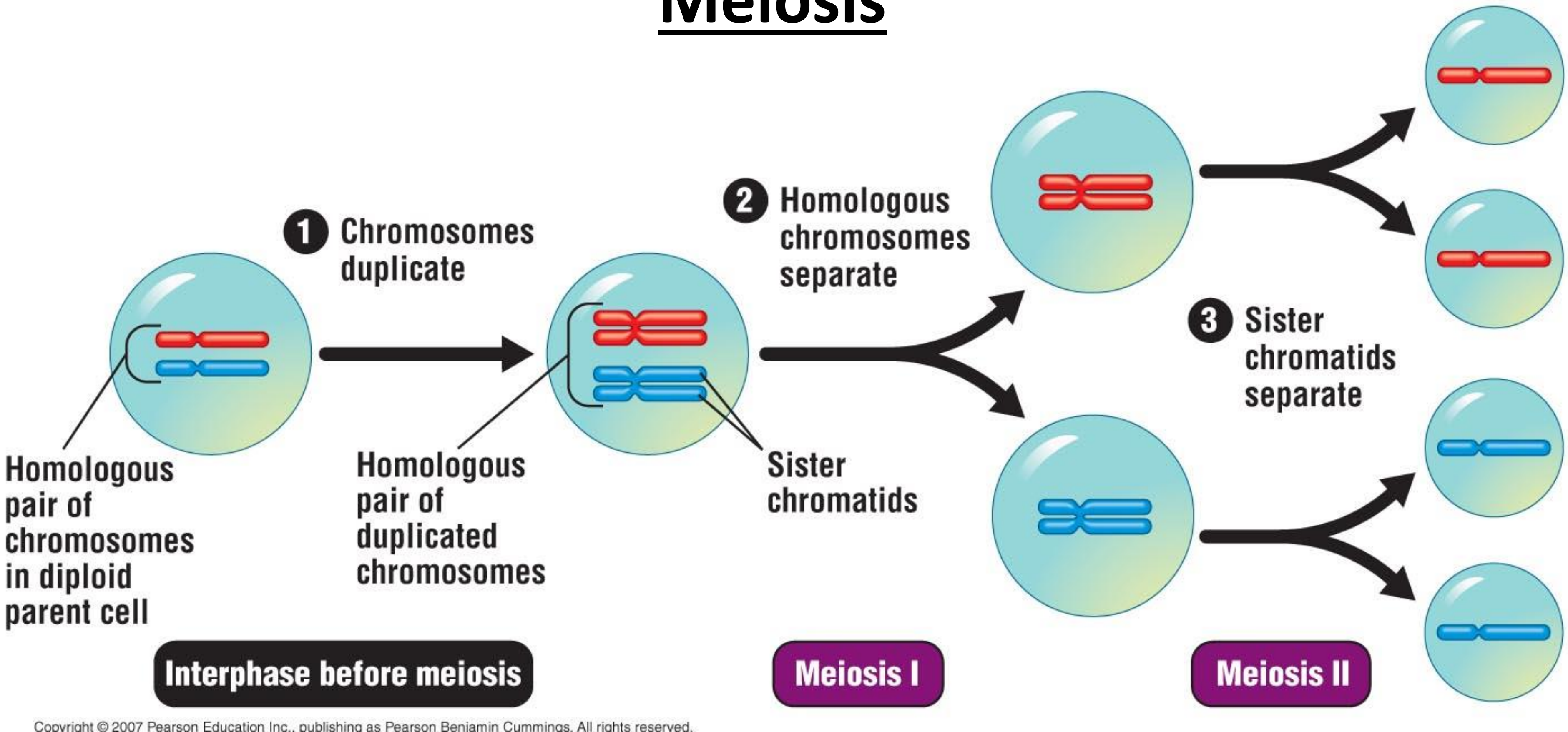
** Genes in the homologous chromosomes at the identical positions are similar but not necessarily identical- concept of alleles



** Genes in the homologous chromosomes at the identical positions are similar but not necessarily identical concept of alleles.



Meiosis



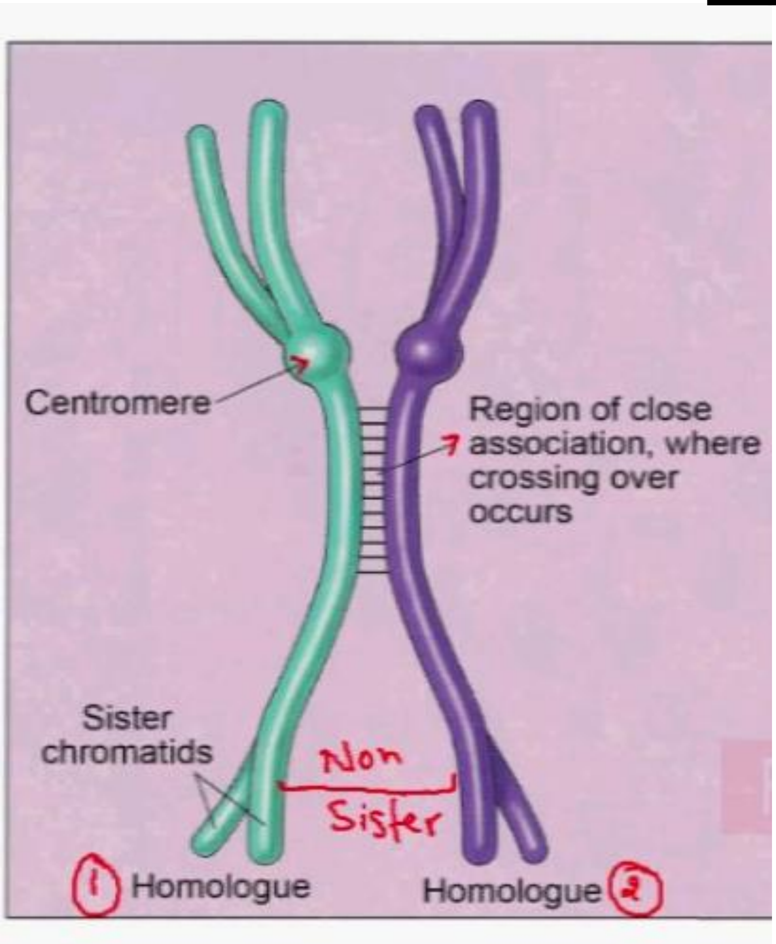
- Prophase I
- Metaphase I
- Anaphase I
- Telophase I

- Prophase II
- Metaphase II
- Anaphase II
- Telophase II

Meiosis-Gamete Production

- Involves two cell divisions
  - Produces four haploid cells
  - Meiosis I is the first division.
    - Preceded by DNA replication
    - Reduction division
      - Chromosome number reduced from diploid to haploid
  - Meiosis II is the second division.

Synapsis



-**Homologous chromosomes** become closely associated or **paired up** in **prophase I** of meiosis.

-Synapsis brings **non-sister chromatids in close proximity,** where they can **physically exchange their parts.**

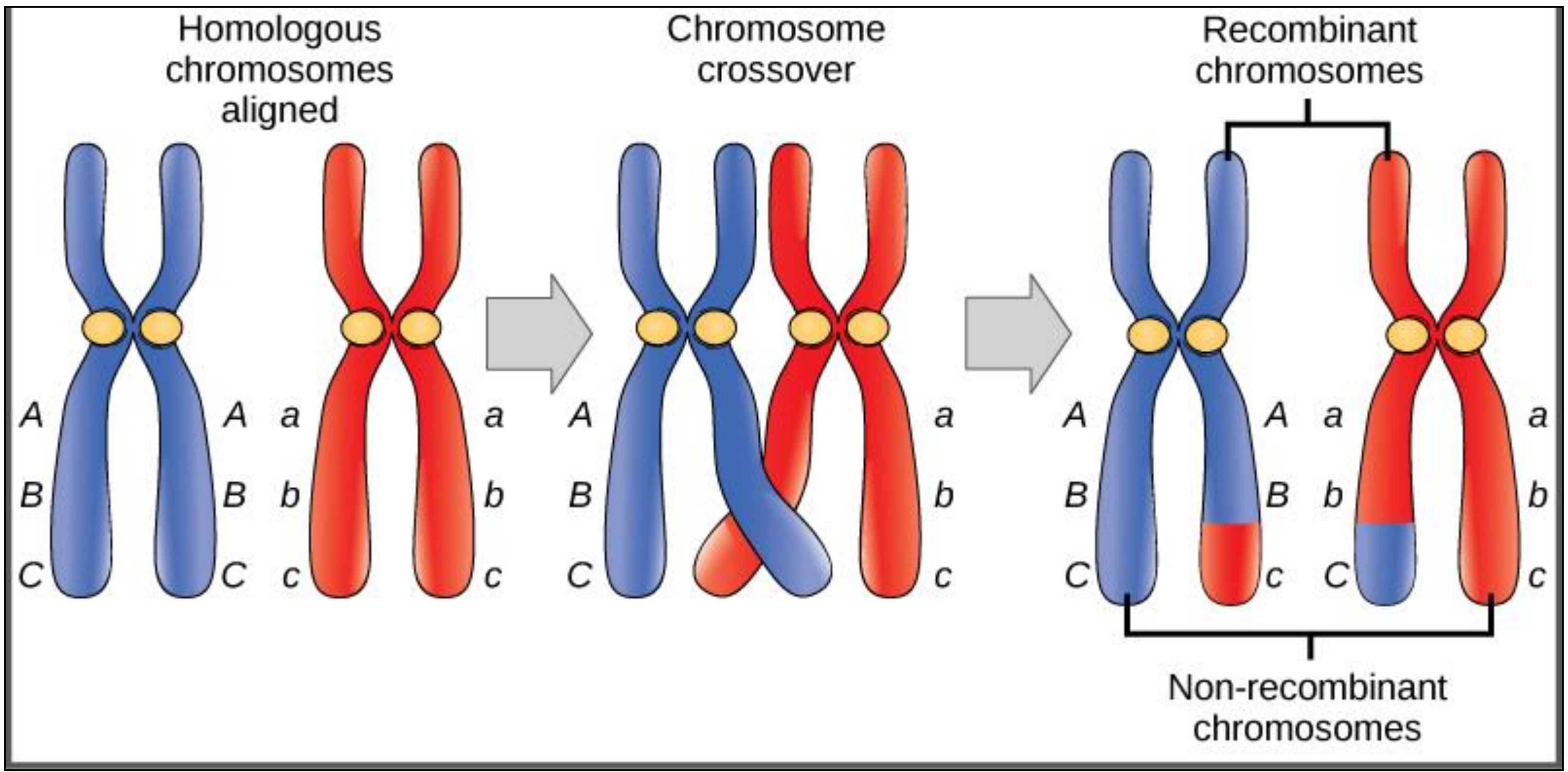
Crossing-over

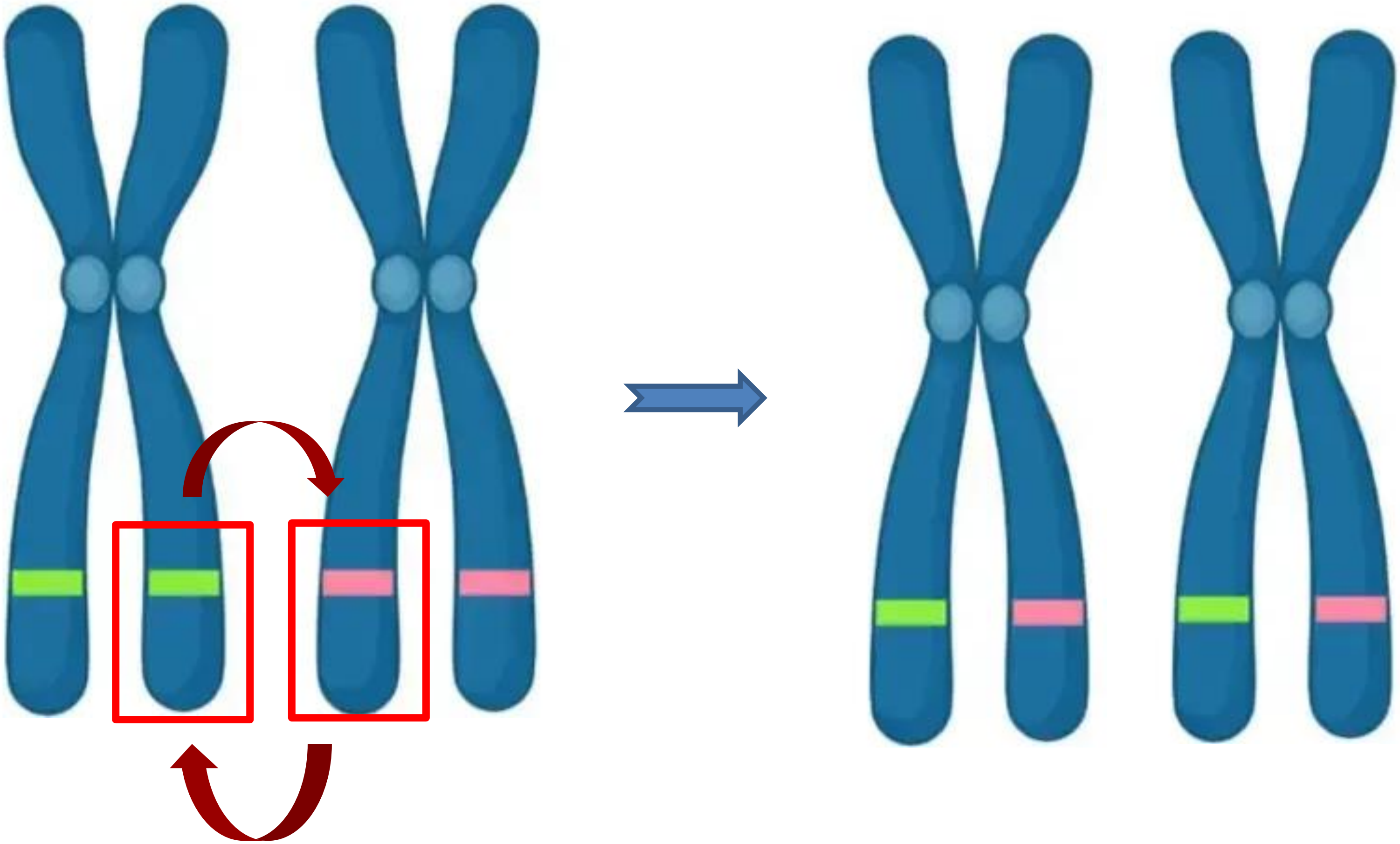
-Takes place in non-sister chromatids.

-Each chromosome arm has one or a few crossovers per meiosis, irrespective of it's size.

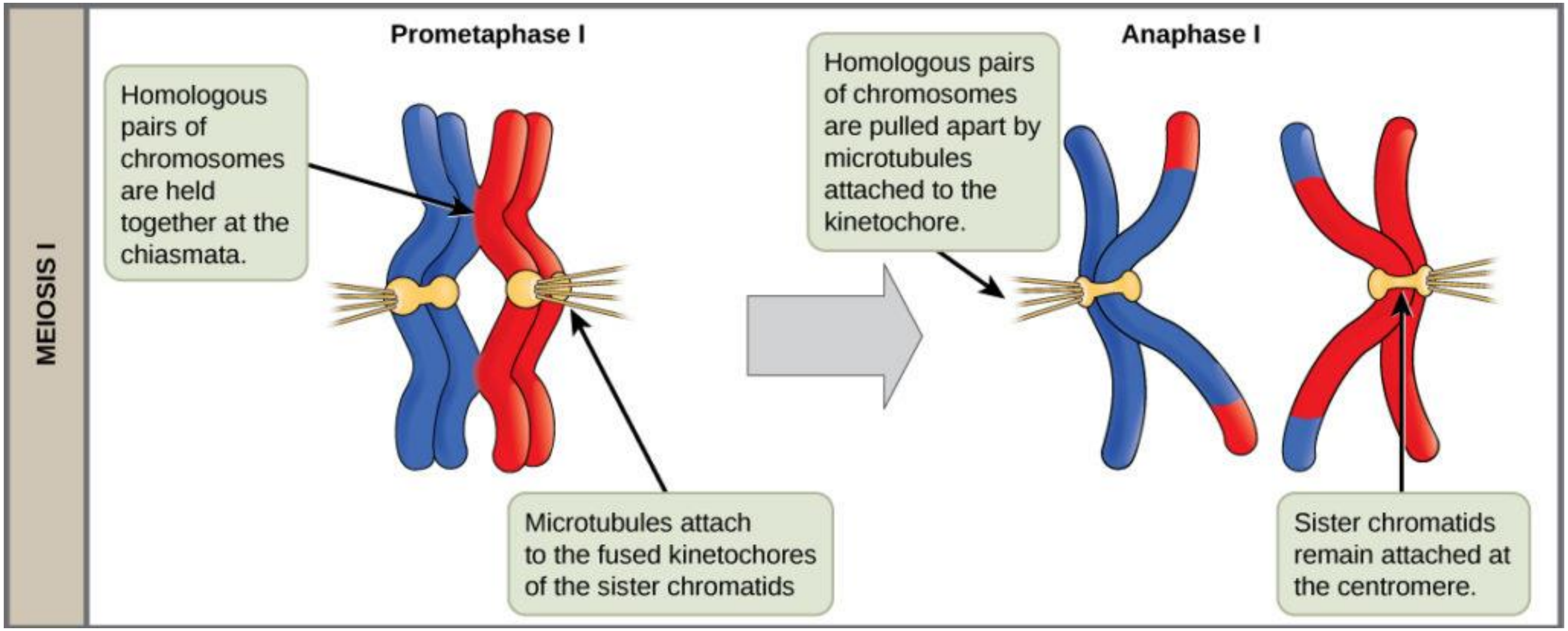
-Human chromosomes typically have two or three crossover points.

-Cross over generates non-identical sister chromatids





Chiasmata and Tetrad



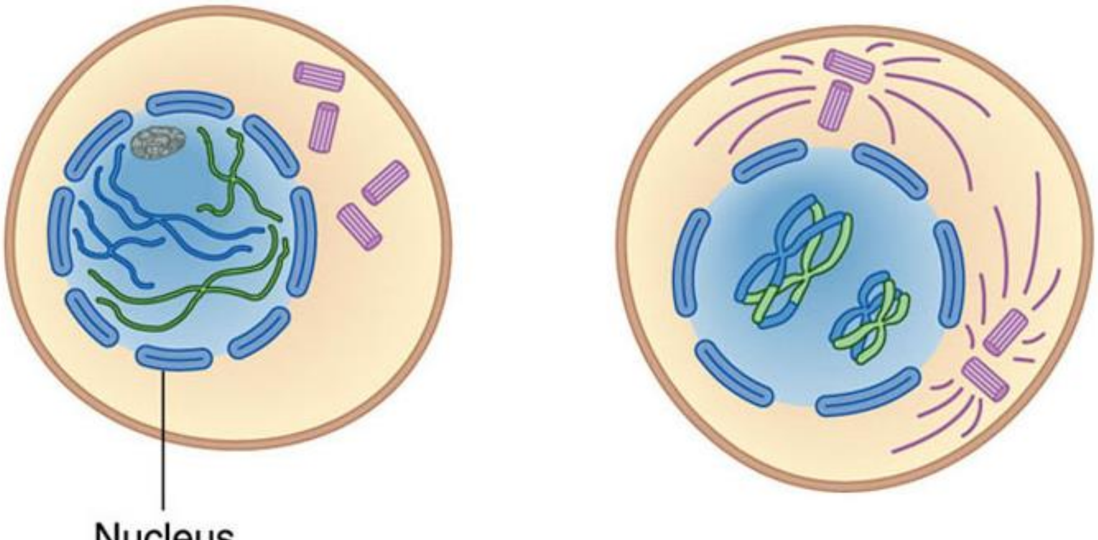
- The **X-shaped structure at crossing over** called **Chiasma** (**plural: Chiasmata).**
- **The presence of a Chiasma indicates two non-sister chromatids have exchanged their parts.**
- **A group of four chromatids** **that forms in Prophase 1, when homologous chromosomes pair up, is known as a Tetrad.**

Meiosis I: Prophase I

- **Prophase I**
  - **Synapsis occurs**
    - Homologous chromosomes move toward one another and associate with one another.
    - While associated homologs experience **crossing over**

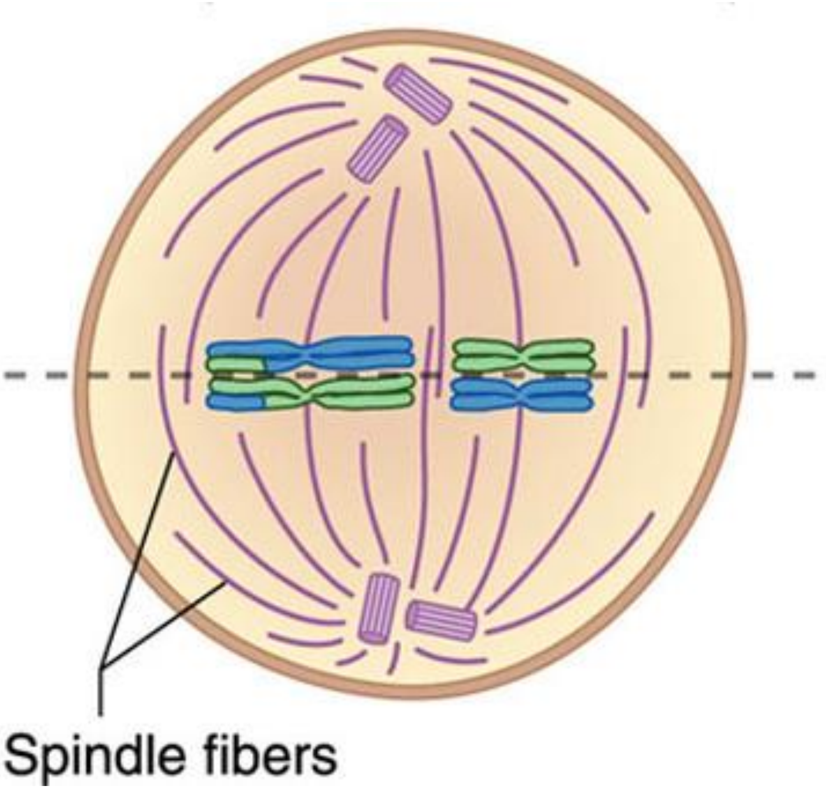
-**Homologs trade equivalent sections of DNA**.

-**Mixes up the genes** that are passed to the next generation



Meiosis I: Metaphase I

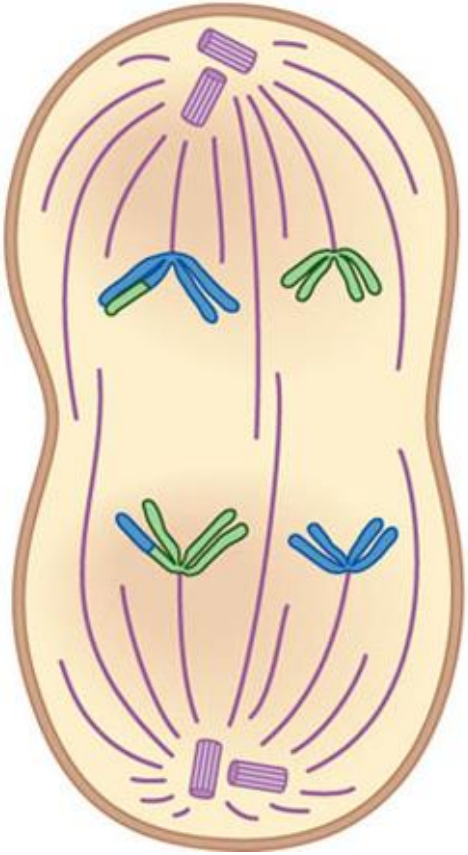
- **Metaphase I:**
  - The synapsed pairs of homologous chromosomes (Tetrads) are moved into position at the equatorial plate.



Meiosis I: Anaphase I

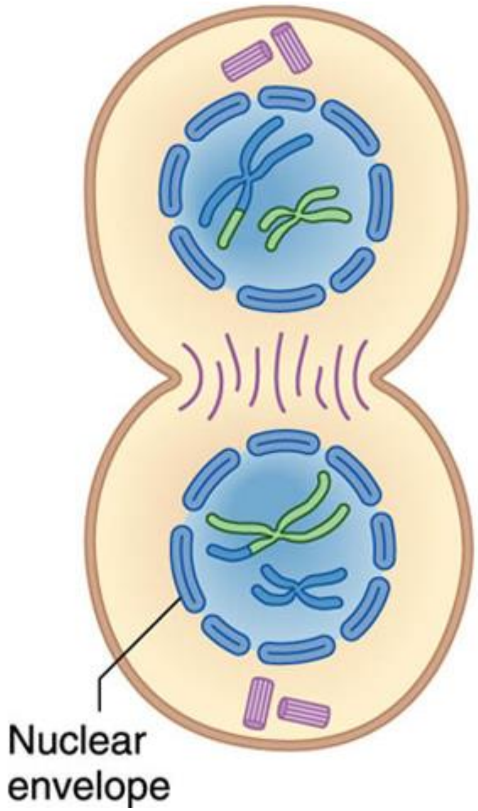
- **Homologous pairs separate.**
  - Homologs move to opposite poles.
    - **Sister chromatids do not separate at this point**.
  - This process is called ***segregation.***

- Results in **reduction of chromosome number from diploid to haploid.**



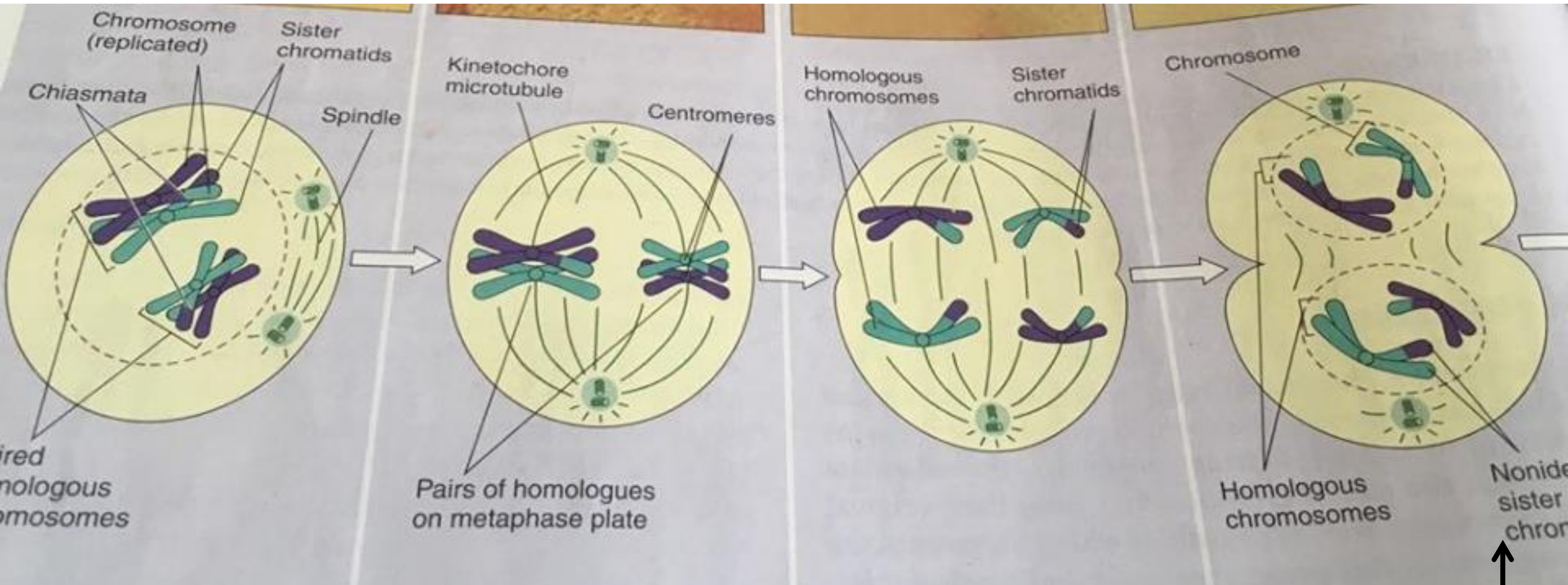
Meiosis I: Telophase I

- **Chromatin uncoils.**
- **Nuclear membrane reforms.**
- **Nucleoli reappear.**
- **Cytokinesis divides the two haploid nuclei into two daughter cells.**
  - **Each chromosome still contains two sister chromatids.**



Meiosis I

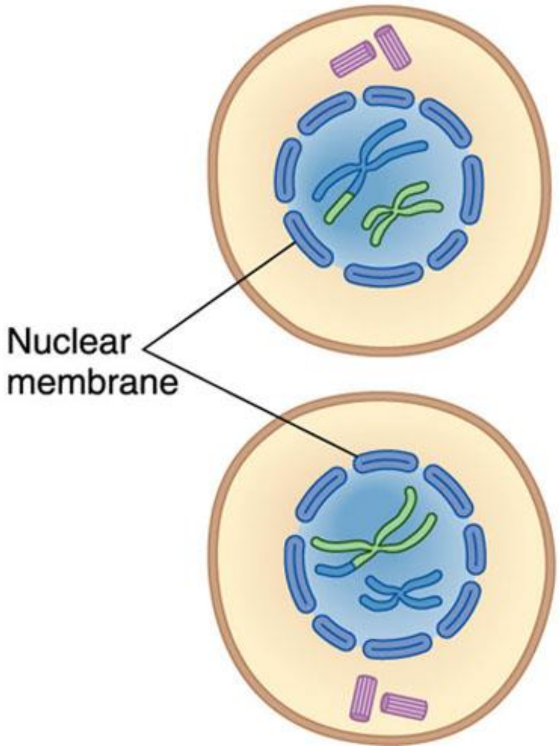
Prophase I **Metaphase I** **Anaphase I** **Telophase I**



Non-identical sister chromatids

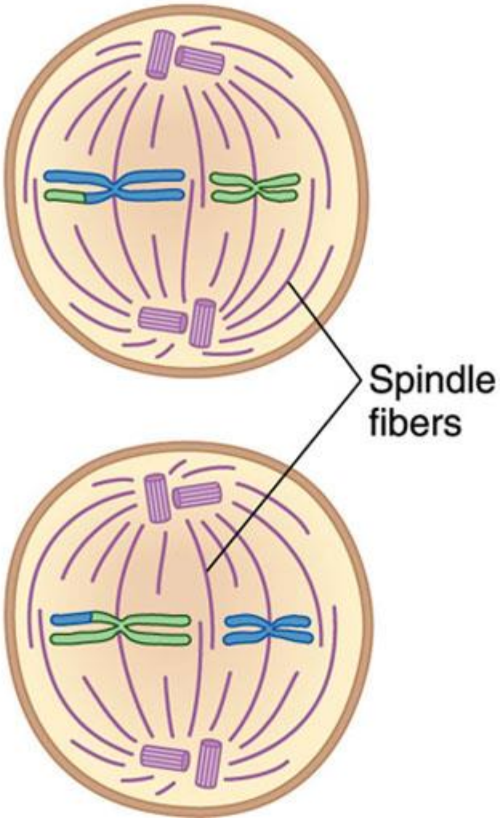
Meiosis II: Prophase II

- Similar to prophase in mitosis
- Nuclear membrane is disassembled.
- Spindle begins to form.

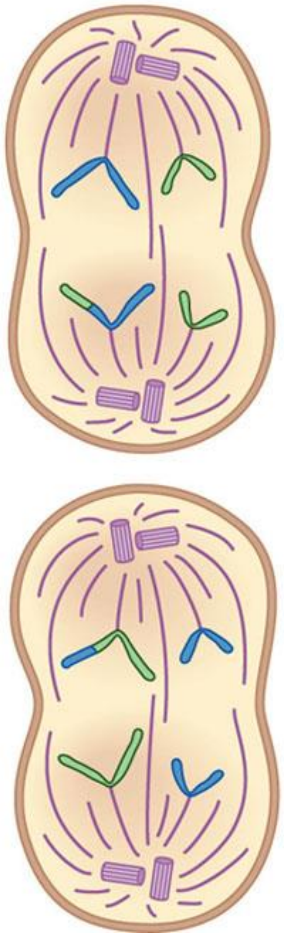


Meiosis II: Metaphase II

- Similar to metaphase in mitosis
- Chromosomes are lined up at the equatorial plate.



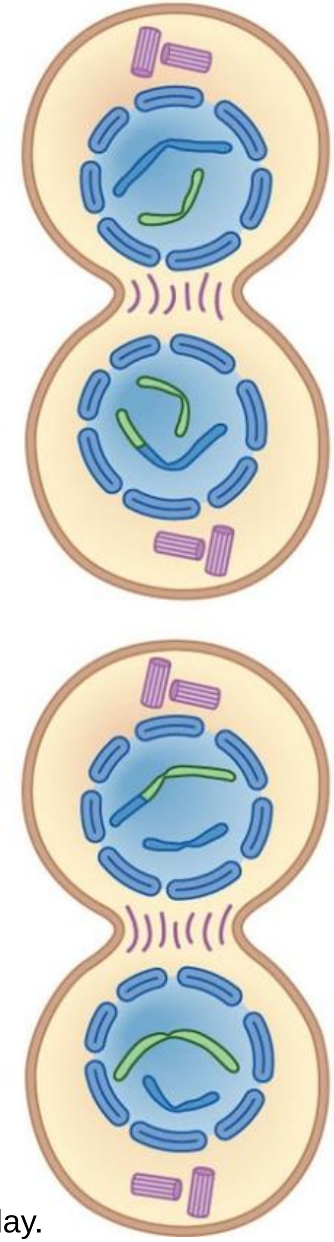
Meiosis II: Anaphase II



- Centromeres divide.
- Sister chromatids separate.
  - Now called daughter chromosomes

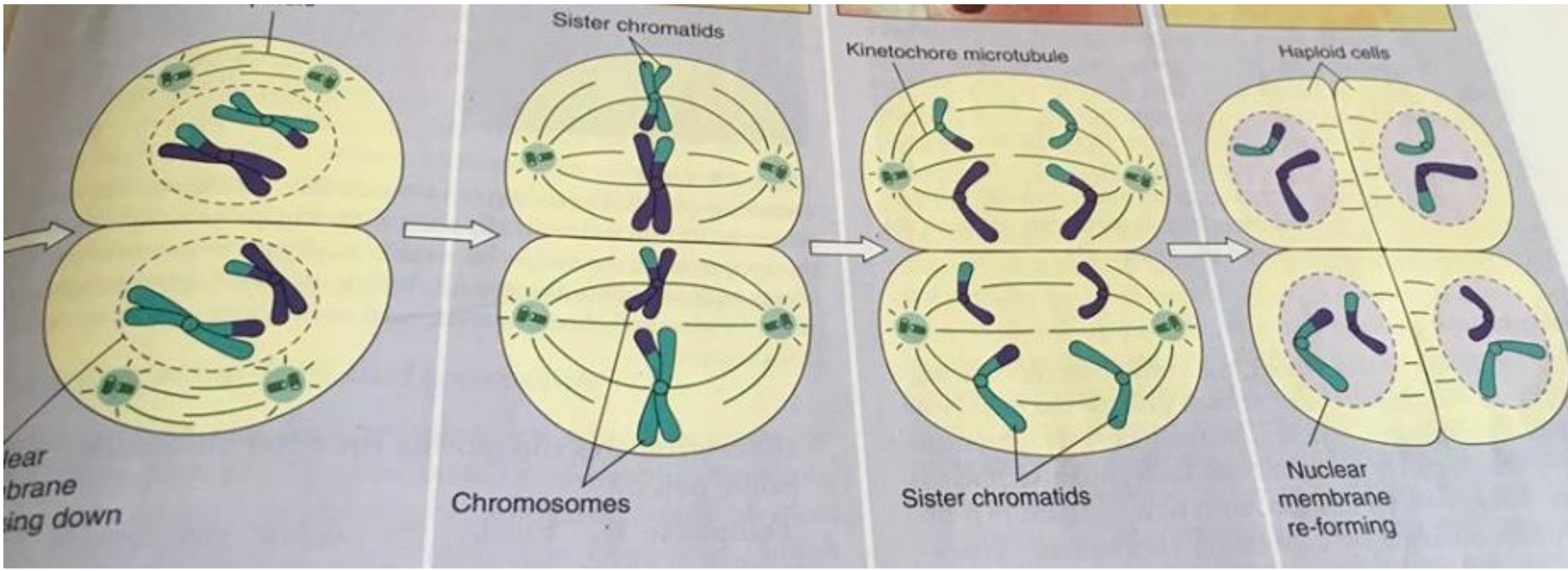
Meiosis II: Telophase II

- Similar to telophase and cytokinesis in mitosis

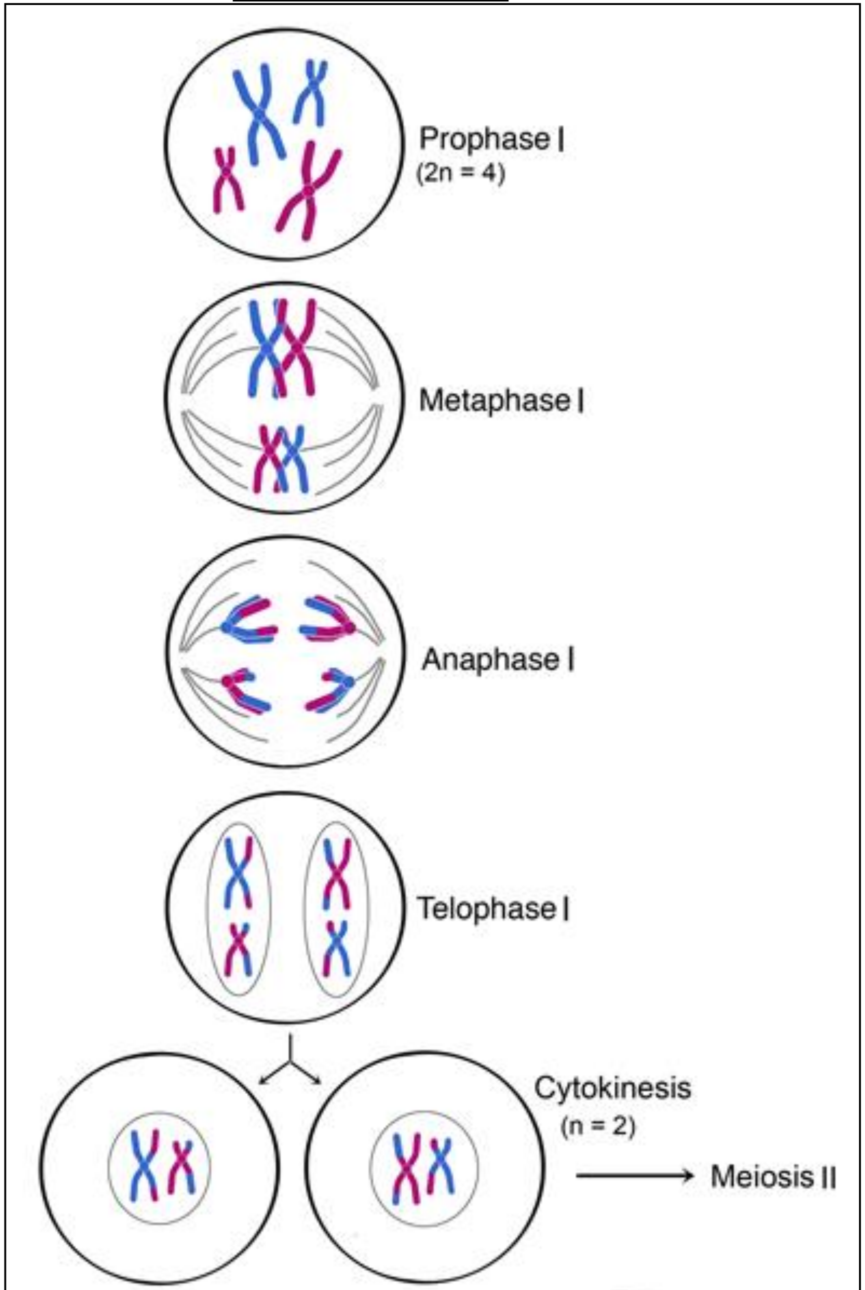


Meiosis II

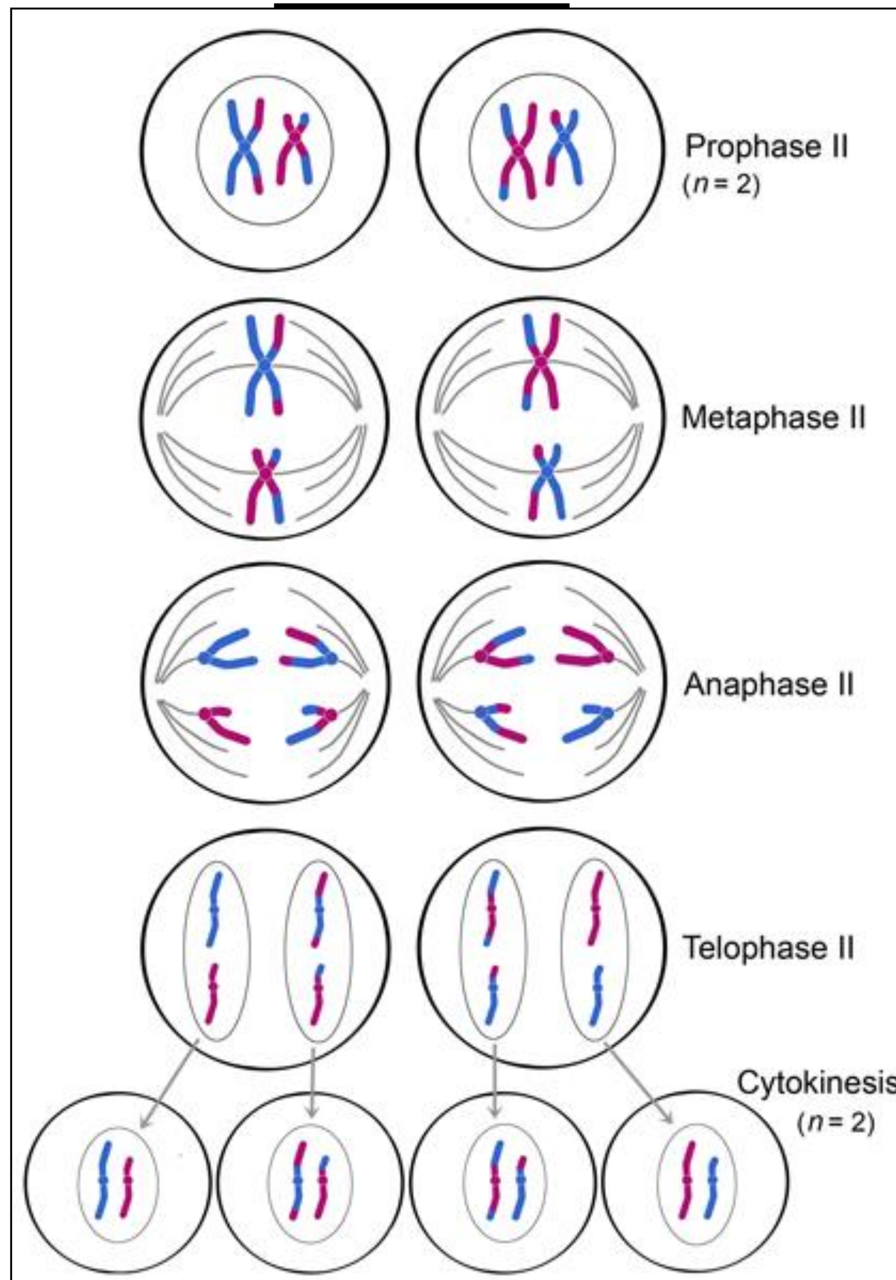
Prophase II **Metaphase II** **Anaphase II** **Telophase II**



Meiosis I



Meiosis II

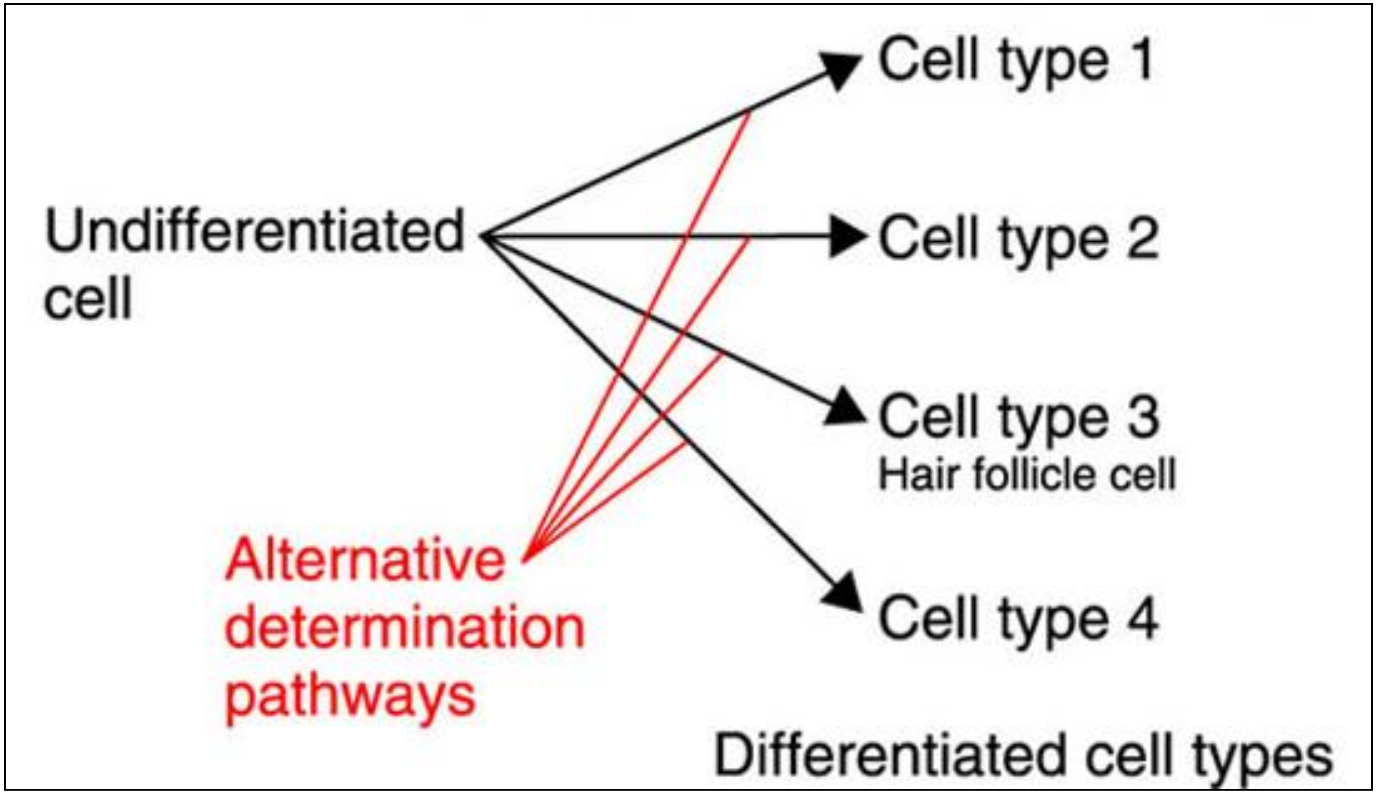


Determination and Differentiation

During sexual reproduction, fertilization of an egg by a sperm results in a single-celled zygote.

- **The zygote undergoes mitosis to develop into an adult.**
- **As mitosis occurs, cells must become specific cell types.**
- **All cells are genetically identical.**
- **Cells differ in the genes they express.**
- **Determination is the process a cell goes through to select which genes it will express, committing itself to becoming a certain cell type.**
- **When a cell is fully developed into a specific type of cell, it is said to be differentiated.**

Determination and Differentiation



Genetic Diversity –
The Advantage of Sexual reproduction

- **Five factors create genetic diversity by creating new alleles, or new combinations of alleles.**
  - **Mutation**
  - **Crossing-over**
  - **Segregation**
  - **Independent assortment**
  - **Fertilization**

Mutations

- Mutations are changes in the nucleotide sequence of DNA.
- This creates new alleles.
- New alleles lead to new forms of proteins.
- Increases genetic diversity
- Examples: Generation of mutated allele in hemoglobin in sickle cell anemia, difference in ABO gene for blood typing etc.

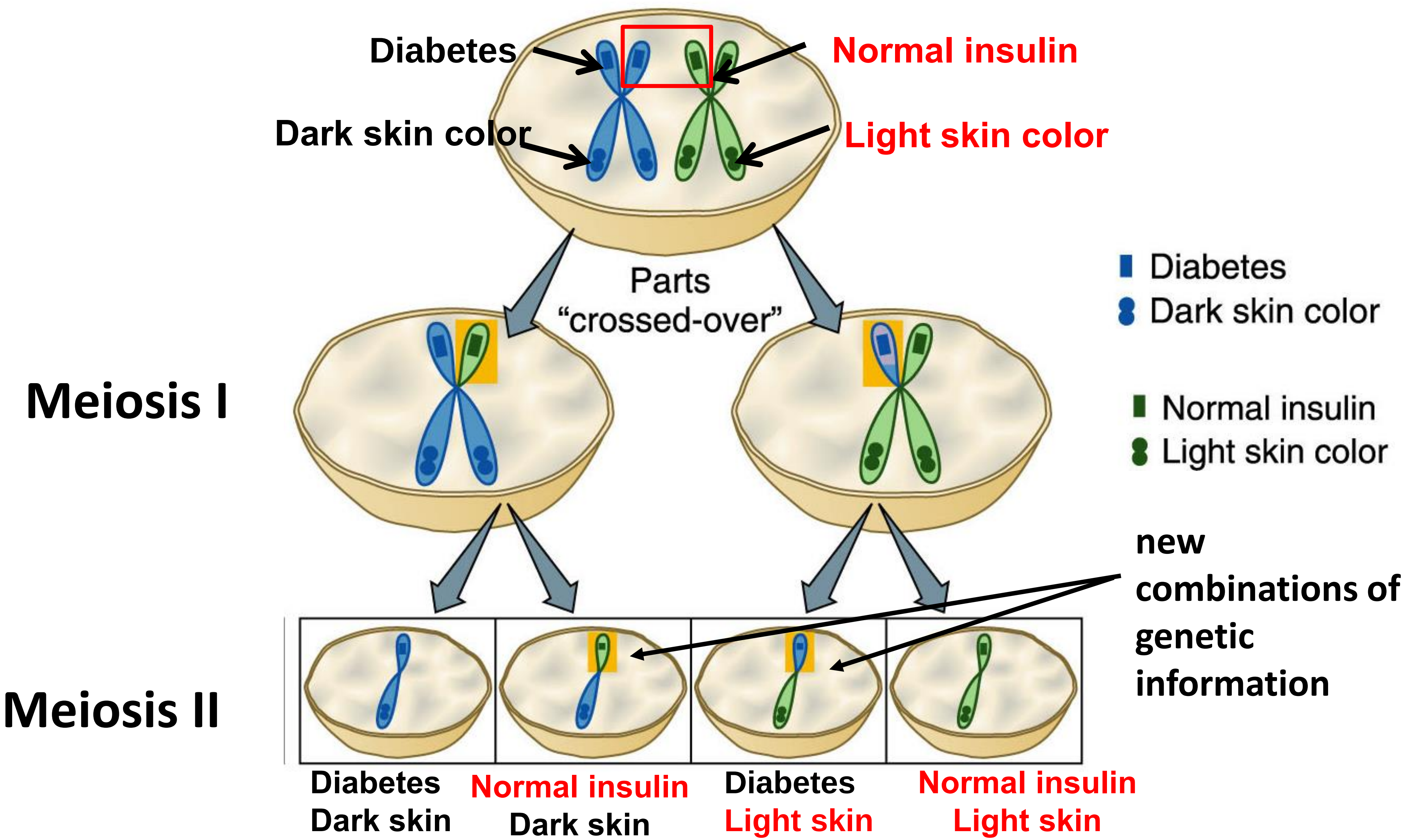
Crossing-over

- The exchange of equivalent portions of DNA between homologous chromosomes

- Occurs during prophase I when chromosomes are synapsed

- Allows new combinations of genetic information to occur

The Results of Crossing-over



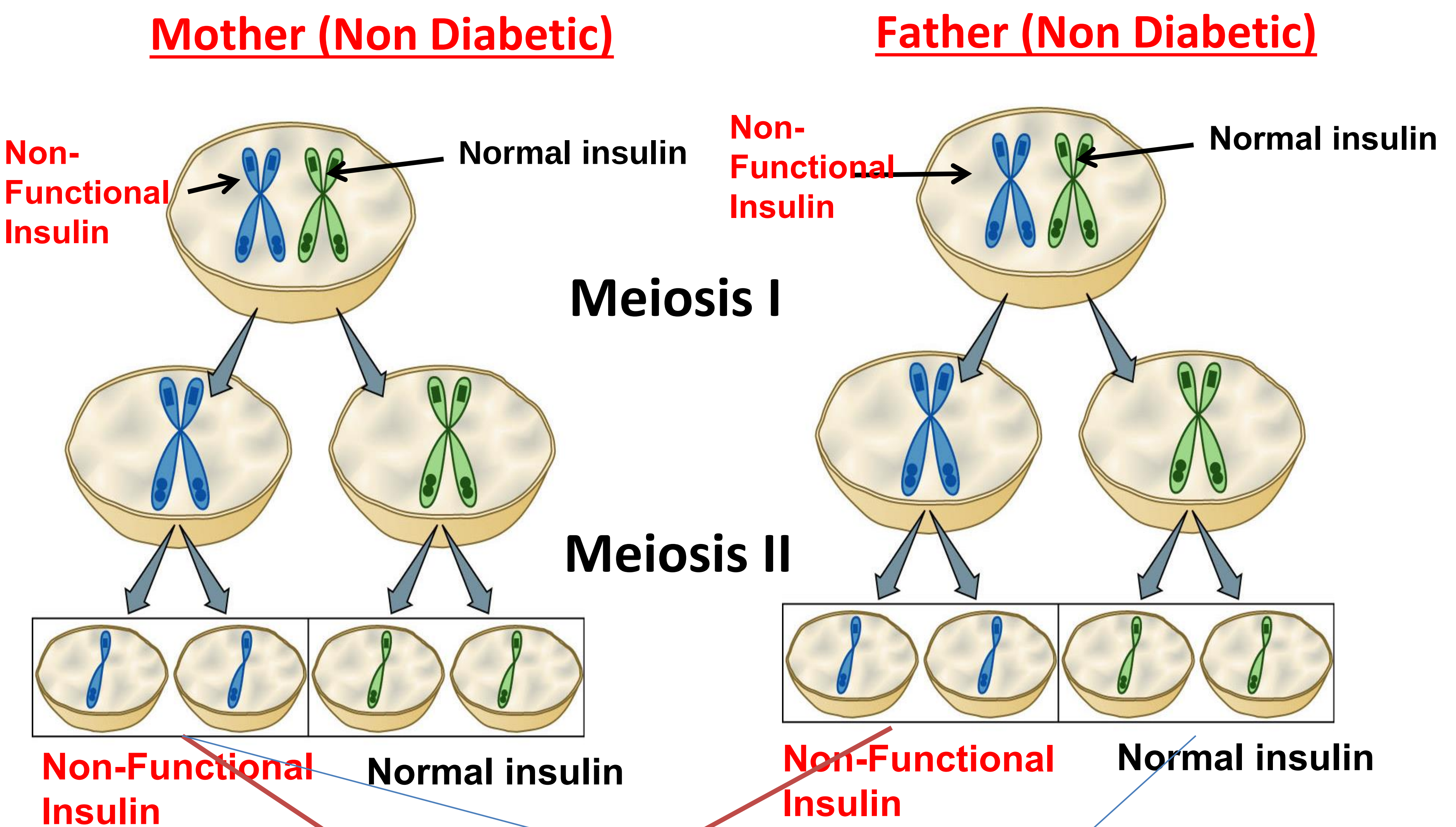
Segregation

Alleles on homologous chromosomes separate during anaphase I

Consider a person who has two alleles for insulin; one normal and one diabetic (non-functional insulin).

- Half of its gametes would get the gene for functional insulin.
- Half of its gametes would get the gene for nonfunctional insulin.
- If these gametes were used during fertilization, and were joined with similar gametes, some of the offspring would not be able to make functional insulin; they are genetically different from both the parents.

Segregation



Genetically different offspring due to segregation

Offspring would be Diabetic

Offspring would be Normal

Independent Assortment

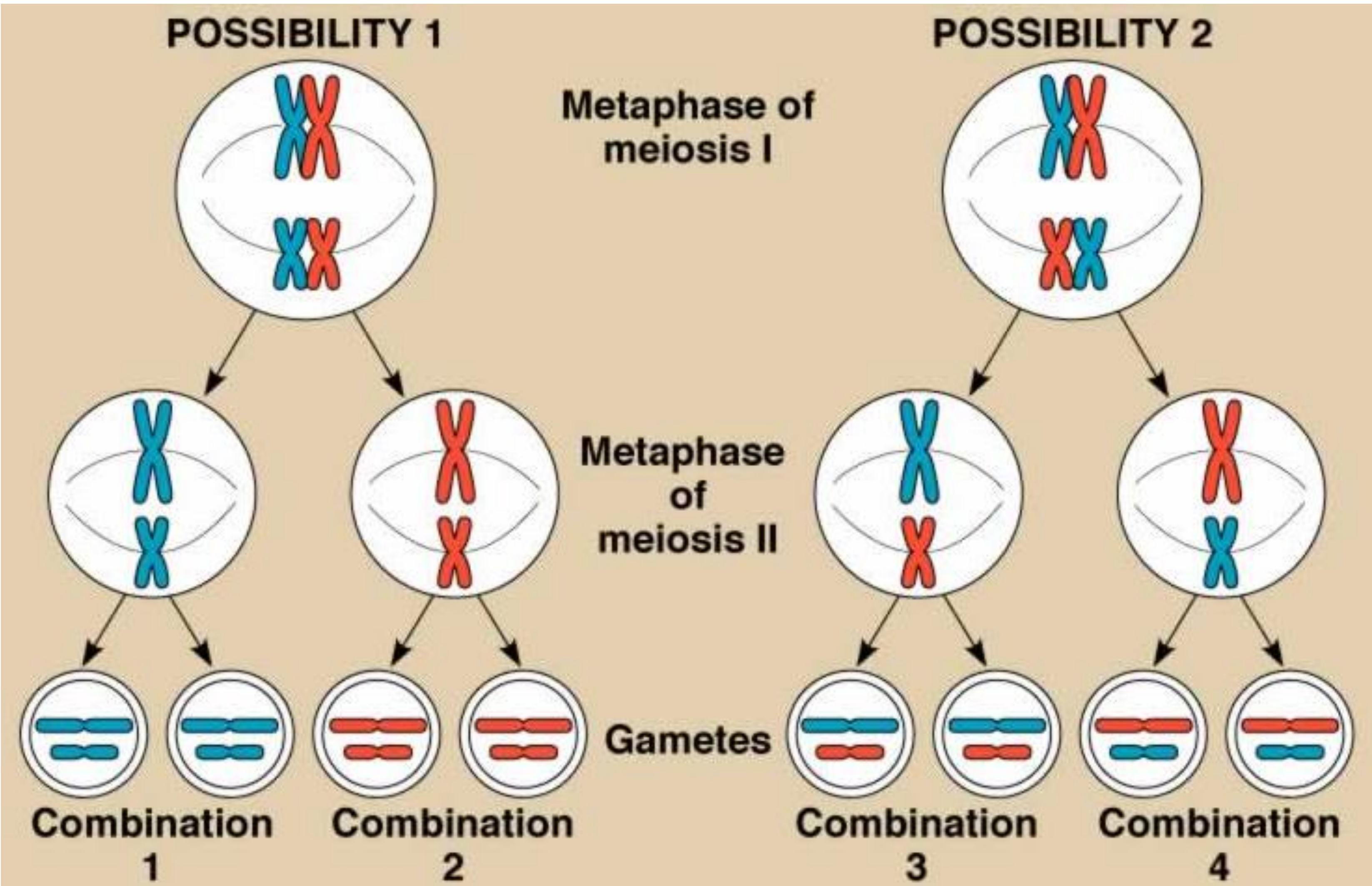
- The segregation of homologous chromosomes in one pair is independent of how other homologous pairs segregate.

Independent Assortment

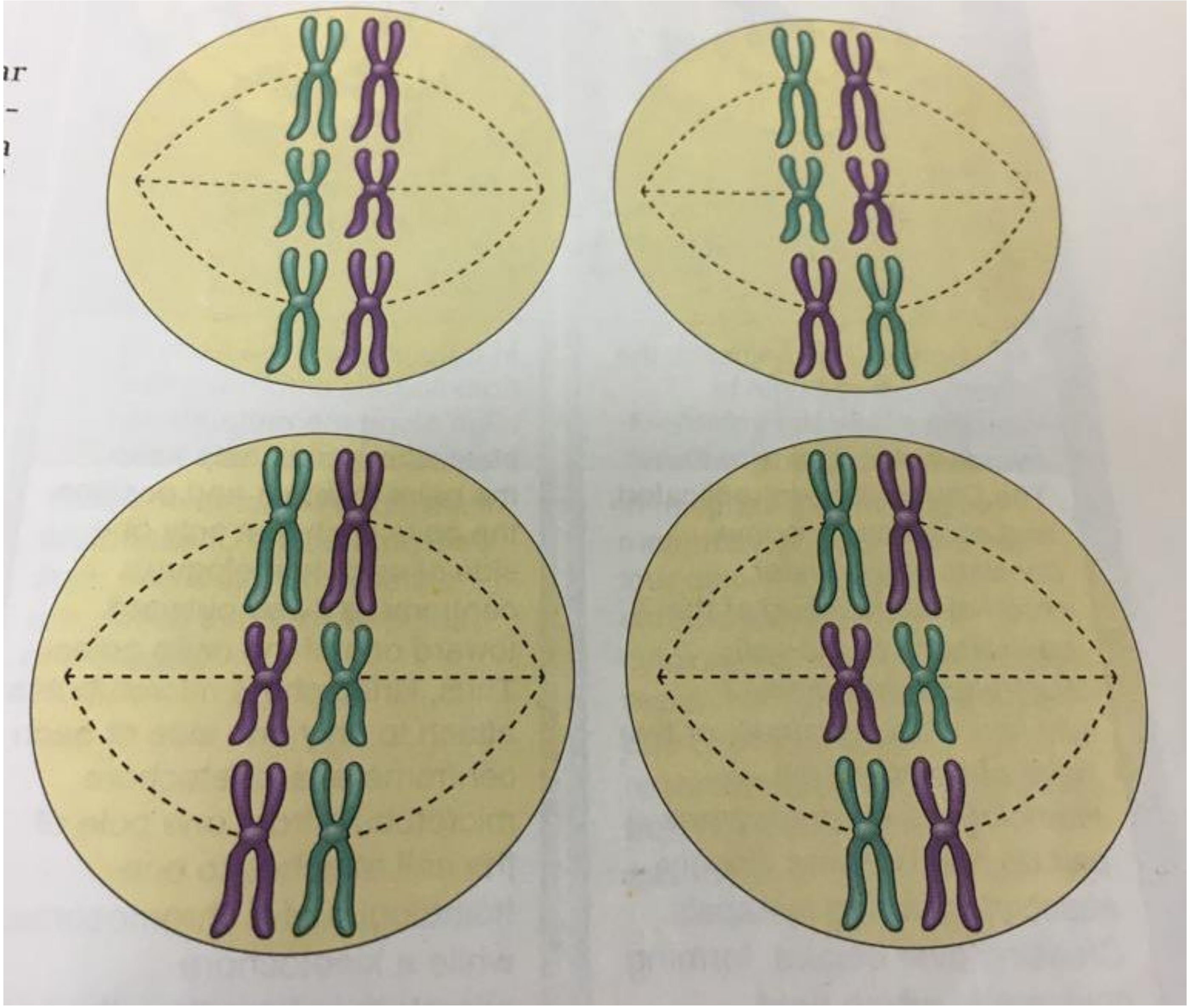
Consider two pairs of chromosomes.

Given the two ways these pairs can line up on the equatorial plate,

There are four possible combinations of chromosomes in gametes.



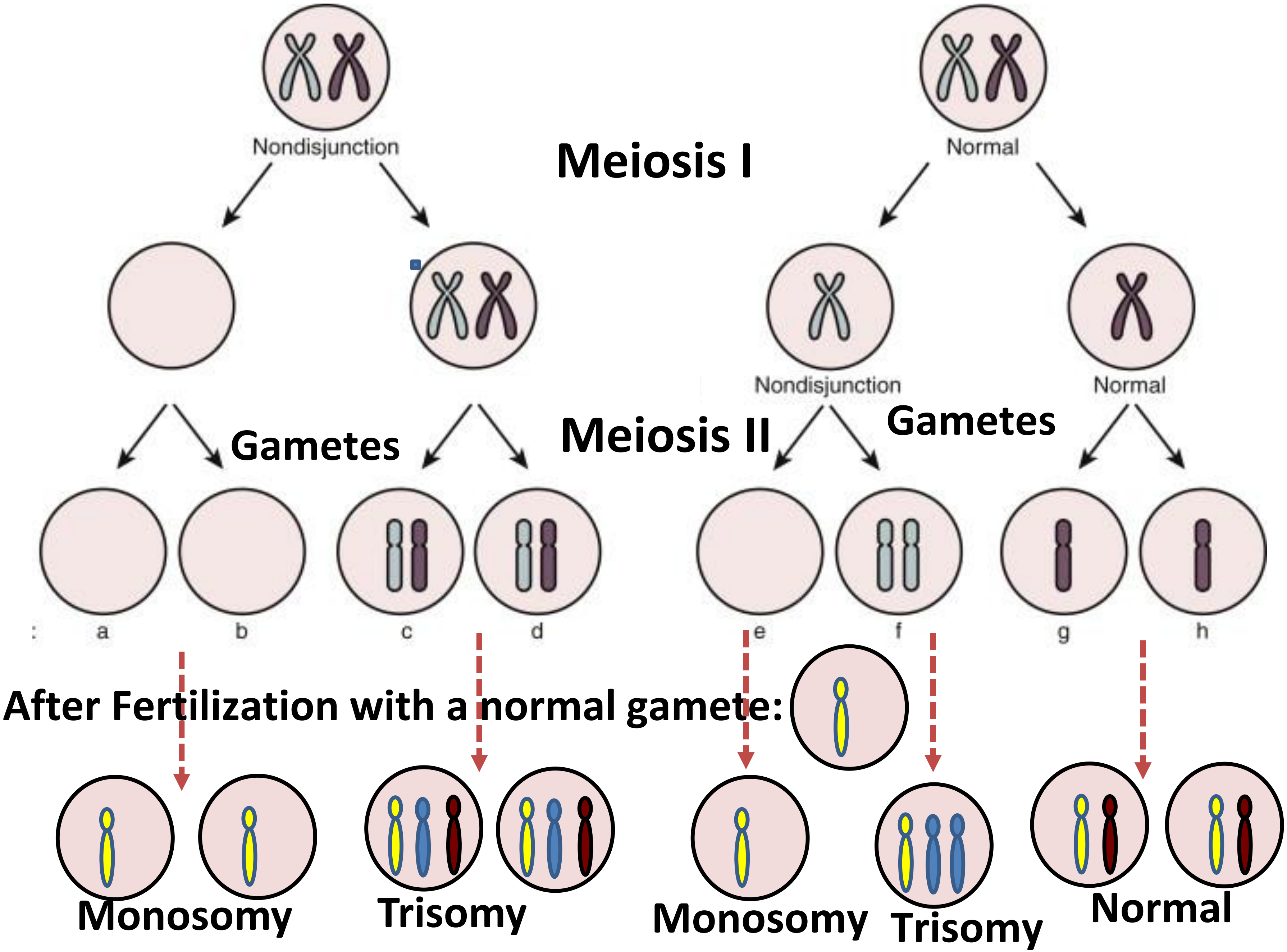
Random orientation of chromosomes in metaphase I



Fertilization

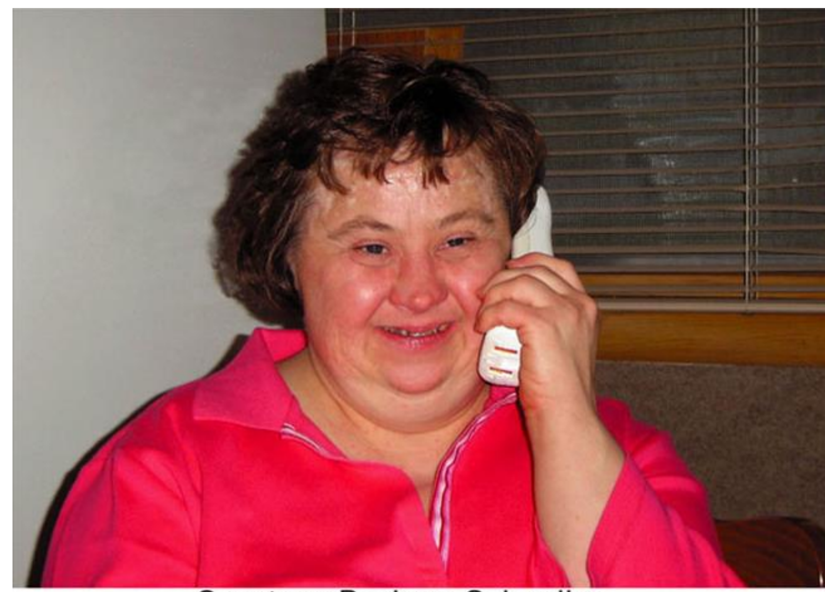
- Due to the large number of possible gametes resulting from independent assortment, segregation, mutation and crossing-over,
  - A large number of different offspring can be generated from two parents.
- Since gametes join randomly
  - The combinations of alleles is nearly infinite.

Nondisjunction During Gametogenesis



A Karyotype can Reveal Trisomy 21

- **Down syndrome**
  - Three copies of chromosome #21
  - Results in 47 chromosomes instead of 46
  - Symptoms include:
    - Thickened eyelids
    - Mental impairment
    - Faulty speech



Courtesy Darlene Schueller

Extra Slides

Nondisjunction During Gametogenesis