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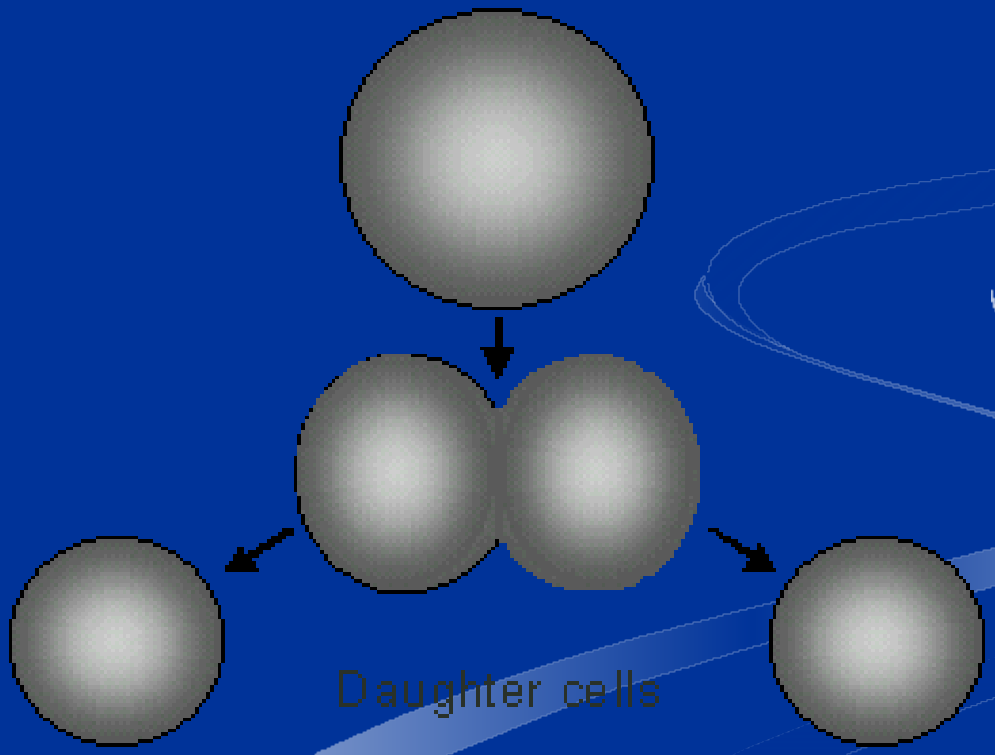
Gen. Embryology lecture I, cell division, part I

CELL DIVISION

A cell divides by pinching into two. Each of two daughter cells produced contains genetic material inherited from the original (parent) cell.



Why Divide ?

- Single-celled organisms divide to reproduce.
- Cell division in multicellular organisms enables the organism to grow larger while the cells remain small.
- Organisms with many cells can have cells which are specialized for different functions and tasks. For example, red blood cells are specialized for carrying oxygen but neurons (nervous tissue) are specialized for conducting signals from one cell to another.

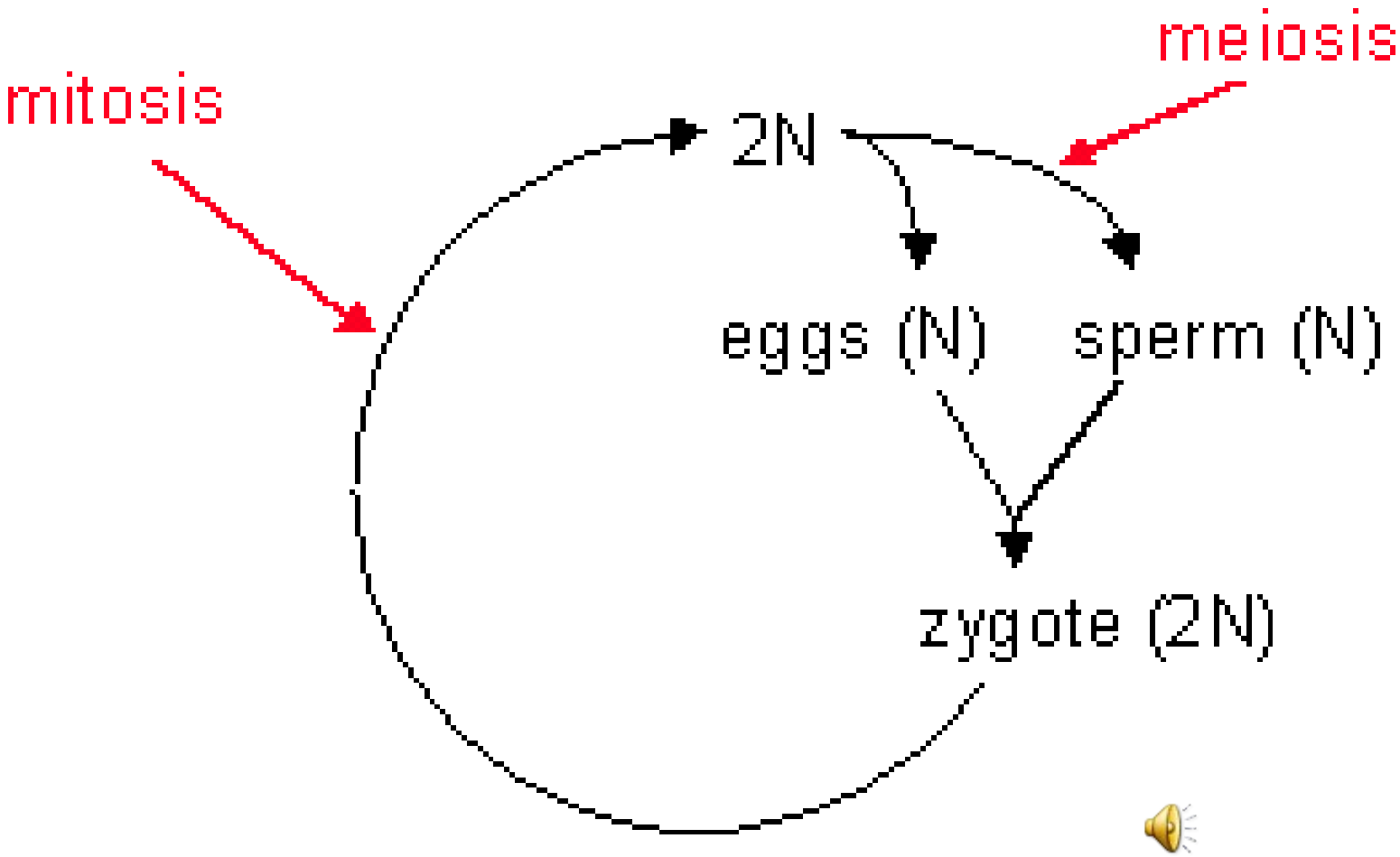
- Some cells of multicellular organisms must divide to produce sex cells (gametes).
- Mammalian cells typically divide only about 50 times.
- This limit is set by the presence of repeated sequences of DNA at the tips of the chromosomes called telomeres.

Types of Cell Division

- Mitosis produces identical daughter cells.
- Meiosis produces cells with 1/2 the number of chromosomes as the parent cell.

Life Cycles_

- Meiosis functions to reduce the number of chromosomes to one half. Each daughter cell that is produced will have one half as many chromosomes as the parent cell.
- Meiosis is part of the sexual process because gametes (sperm, eggs) have one half the chromosomes as diploid (2N) individuals.


meiosis
mitosis
2N
eggs (N)
sperm (N)
zygote (2N)

Mitosis

- Mitosis produces two daughter cells that are identical to the parent cell. If the parent cell is haploid (N), then the daughter cells will be haploid. If the parent cell is diploid, the daughter cells will also be diploid.

  N → N

  2N → 2N

- This type of cell division allows multicellular organisms to grow and repair damaged tissue.

Chromatin, Chromosomes

- Chromatin is a mass of uncoiled DNA and associated proteins called histones.
- When cell division begins, DNA coils around the proteins forming visible structures called chromosomes.

Haploid, Diploid

- Diploid cells (2N) have two complete sets of chromosomes. The body cells of animals are diploid.
- Haploid cells have one complete set of chromosomes. In human, gametes (sperm and

Homologous Chromosomes

- Diploid organisms have two copies of each chromosome (except the sex chromosomes). Each pair of chromosomes is homologous. For example, the two #7 chromosomes are homologous. The homologue to the #3 chromosome would be the other #3 chromosome.

Genes

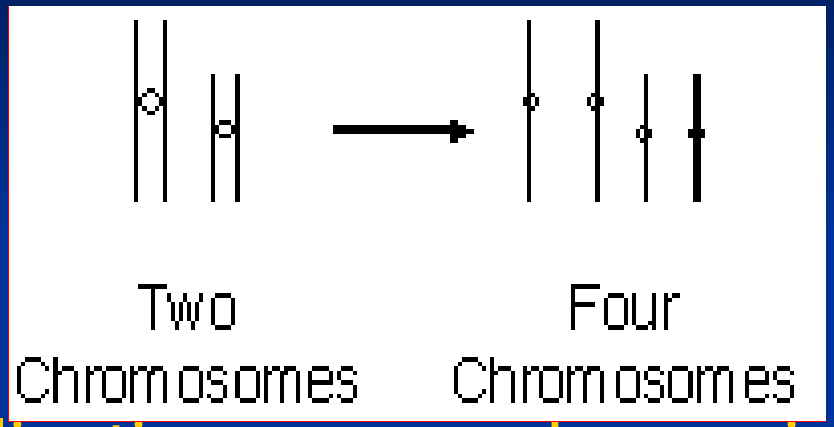
- A small segment of DNA that contains the information necessary to construct a protein or part of a protein (polypeptide) is called a gene. Genes are the unit of inheritance

Chromosome Structure and Replication

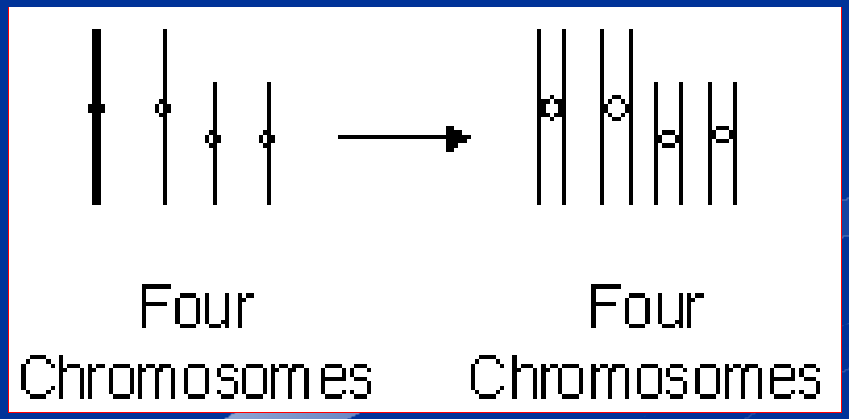
- A chromatid is a single DNA molecule.
- Double-stranded chromosomes have two chromatids; normally, each one is identical to the other. The point where the two chromatids are attached is called the centromere

Chromosome Doubling vs DNA Synthesis

Splitting chromosomes into two will double their number because each chromatid is identical.



DNA replication occurs when a single-stranded chromosome produces a second chromatid.



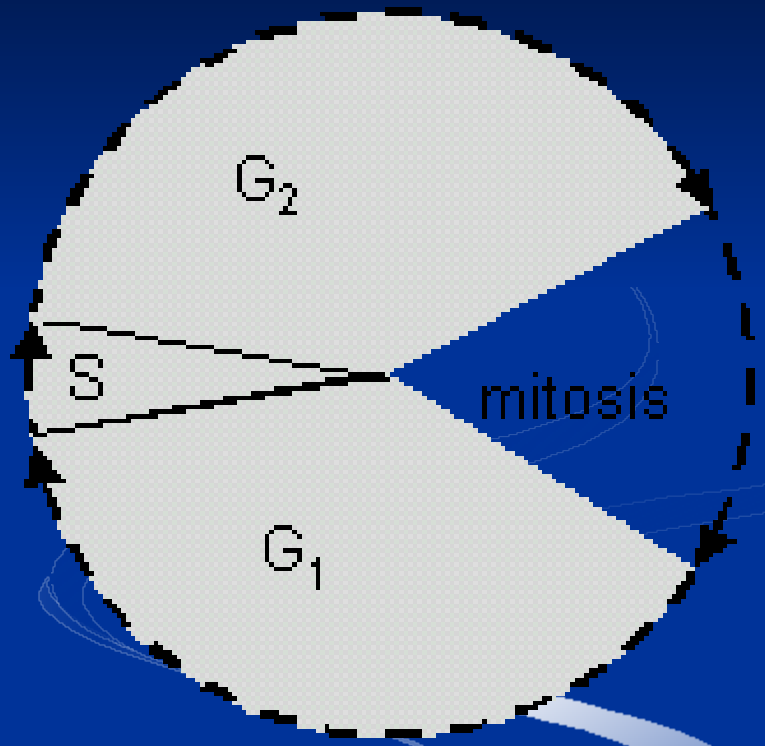
Summary of Mitosis

prophase - coil_

metaphase - align_

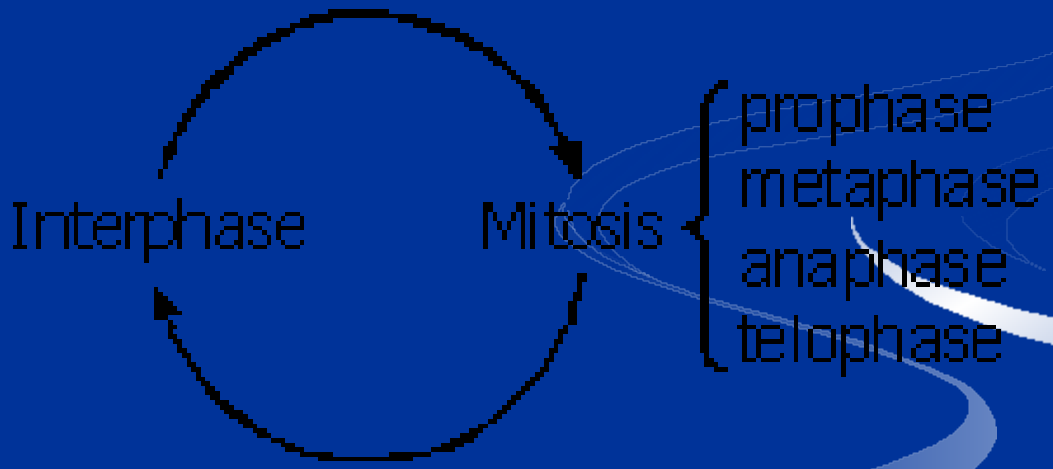
anaphase - separate_

telophase – uncoil



The Cell Cycle

The cell cycle alternates between interphase and mitosis as diagrammed below.



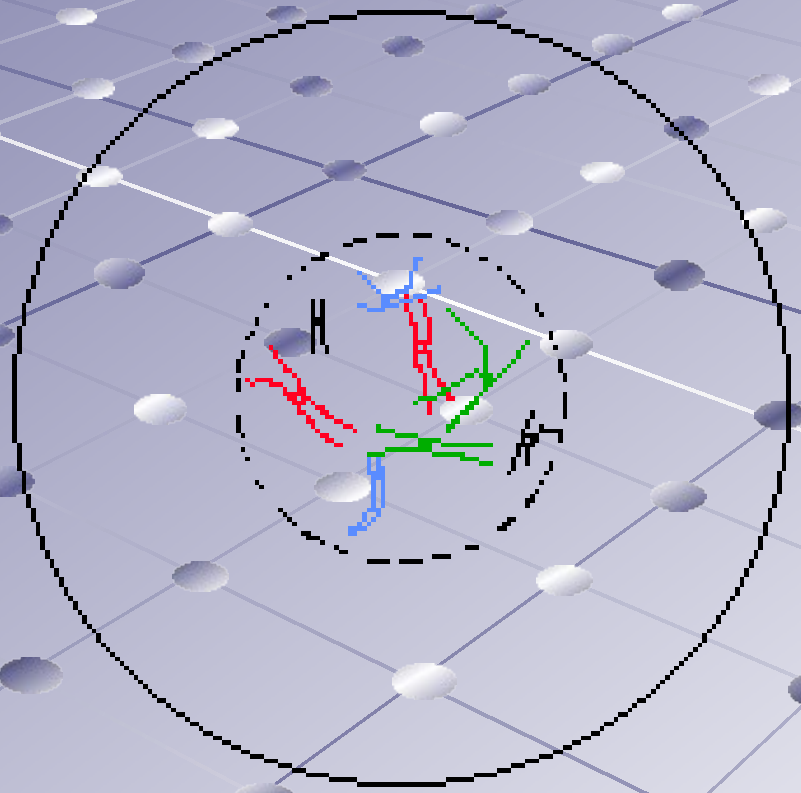
Mitosis has these four phases: prophase, metaphase, anaphase, and telophase.

1- Prophase

The chromosomes coil.

The nuclear membrane disintegrates.

The spindle apparatus forms

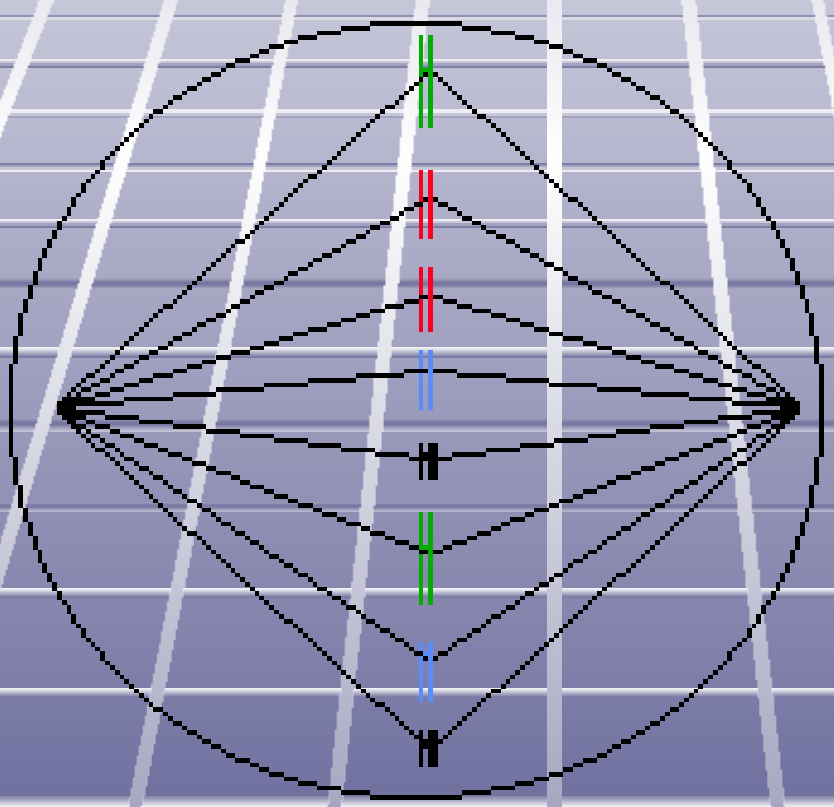


Prophase

- During prophase, chromosomes begin condensing (forming) as DNA becomes coiled. The genes cannot function (produce mRNA and therefore protein) when the DNA is coiled. Coiling facilitates movement.
- The nucleolus disappears.
- The nuclear membrane becomes fragmented and disappears by the end of prophase.

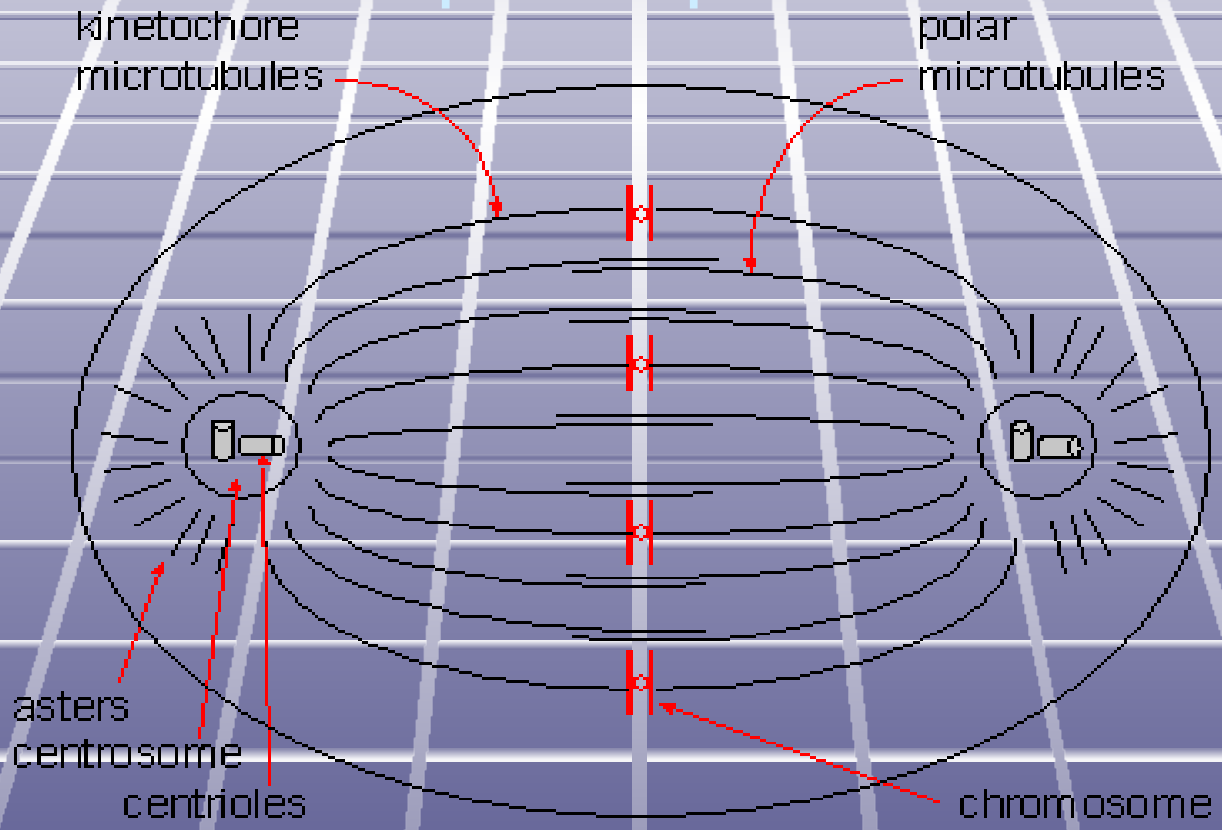
2- Metaphase

The chromosomes become aligned.

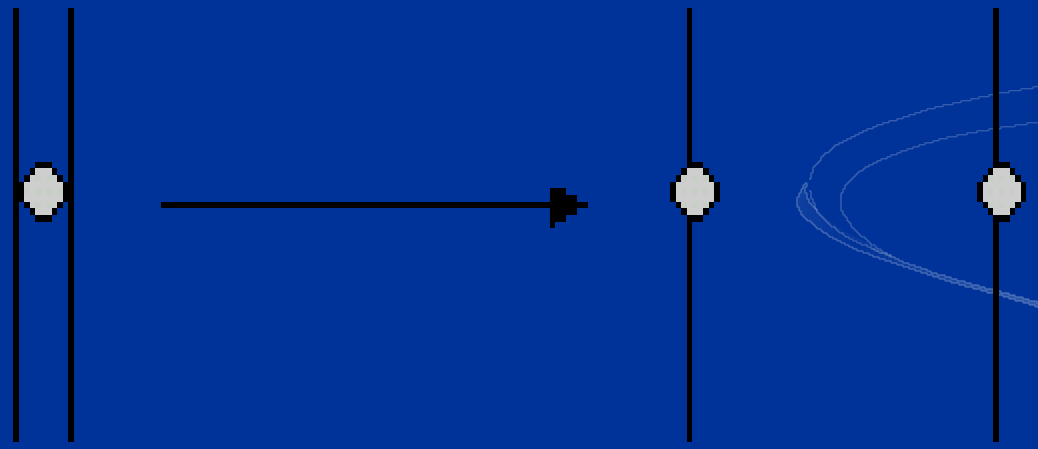


Metaphase

During metaphase, the chromosomes have moved to the center of the cell (diagram below, photograph above). This line of chromosomes is referred to as the metaphase plate.



- Metaphase ends when chromosomes split, thus doubling the number of chromosomes.

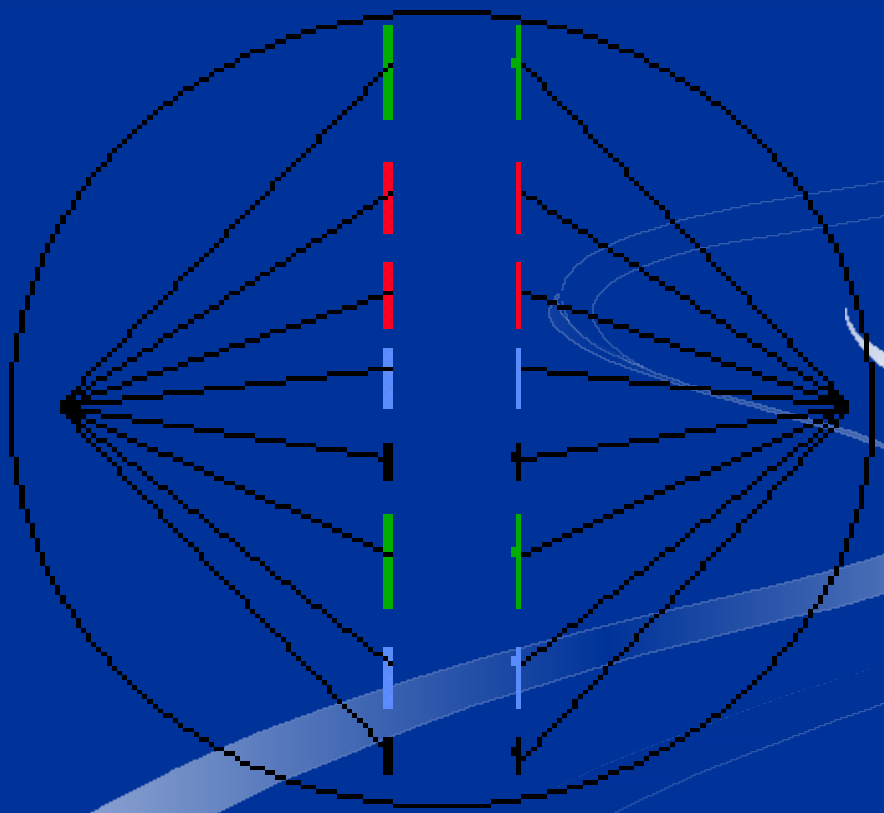


one chromosome

two chromosomes

3- Anaphase

The chromatids separate (The number of chromosomes doubles).

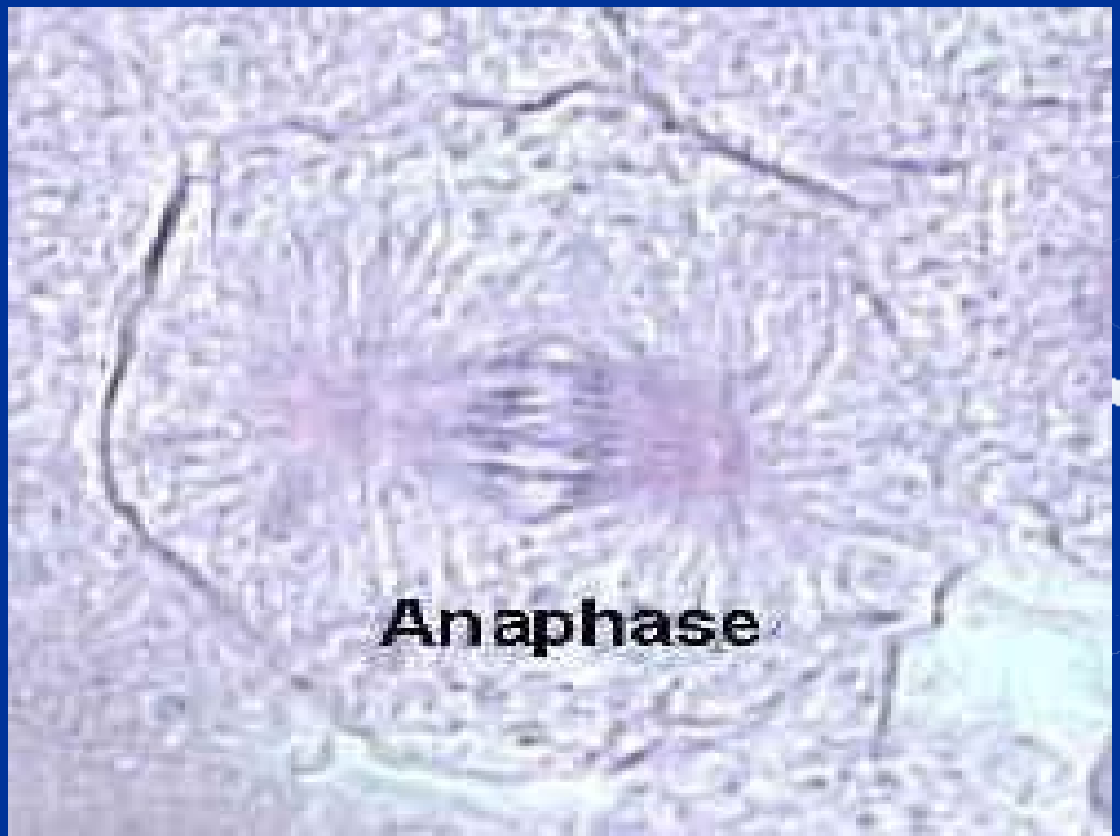


Anaphase

- When the chromosomes split at the end of metaphase, the chromosome number is doubled. For example, the number of chromosomes and chromatids during each phase in a human cell is:

Phase	# Chromosomes	# Chromatids
Prophase	46	92
Metaphase	46	92
Anaphase	92	92
Telophase	92	92

- The chromosomes move toward poles of cell.
- Cytokinesis (division of the cytoplasm) begins in anaphase. A cleavage furrow forms as actin filaments underneath the plasma membrane constrict in a band called the contractile ring. Two cells will be produced as this process continues.



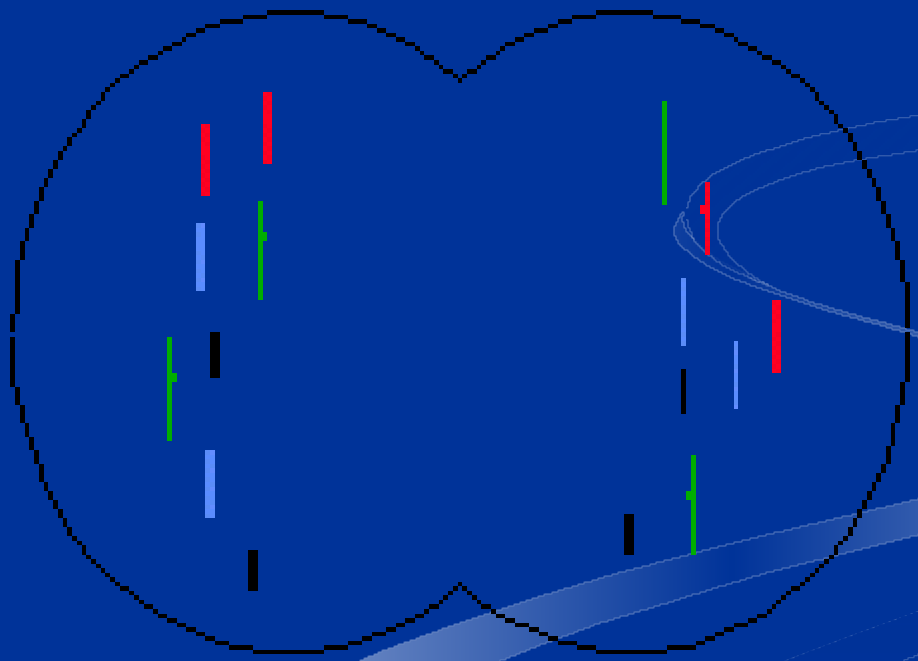
4- Telophase

The nuclear membrane reappears.

The chromosomes uncoil.

The spindle apparatus breaks down.

The cell divides into two



Telophase

- Telophase begins when chromosomes reach the poles of the daughter cells.
- Many of the events in telophase are the reverse of prophase. The chromosomes uncoil, the nuclear membranes around daughter nuclei appear, the spindle apparatus breaks down, and the nucleolus reappears.
- Cytokinesis is completed as telophase ends.

Interphase

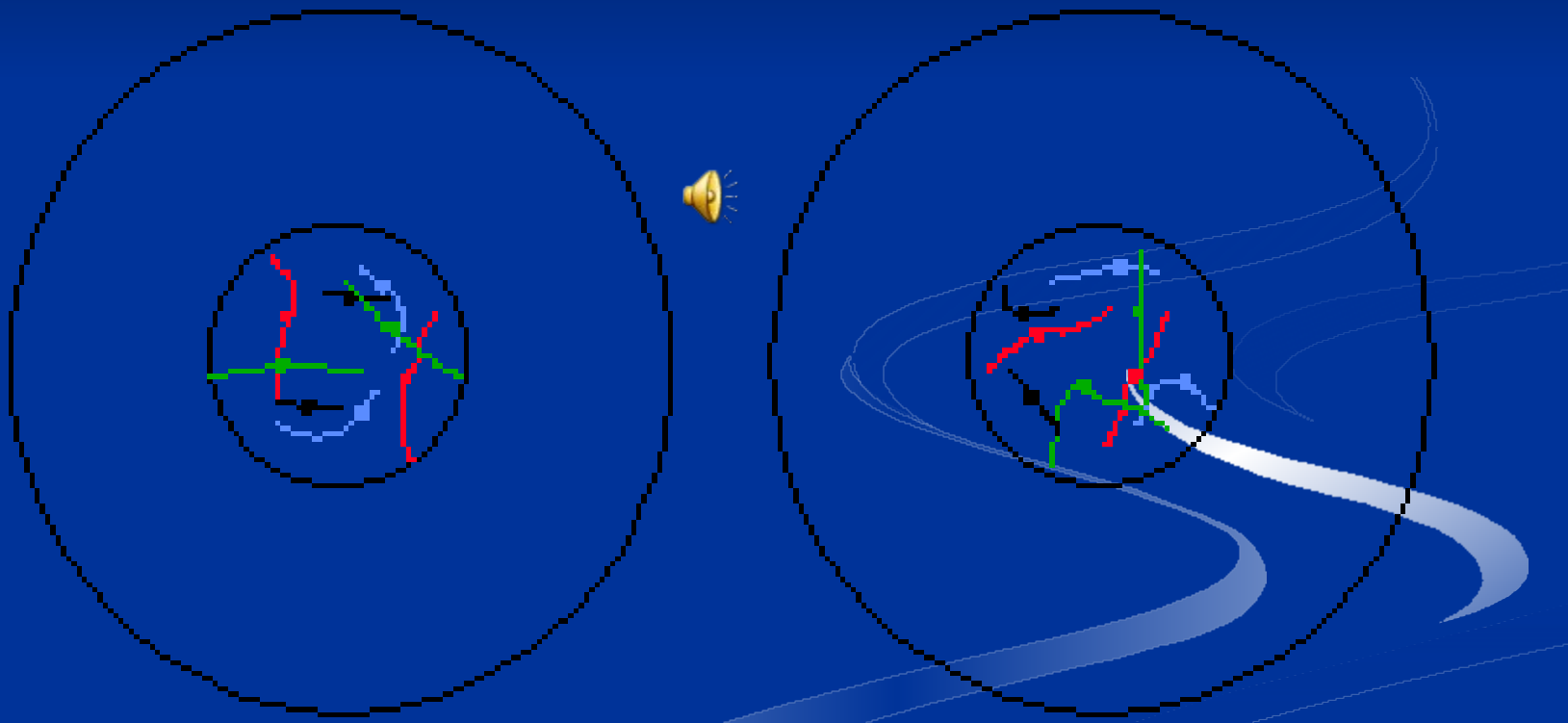
- This is the non-dividing phase.
- During interphase, the nucleus is visible and the chromosomes are uncoiled and invisible.
- Interphase includes G1, S and G2.

G1 Interphase

The chromosomes have only one chromatid_

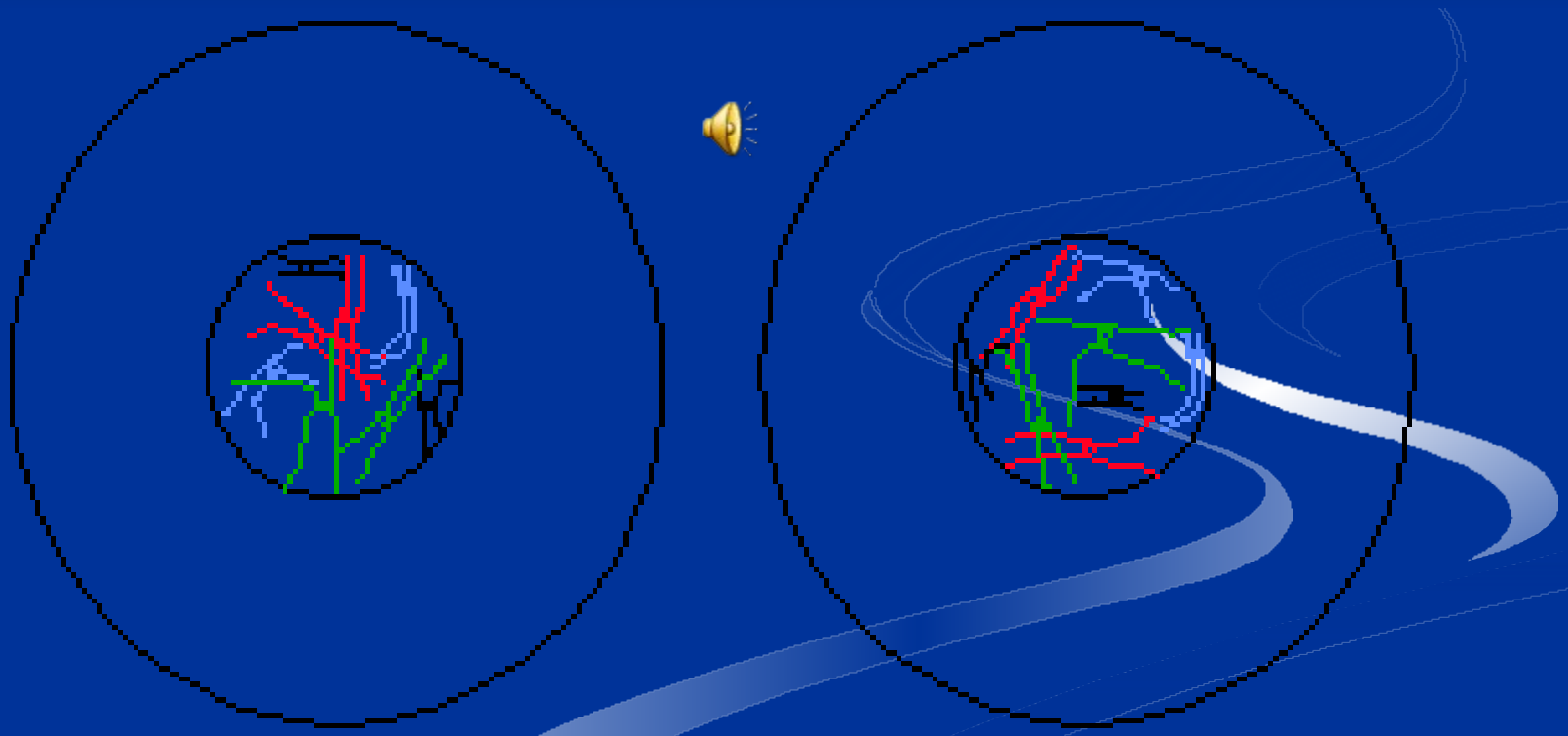
The cell grows in size.

Synthesis of organelles occurs.

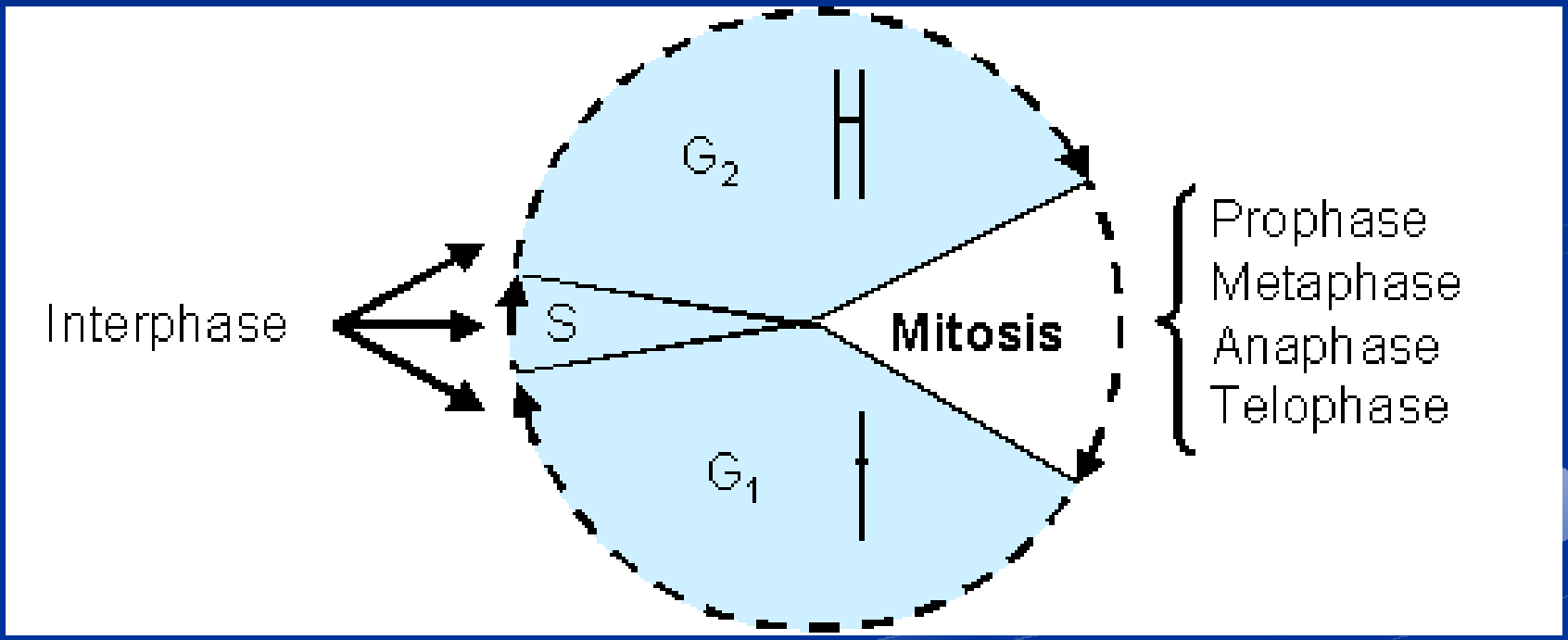


G2 Interphase

The chromosomes have two chromatids.
The synthesis of enzymes and other proteins in preparation for mitosis occurs during this period.



S Interphace
This is when DNA synthesis occurs.



Control of the cell cycle_

1- Telomeres

- Mammalian cells typically divide only about 50 times.
- This limit is set by the presence of repeated sequences of DNA at the tips of the chromosomes called telomeres.
- When the telomere is reduced to a certain size, the cell will no longer divide.
- Telomeres are restored to their original length by an enzyme called telomerase. This enzyme contains a single strand of RNA that is used to synthesize the telomeres.
- Telomerase is usually found in cells involved in the production of gametes. It is not normally found in

2- Cyclin-Dependent Kinases

- Some cells stop dividing in G1; others stop in G2.
- Kinases are enzymes that activate proteins by transferring a phosphate group from ATP to the protein being activated. An activated protein is needed for the cell cycle to proceed from G1 to S. Similarly, another activated protein is needed to move the cycle from G2 to mitosis.
- Kinases activate these proteins and thus stimulate the cell cycle to continue.
- Kinases are normally inactive and must be activated before they can activate other proteins. Cyclin-dependent kinases become activated by combining with a protein called cyclin.

- The level of cyclin fluctuates (cycles). At low levels, kinases are not activated and the cell cycle is halted. At high levels, activation occurs and the cycle resumes.

3- Growth Factors

- Growth factors are molecules that stimulate nearby cells to divide by promoting the binding of cyclin to kinase.
- Under normal conditions, cyclin combines with kinase only when growth factors are present. For example, damaged tissue releases growth factors to stimulate cell division needed to repair the tissue.
- S-Cyclin
- S-Kinase combines with S-cyclin and the resulting

Thank you

Gen. Embryology lecture II, cell division, part II

Meiosis

- Meiosis produces daughter cells that have one half the no. of chromosomes as the parent cell.

  $2N \longrightarrow N$

- Meiosis enables organisms to reproduce sexually. Gametes (sperm and eggs) are haploid.
- Meiosis is necessary in sexually-reproducing organisms because the fusion of two gametes (fertilization) doubles the No. of chromosomes.
- Meiosis involves two divisions producing a total of four daughter cells

- Sexually ; sexual reproduction is reproduction that involves the fusion of gametes from two different parents.

As a consequence of combining genes from two different parents, sexual reproduction promotes genetic variation in populations.

Phases of Meiosis_

- There are two divisions in meiosis; the first division is meiosis 1 and the second is meiosis 2.

- The phases have the same names as those of mitosis:

  Meiosis 1: prophase 1, metaphase 1, anaphase 1, and telophase 1

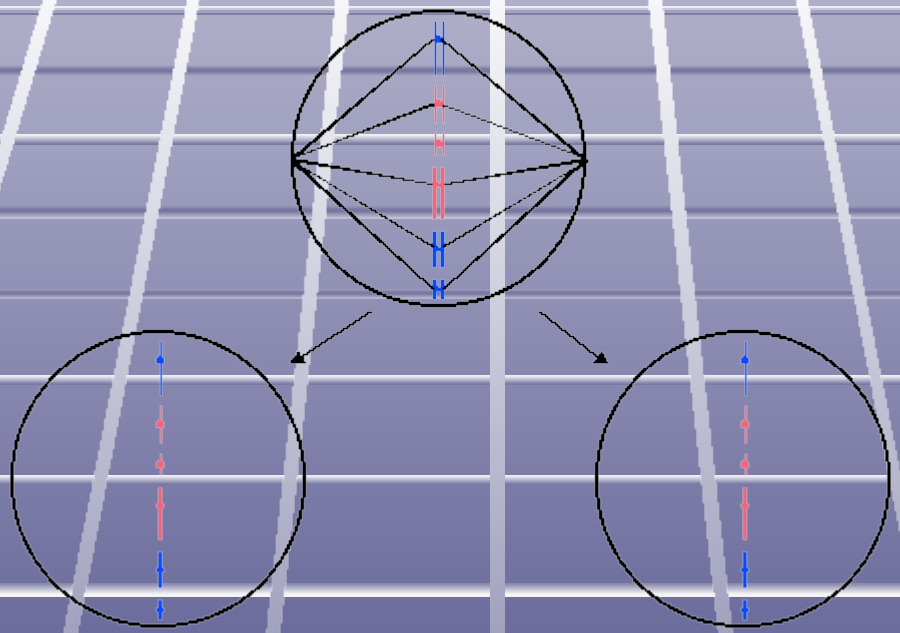
  Meiosis 2: prophase 2, metaphase 2, anaphase 2, and telophase 2

- In the first meiotic division, the number of cells is doubled but the number of chromosomes is not. This results in 1/2 as many chromosomes per cell.

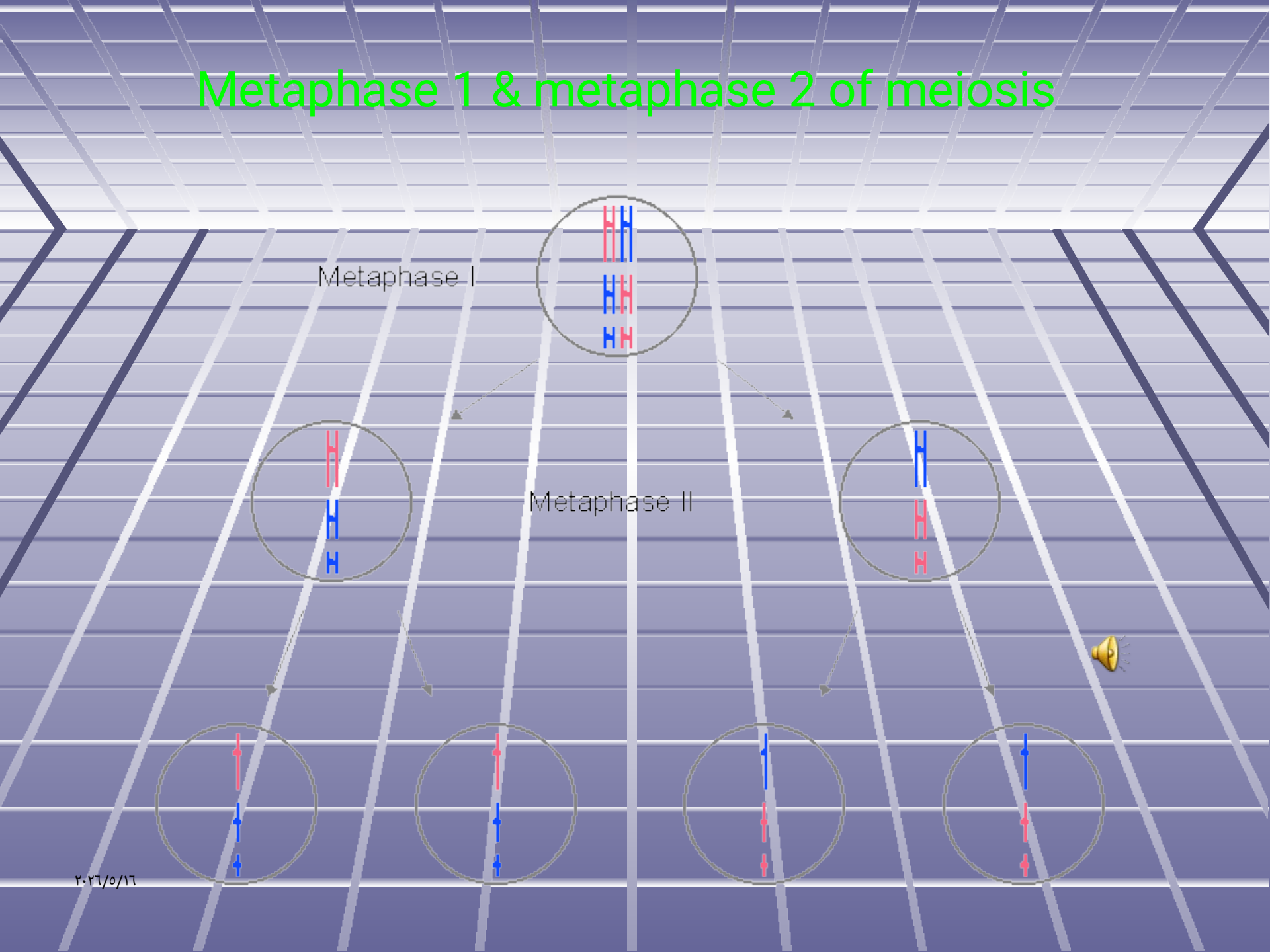
- The second meiotic division is like mitosis; the number of chromosomes does not get reduced.

The diagram below shows that the chromosome alignment pattern during metaphase of mitosis results in the chromosomes splitting (doubling). Prophase, anaphase and telophase are not shown.

The alignment pattern during metaphase I of meiosis results in pairs separating; there is no doubling.

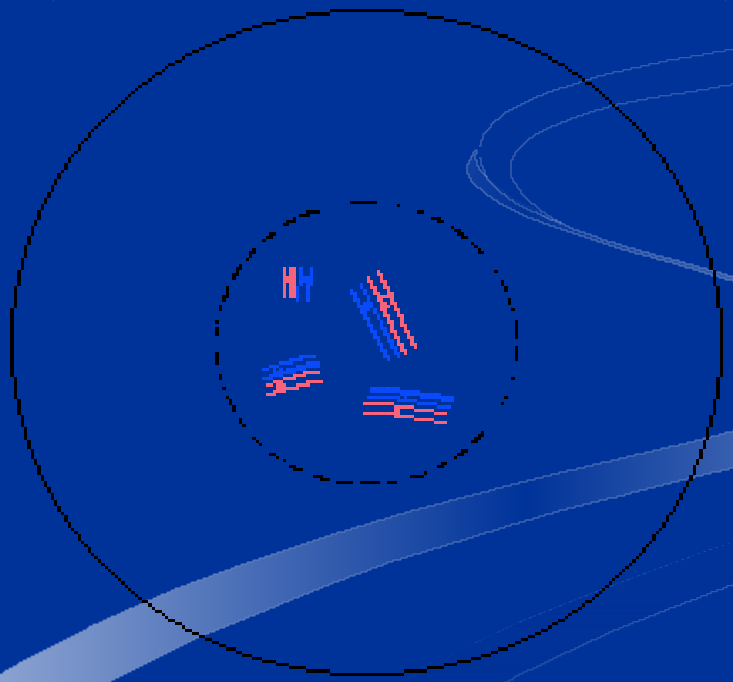


Metaphase 1 & metaphase 2 of meiosis

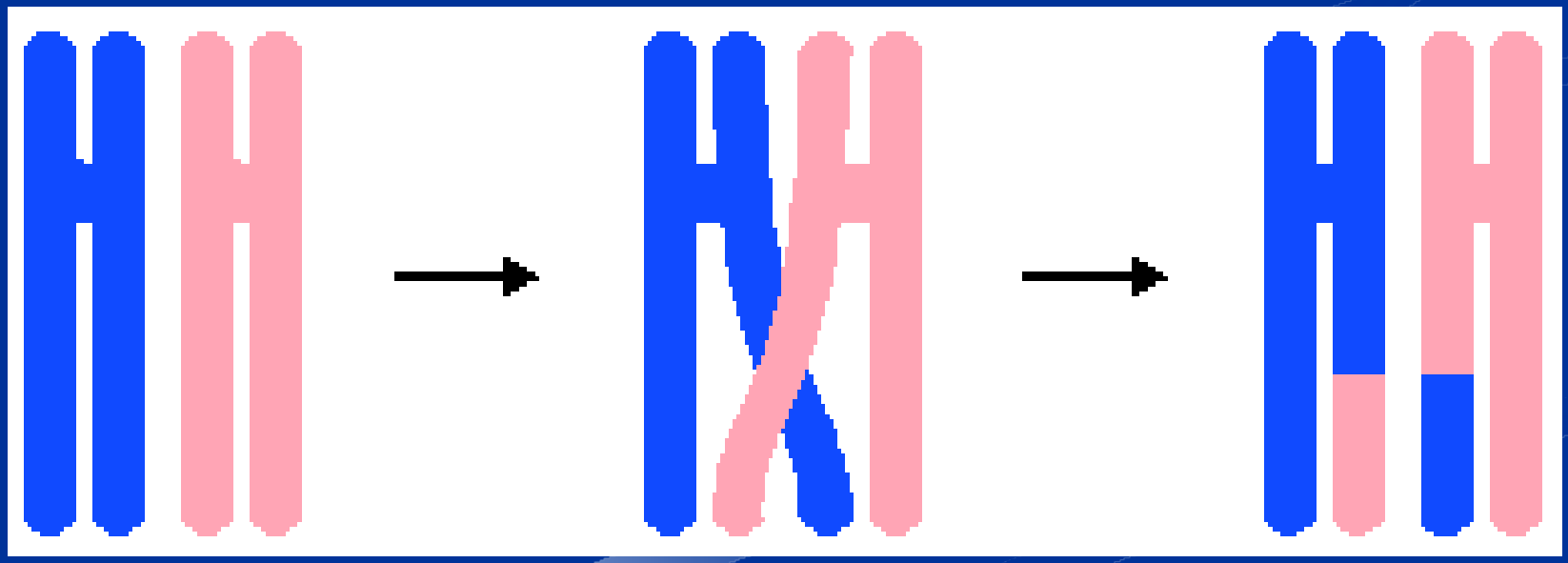


Prophase I

The events that occur during prophase of mitosis also occur during prophase I of meiosis. The chromosomes coil up, the nuclear membrane begins to disintegrate, and the centrosomes begin moving apart.
Synapsis (joining) of homologous chromosomes produces tetrads (also called bivalents).



The two chromosomes may exchange fragments by a process called crossing over.

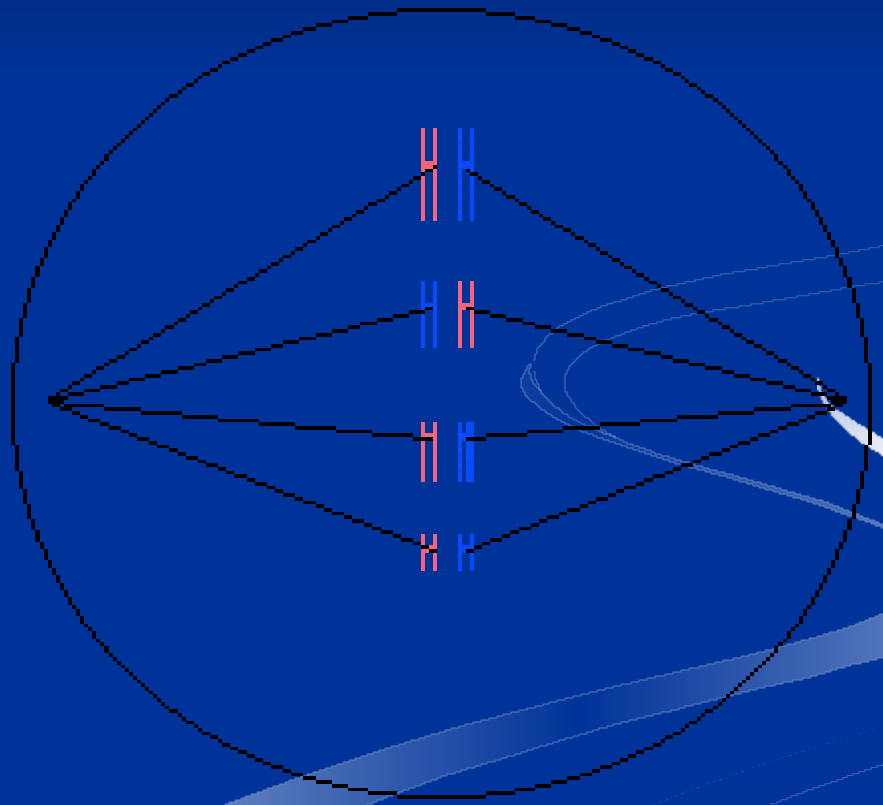


- When the chromosomes partially separate in late prophase, the areas where crossing over occurred remain attached and are referred to as Chiasmata . They hold the chromosomes together until they separate during anaphase.

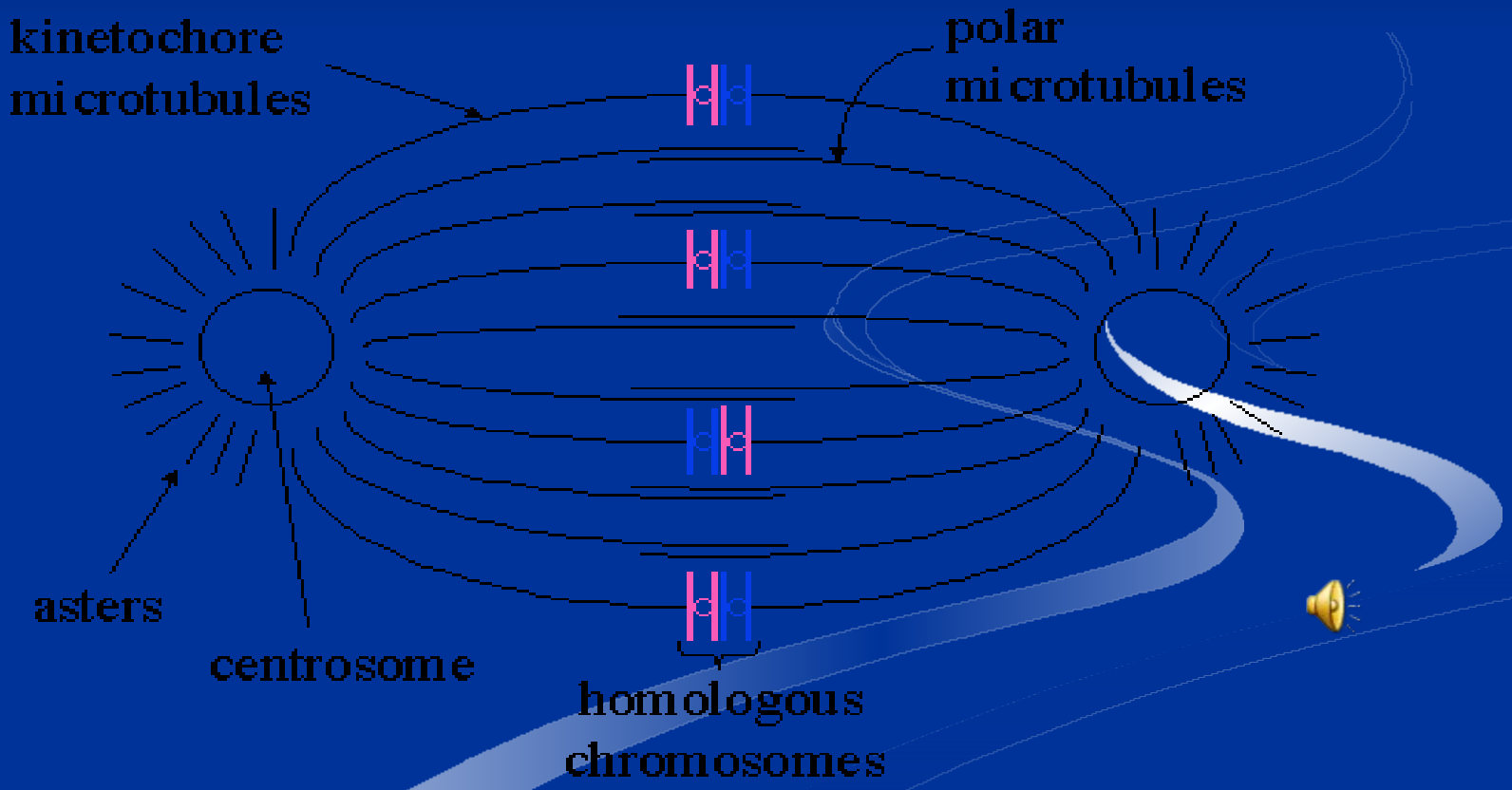
- Crossing over between homologous chromosomes is likely to occur at several different points, resulting in chromosomes that are mixtures of the original two chromosomes.

Metaphase I

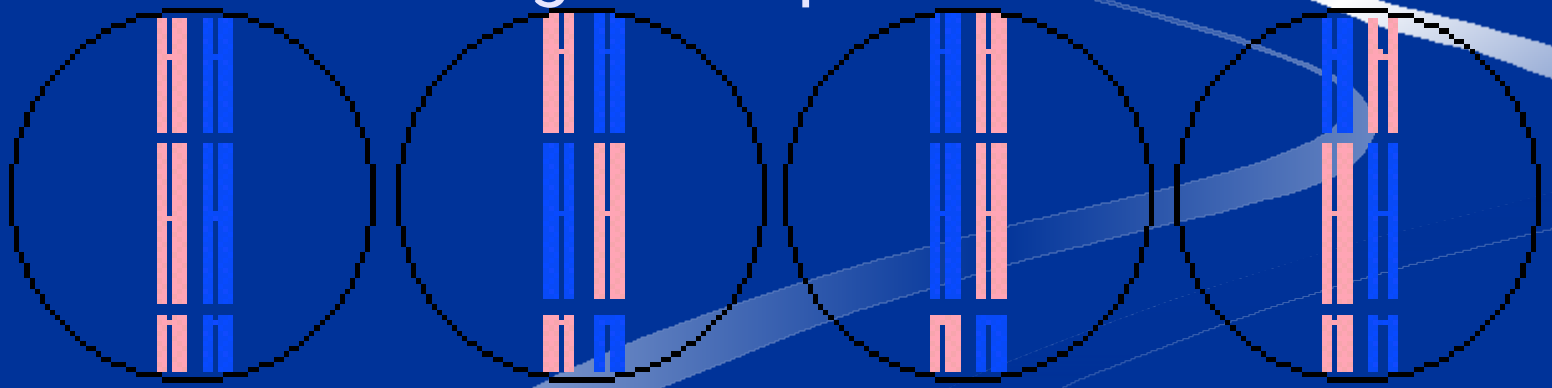
Bivalents (tetrads) become aligned in the center of the cell and are attached to spindle fibers.



The chromosome alignment illustrated below is from a cell with a diploid chromosome number of 8.

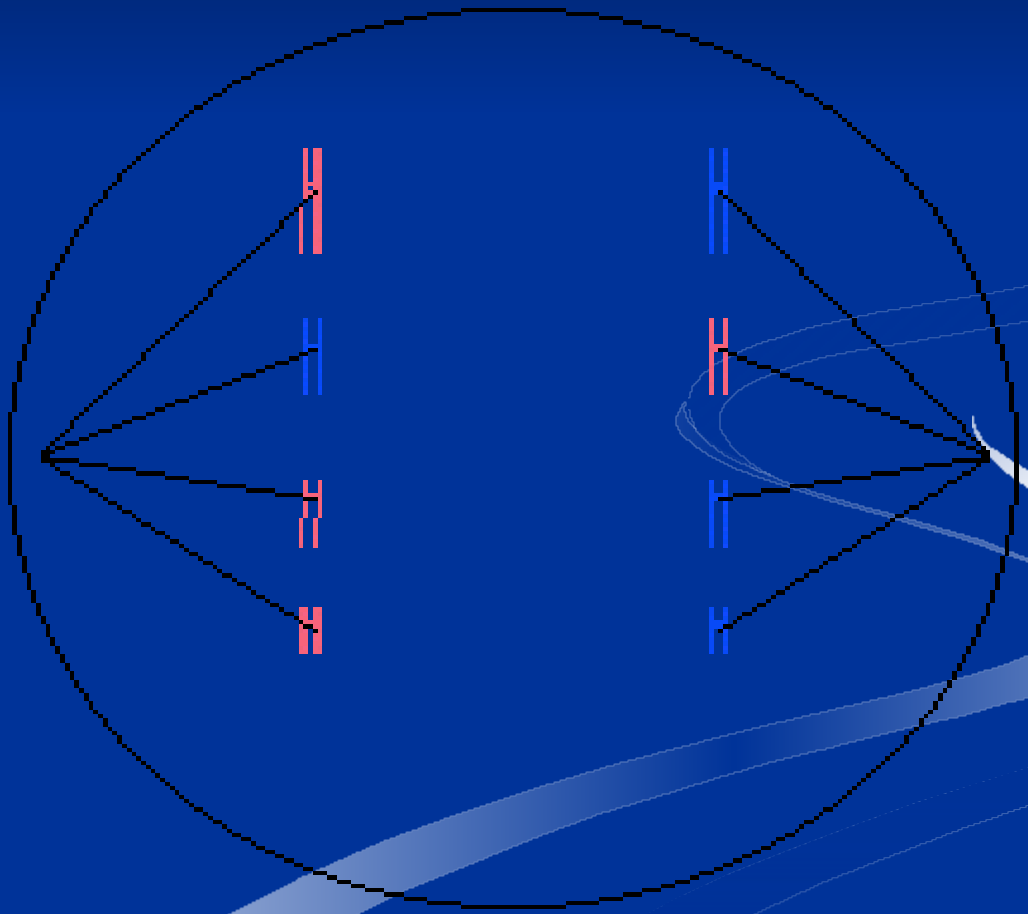


Independent assortment refers to the random arrangement of pairs of chromosomes. The diagram below shows four possible arrangements of chromosomes during metaphase 1 from an individual that has 6 total chromosomes. Suppose that the pink chromosomes are those that the individual inherited from its mother and the blue colored ones were inherited from its father. For each chromosome pair, the chromosome that is on the left (maternal or paternal) is determined randomly. As can be seen, there are several alignment possibilities.



Anaphase I

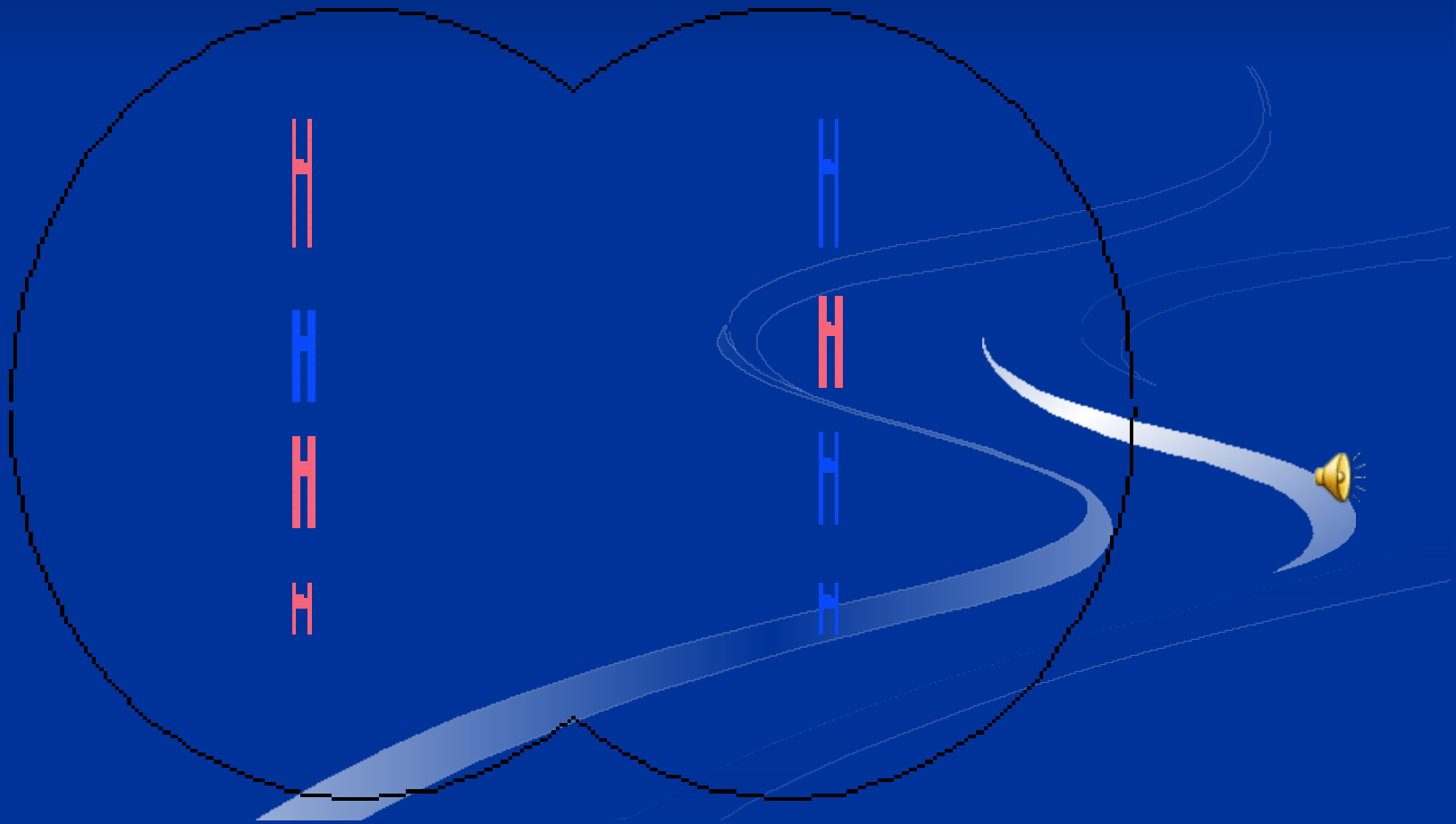
Anaphase I begins when homologous chromosomes separate.



Telophase I

The nuclear envelope reforms and nucleoli reappear.

This stage is absent in some species.

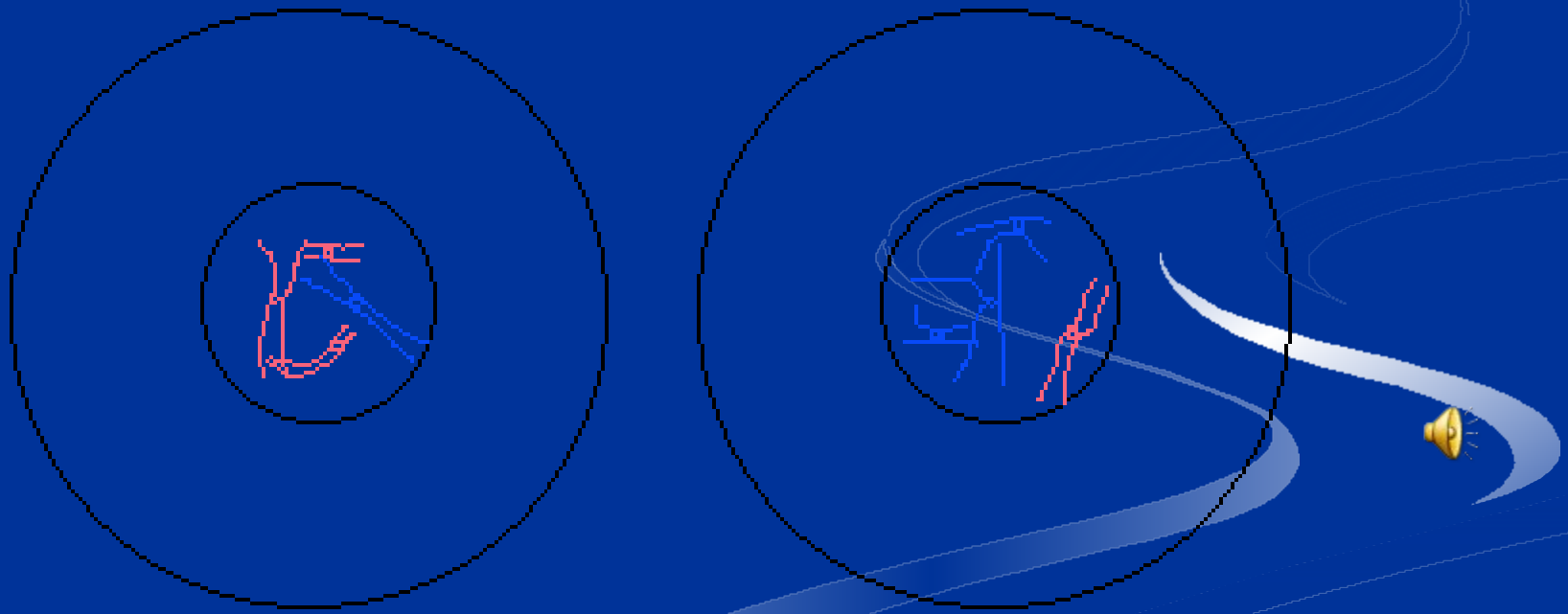


Interkinesis

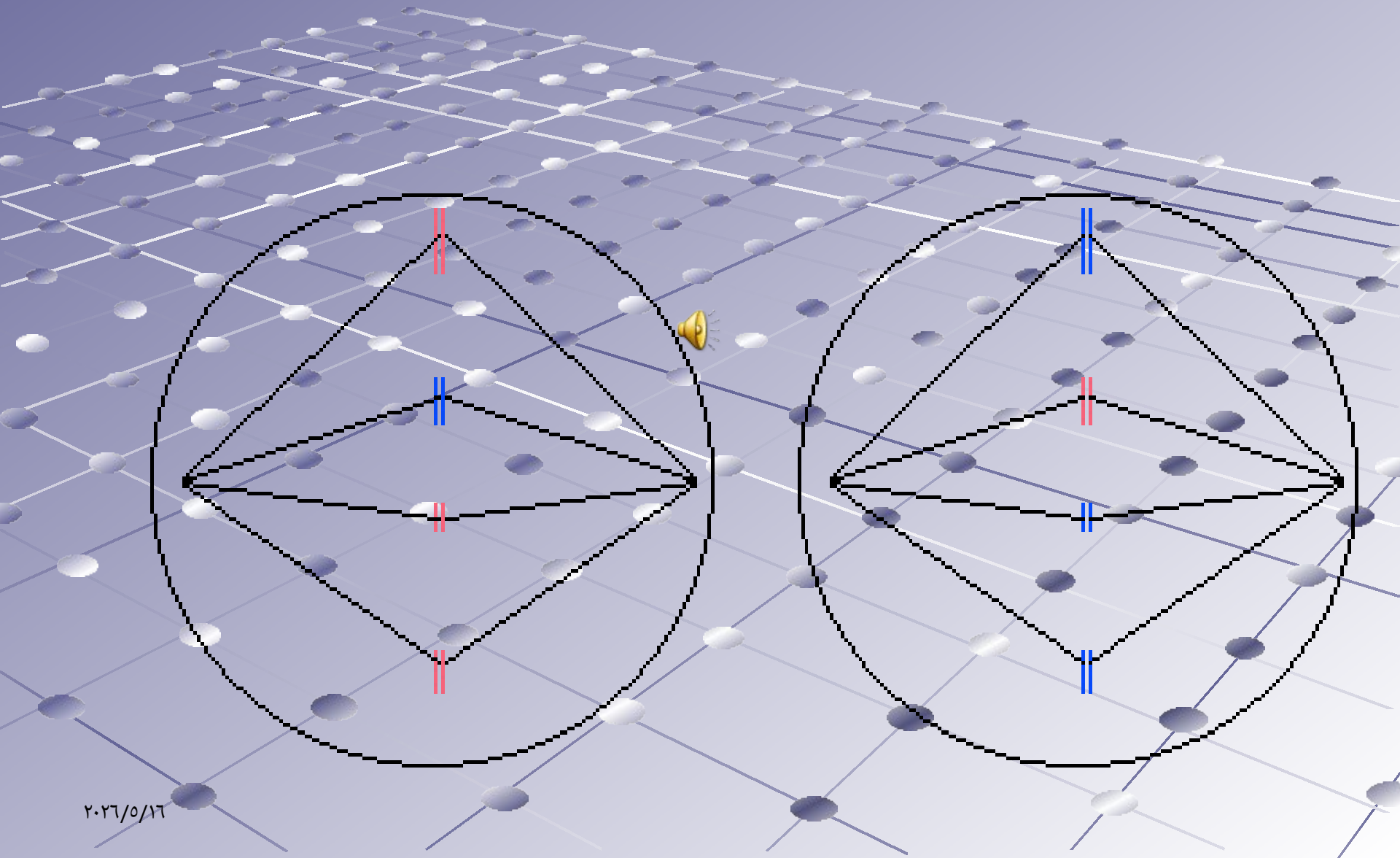
- Interkinesis is similar to interphase except DNA synthesis does not occur.
- The events that occur during meiosis II are similar to mitosis.

The events that occur during meiosis II are similar to mitosis.

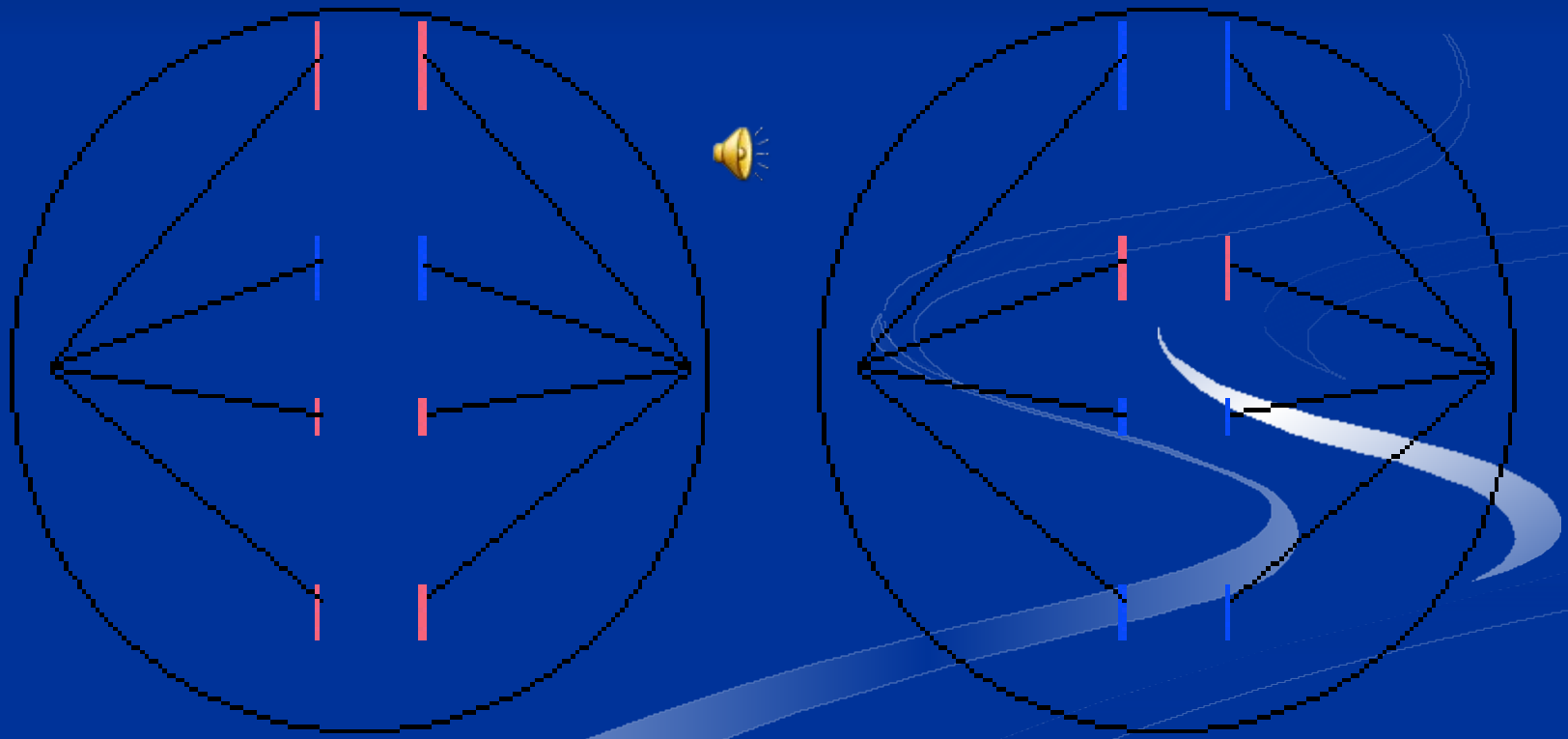
1- Prophase II



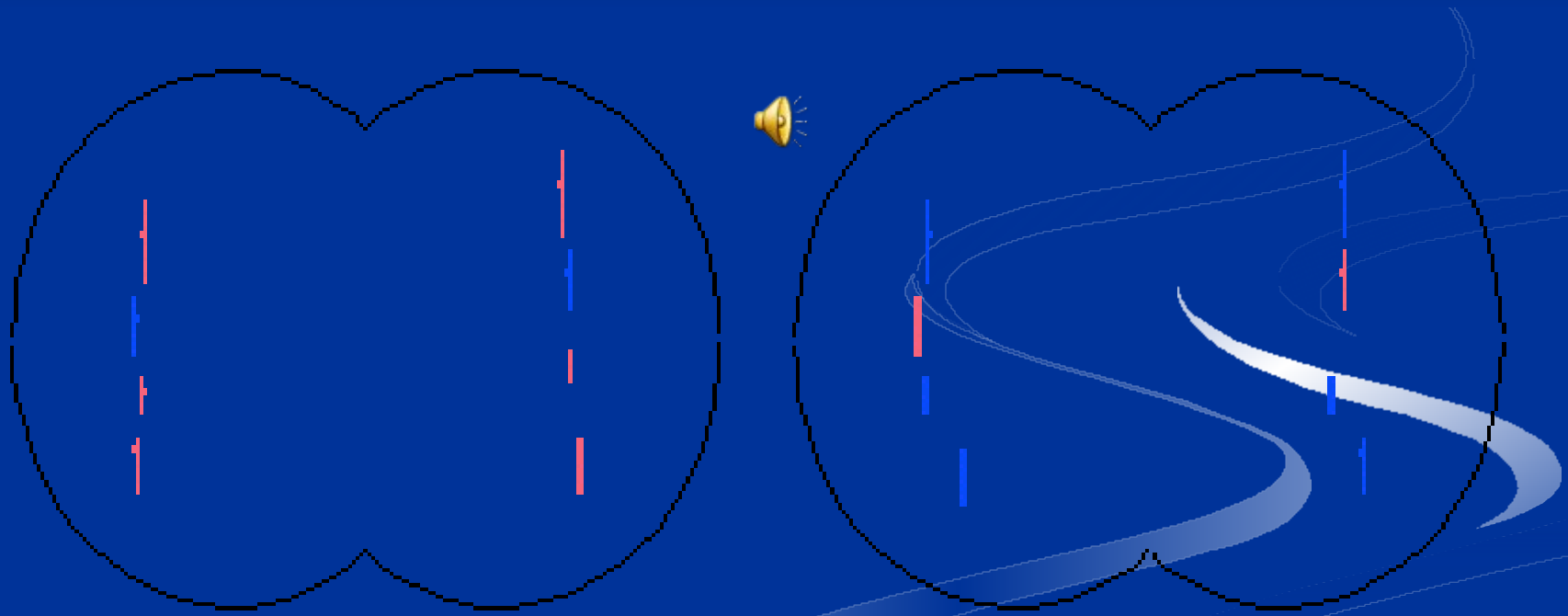
2- Metaphase II



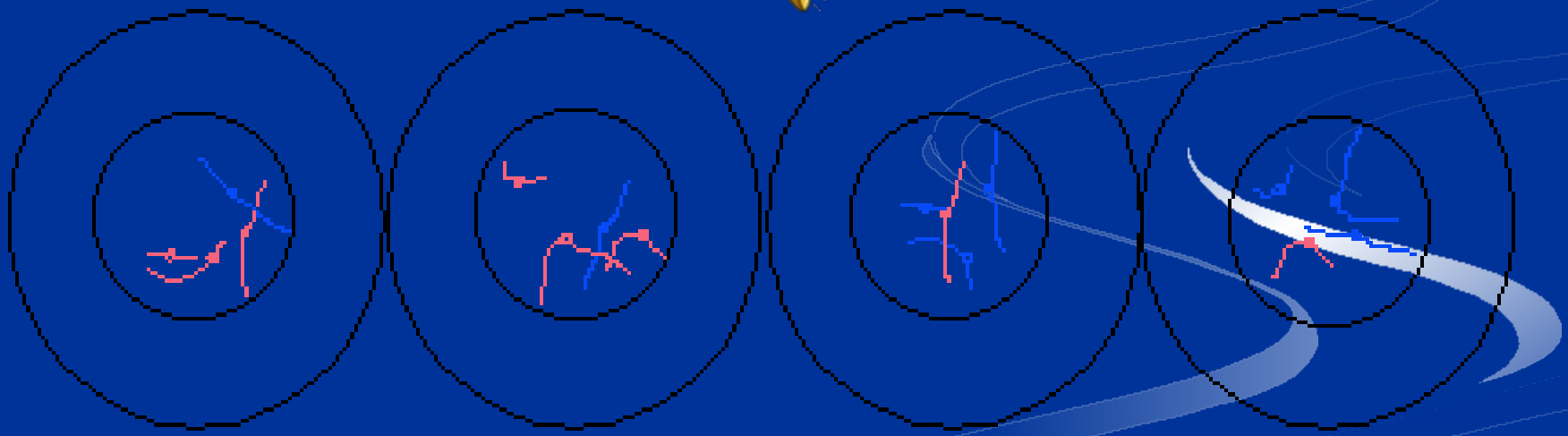
3- Anaphase II



4- Telophase II



Daughter Cells



Variation_

- Sexual reproduction promotes variation because each gamete (sperm or egg) contains a mixture of genes from two different parents.
- Crossing-over and Independent assortment promote variation. During prophase of meiosis, crossing-over results in chromosomes that have some genes from one parent and some genes from the other parent.

- Individuals contain two sets of each chromosome but gametes contain only one set. For each homologous pair of chromosomes, one chromosome will be randomly selected for each gamete formed (independent assortment).
- Variation is necessary for natural selection. Recall that natural selection favors individuals with characteristics that are best adapted to their environments. Variation is therefore necessary for species to become adapted to their environment and it enables them to change when the environment changes.

THANK YOU