Topic 3: Meiosis

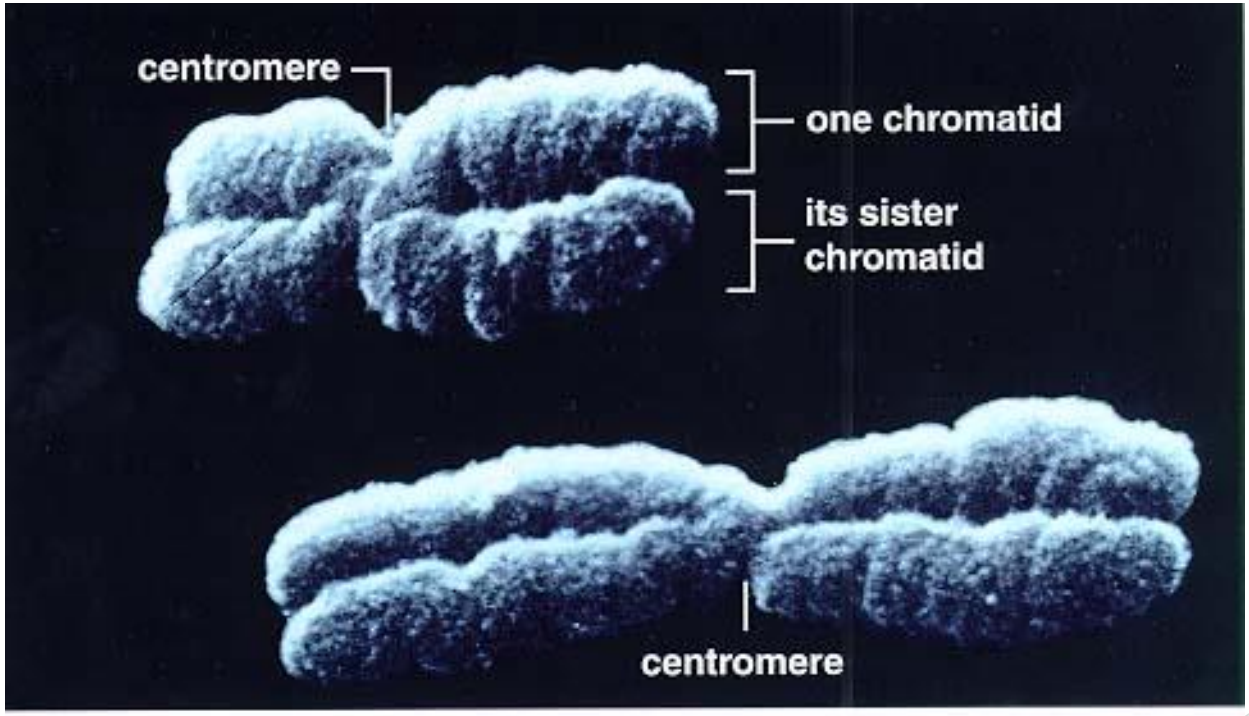
By the end of this topic, you should be able to…

- *Compare and contrast sexual and asexual reproduction*
- *Illustrate meiosis I and meiosis II*
- *Explain fertilization of eukaryotic cells*
- *Explain production of egg and sperm cells*
- *Explain nondisjunction and read a karyotype*

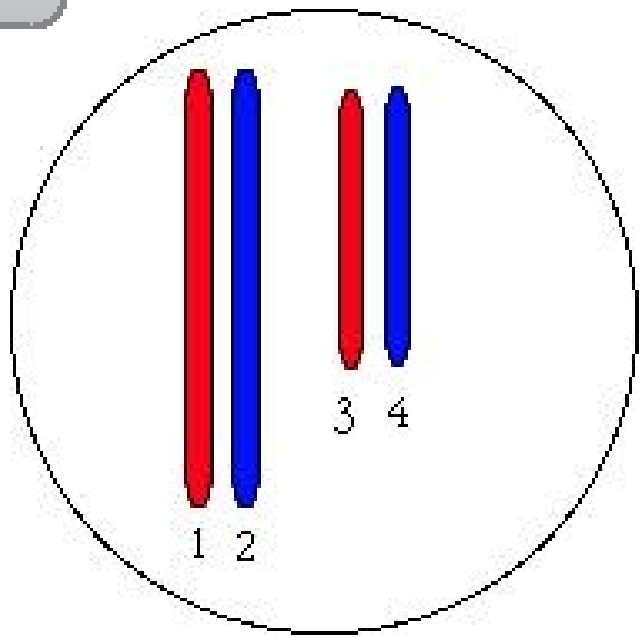
Warm-Up

- Are somatic (body) cells haploid or diploid and what does this mean?
  - Haploid = one set of chromosomes (egg, sperm… gametes)
  - Diploid = two sets of chromosomes (body cells)
- How many chromosomes are found in human body cells?
  - 46 chromosomes (23 pairs – 1 set from mom, 1 set from dad)
- Why is mitosis necessary and important?
  - Grow; repair; development
- How do daughter cells differ from parent cells in mitosis?
  - Genetically identical (don't differ)
- How does mitosis differ from meiosis?

Chromosome Structure, revisited



Diploid Cell- where DNA comes from



Example - an organism is $2n = 4$.

- Chromosomes 1 & 2 are homologous chromosomes
- Chromosomes 3 & 4 are homologous chromosomes
- Chromosomes 1 & 3 came from the mother
- Chromosomes 2 & 4 came from the father

Meiosis does two things -

1) Meiosis takes a cell with two copies of every chromosome (**diploid**) and makes cells with a single copy of every chromosome (**haploid**)

*In meiosis, one diploid cells produces **four haploid cells**.*

2) Meiosis scrambles the specific forms of each gene that each sex cell (egg or sperm) receives.

This makes for a lot of genetic diversity. This trick is accomplished through independent assortment and crossing-over.

Genetic diversity is important for the evolution of populations and species.

Why do we need meiosis?

- Meiosis is necessary to halve the number of chromosomes going into the sex cells

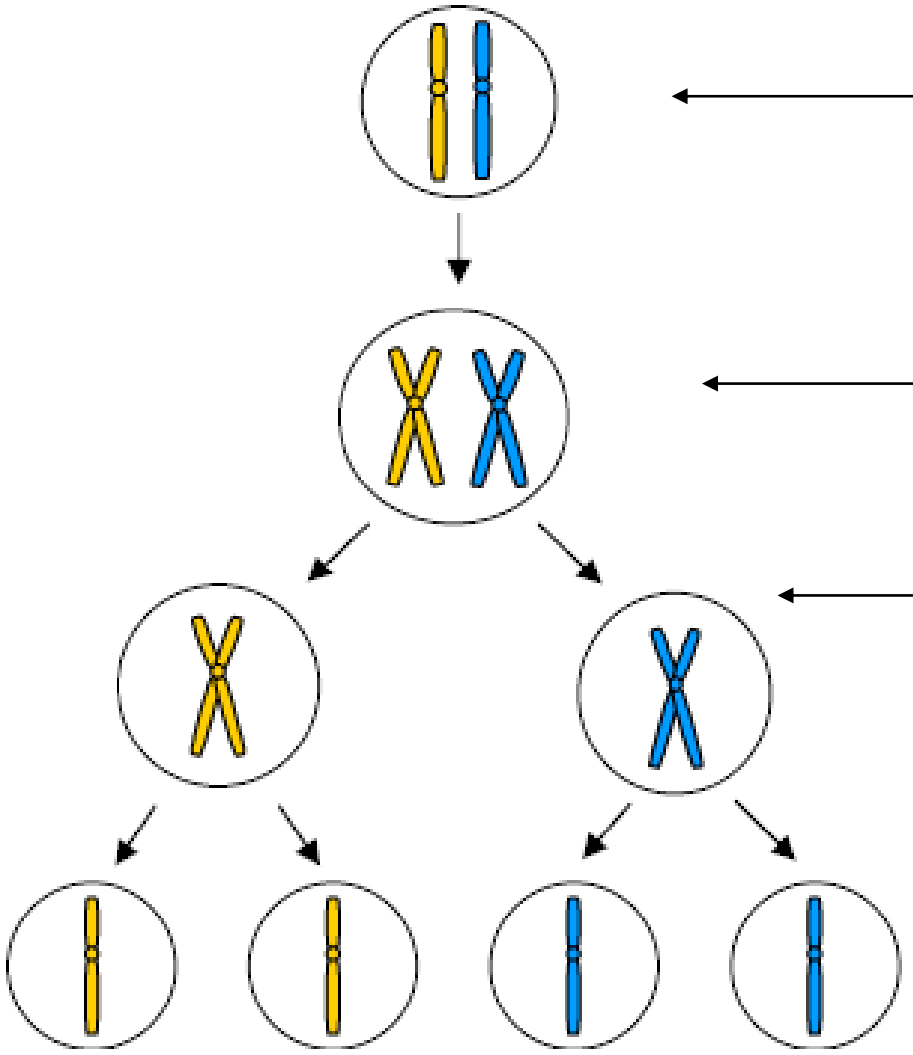
Why halve the chromosomes in gametes?

- At fertilization the male and female sex cells will provide ½ of the chromosomes each – so the offspring has genes from both parents

Purpose

- Meiosis is used to make special cells - sperm cells and egg cells - that have half the normal number of chromosomes. It reduces the number from 23 pairs of chromosomes to 23 single chromosomes. The cell copies its chromosomes, but then separates the 23 pairs to ensure that each daughter cell has only one copy of each chromosome. A second division that divides each daughter cell again to produce four daughter cells.

Meiosis



Parent cell - chromosome pair

Chromosomes copied

1st division - pairs split

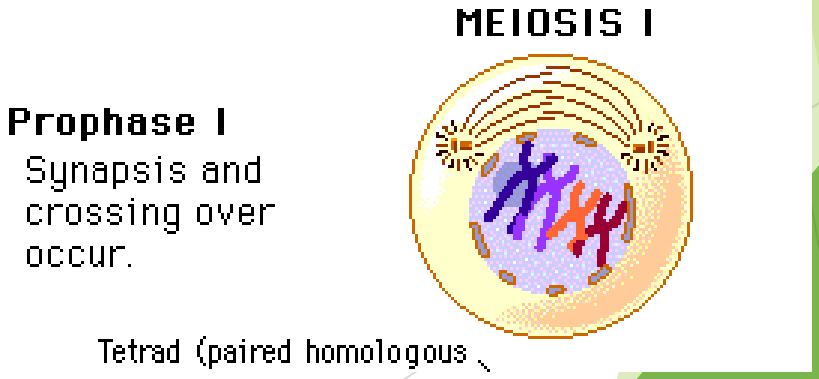
2nd division - produces 4 gamete cells with ½ the original no. of chromosomes

Meiosis I : Separates Homologous/Matching Chromosomes

- Interphase
  - DNA is replicated
  - The result is two genetically identical sister chromatids which remain attached at their centromeres

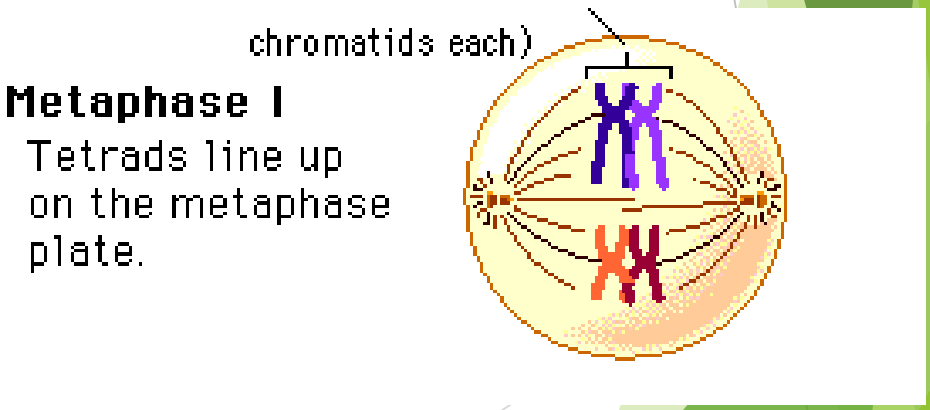
Prophase I

- During this phase each pair of chromatids don't move to the equator alone, they match up with their homologous pair and fasten together (synapsis) in a group of four called a tetrad.
- Extremely IMPORTANT!!! It is during this phase that crossing over can occur.
- Crossing Over is the exchange of segments during synapsis.



Metaphase I

- The chromosomes line up at the equator attached by their centromeres to spindle fibers from centrioles.
  - Still in homologous pairs



Anaphase I

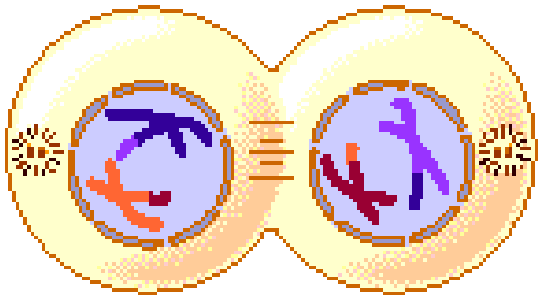
- The spindle guides the movement of the chromosomes toward the poles
  - Sister chromatids remain attached
  - Move as a unit towards the same pole
- The homologous chromosome moves toward the opposite pole

Anaphase I
Homologous pairs separate.

Telophase I

- This is the end of the first meiotic cell division.
- The cytoplasm divides, forming two new daughter cells.
- Each of the newly formed cells has half the number of the parent cell's chromosomes, but each chromosome is already replicated ready for the second meiotic cell division

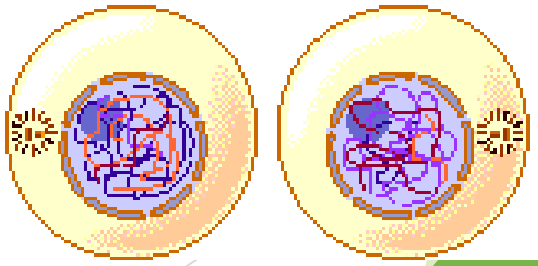
Telophase I

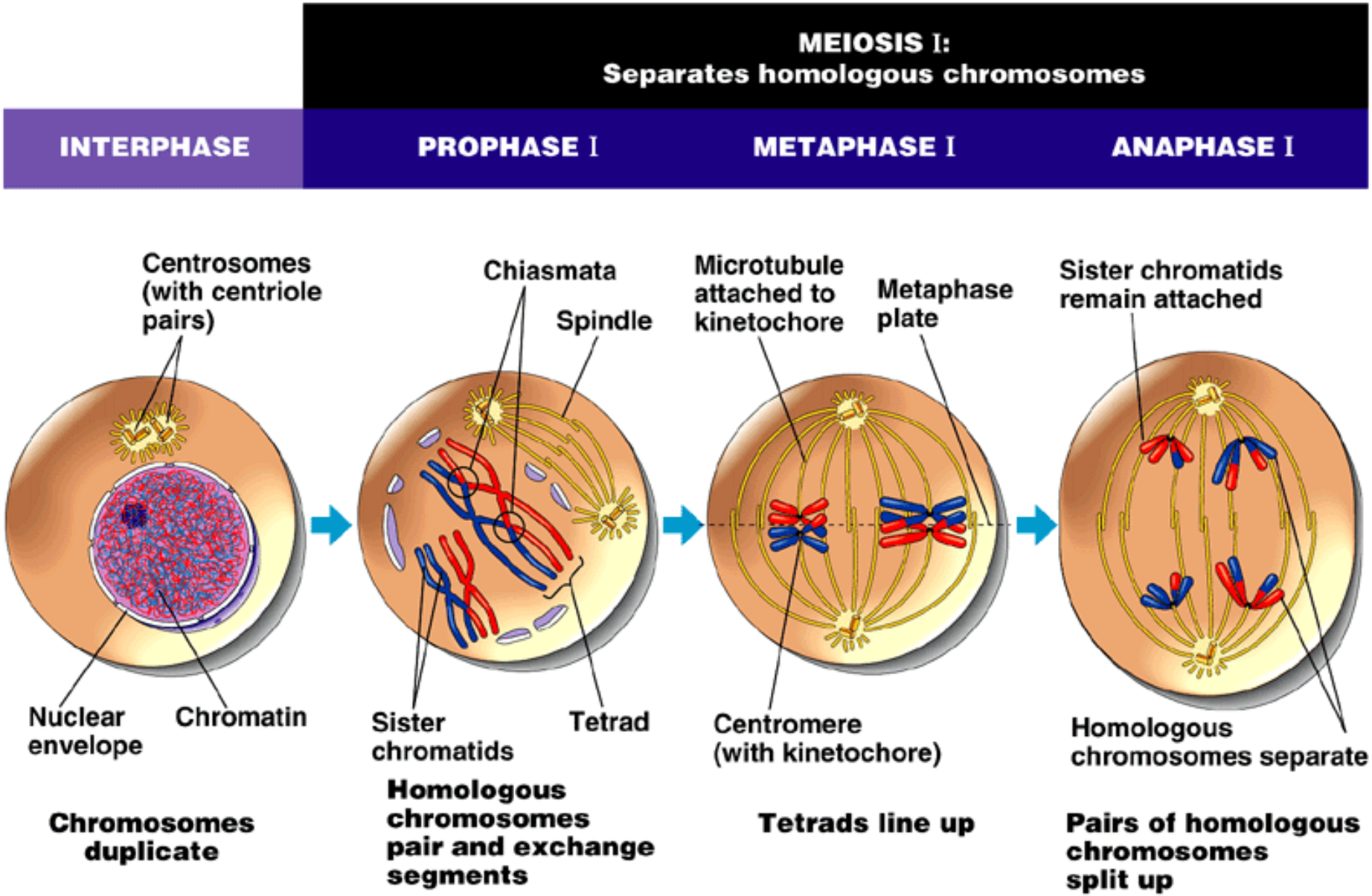


Cytokinesis

- Occurs simultaneously with telophase I
  - Forms 2 daughter cells
- Plant cells – cell plate
- Animal cells – cleavage furrows
- NO FURTHER REPLICATION OF GENETIC MATERIAL PRIOR TO THE SECOND DIVISION OF MEIOSIS

Cytokinesis I





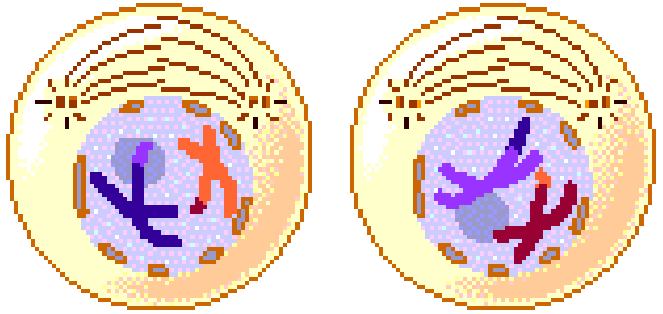
Meiosis II :
Separates sister chromatids

- Proceeds very similar to mitosis
- ***THERE IS NO INTERPHASE II !***

Prophase II

- Each of the daughter cells forms a spindle, and the double stranded chromosomes move toward the equator

Prophase II

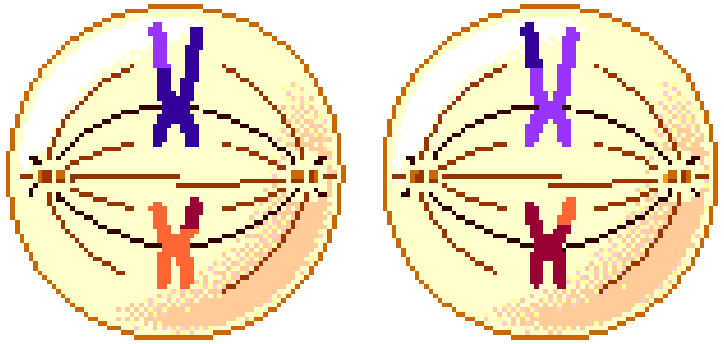


Metaphase II

- The chromosomes are positioned on the metaphase plate in a mitosis-like fashion

Metaphase II

Chromosomes line up on the metaphase plate.



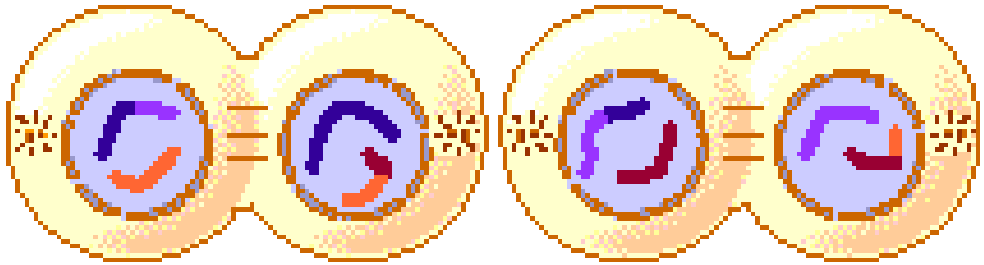
Anaphase II

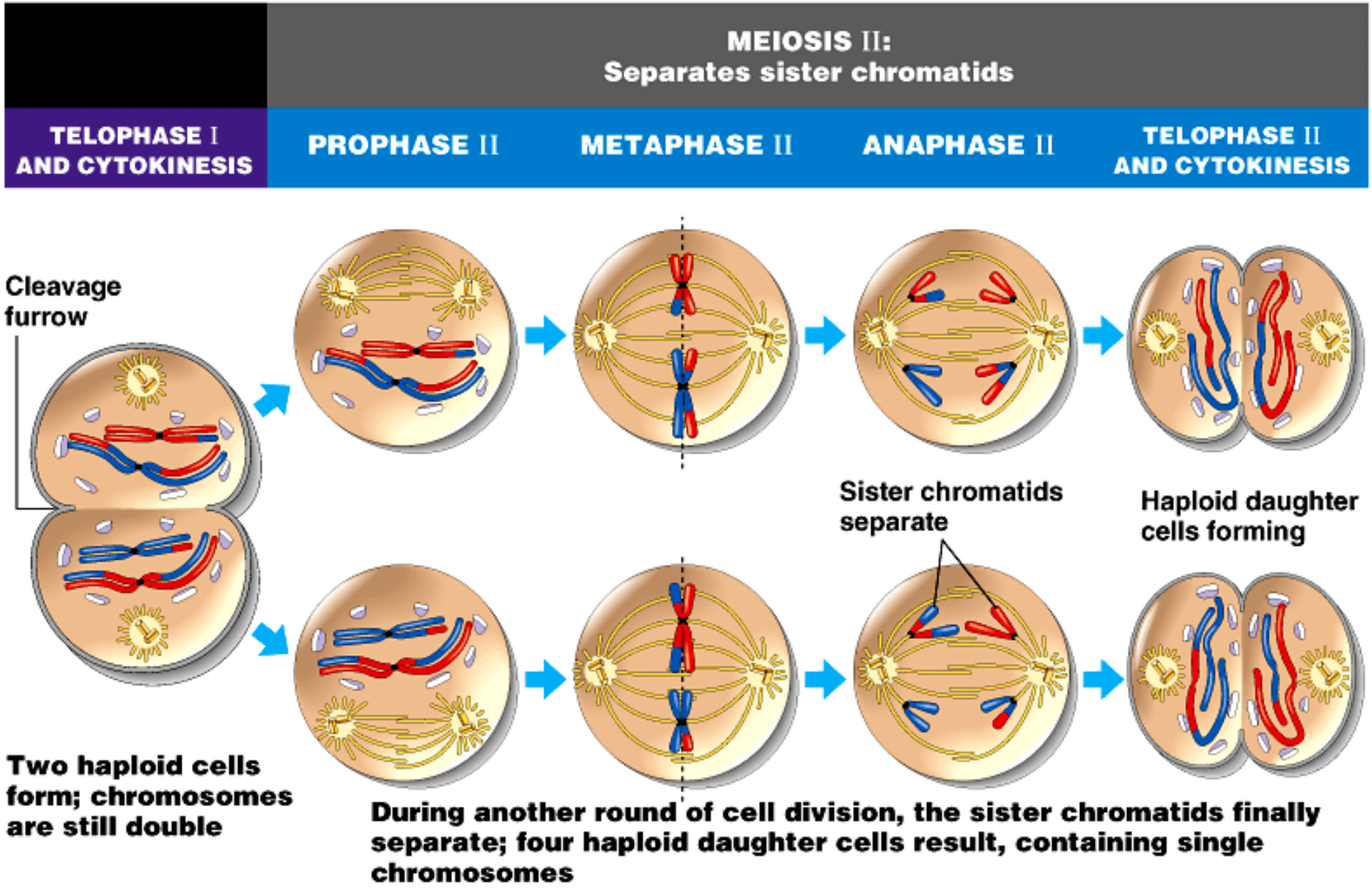
- The centromeres of sister chromatids finally separate
- The sister chromatids of each pair move toward opposite poles
  - Now individual chromosomes

Telophase II and Cytokinesis

- Nuclei form at opposite poles of the cell and cytokinesis occurs
- After completion of cytokinesis there are four daughter cells
  - All are haploid (n)

Telophase II

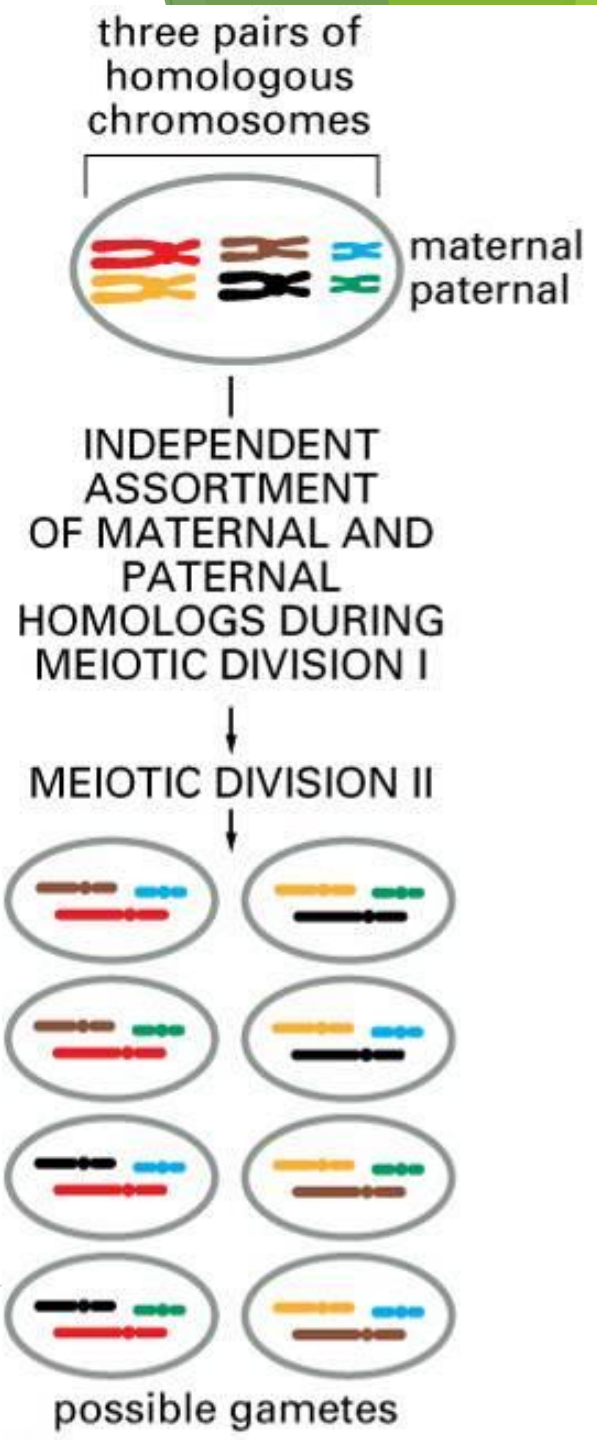


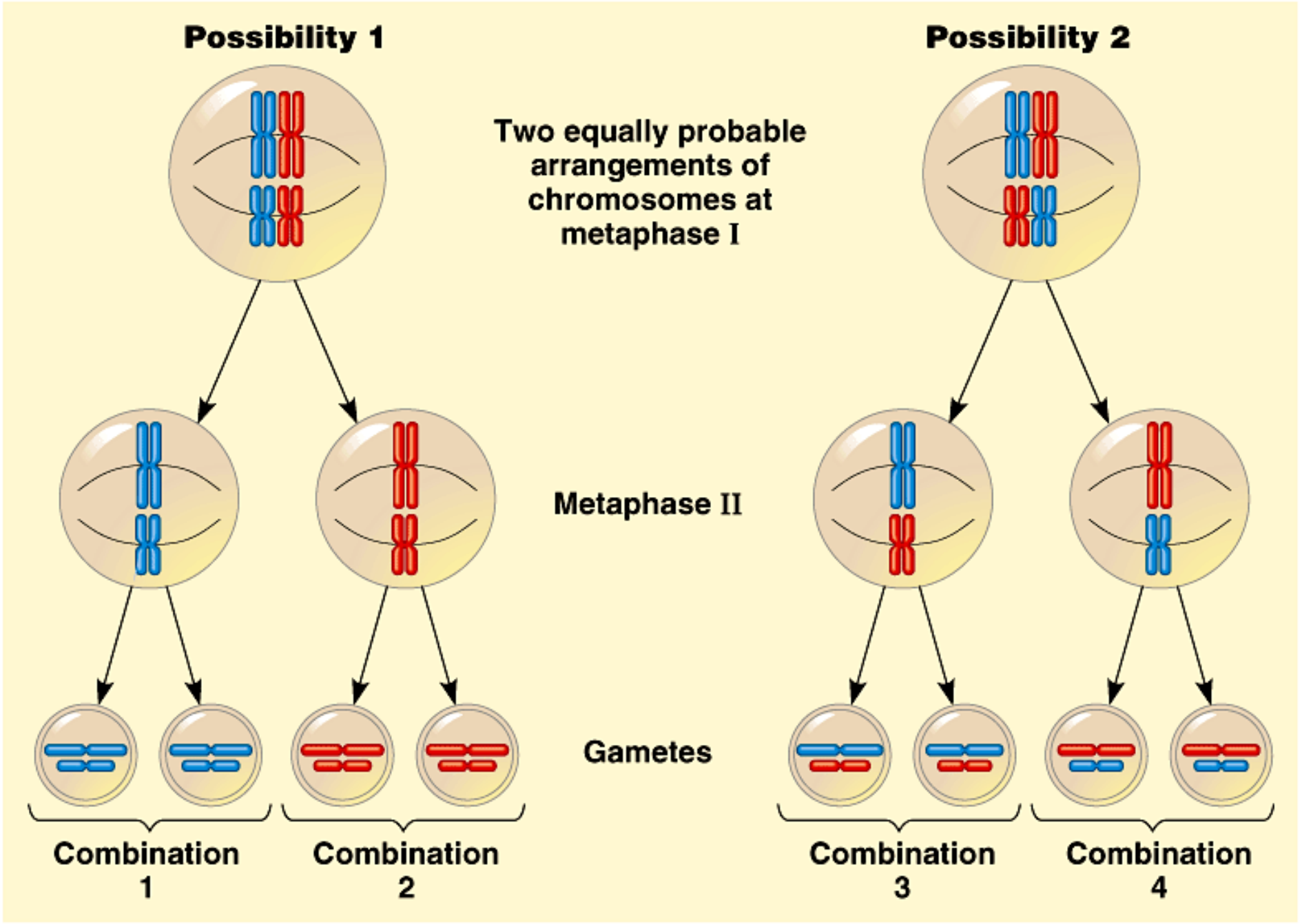


One Way Meiosis Makes Lots of Different Sex Cells (Gametes) - Independent Assortment

Independent assortment produces 2^n distinct gametes, where n = the number of unique chromosomes.

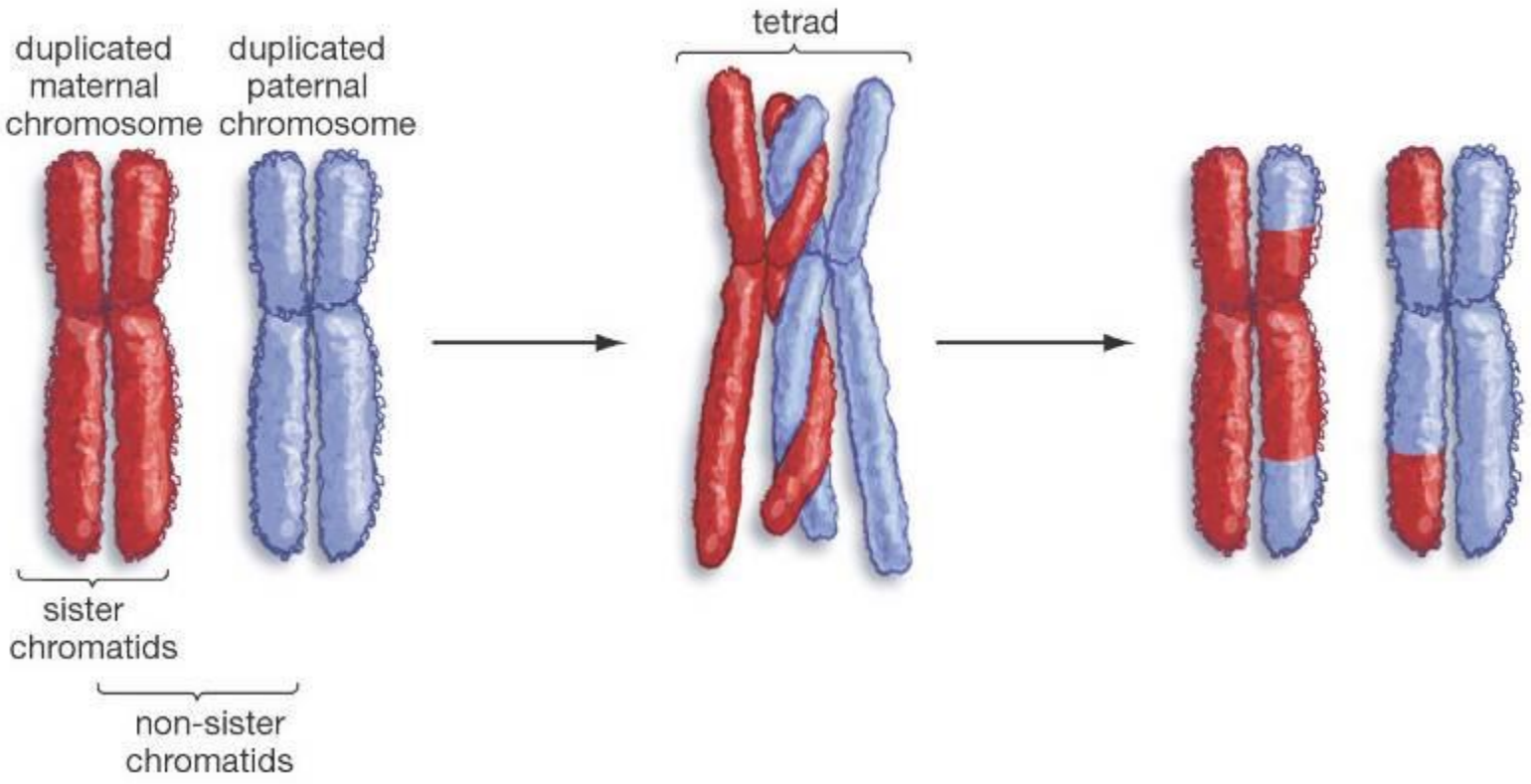
In humans, n = 23 and 2^{23} = 6,000,0000.





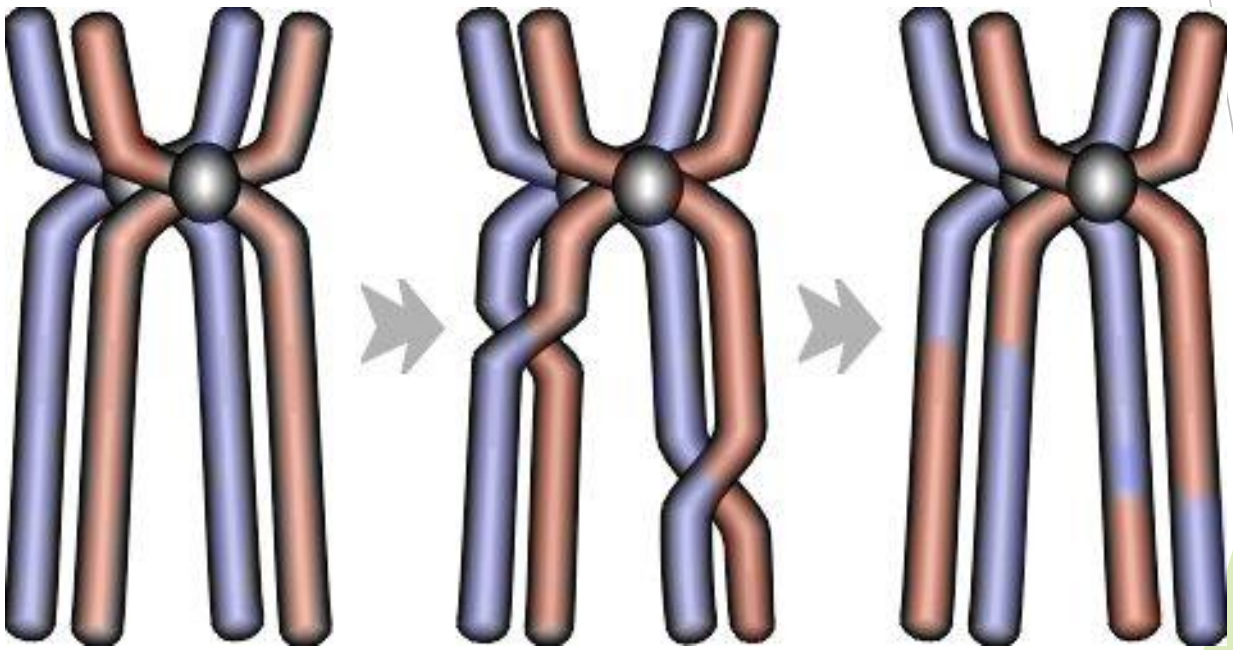
Another Way Meiosis Makes Lots of Different Sex Cells - Crossing-Over

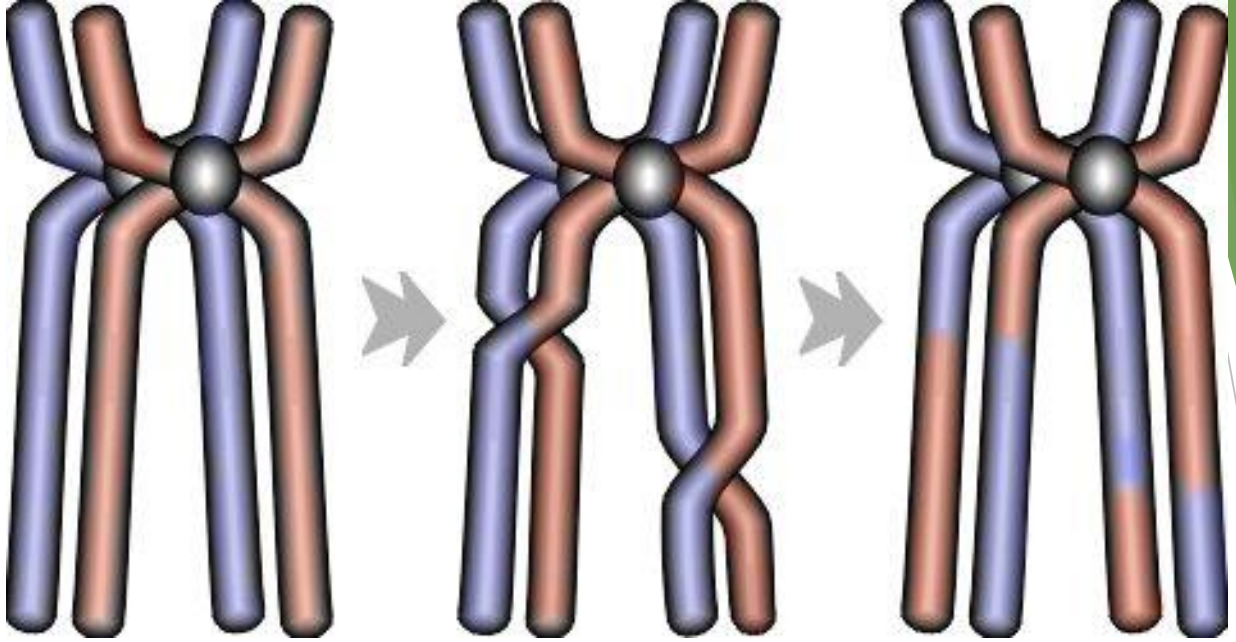
Exchange of parts of non-sister chromatids.



Crossing-over multiplies the already huge number of different gamete types produced by independent assortment.

swapping genes is known as a crossing over





Crossovers occur while the homologous chromosomes are paired in **prophase I**.

Meiosis

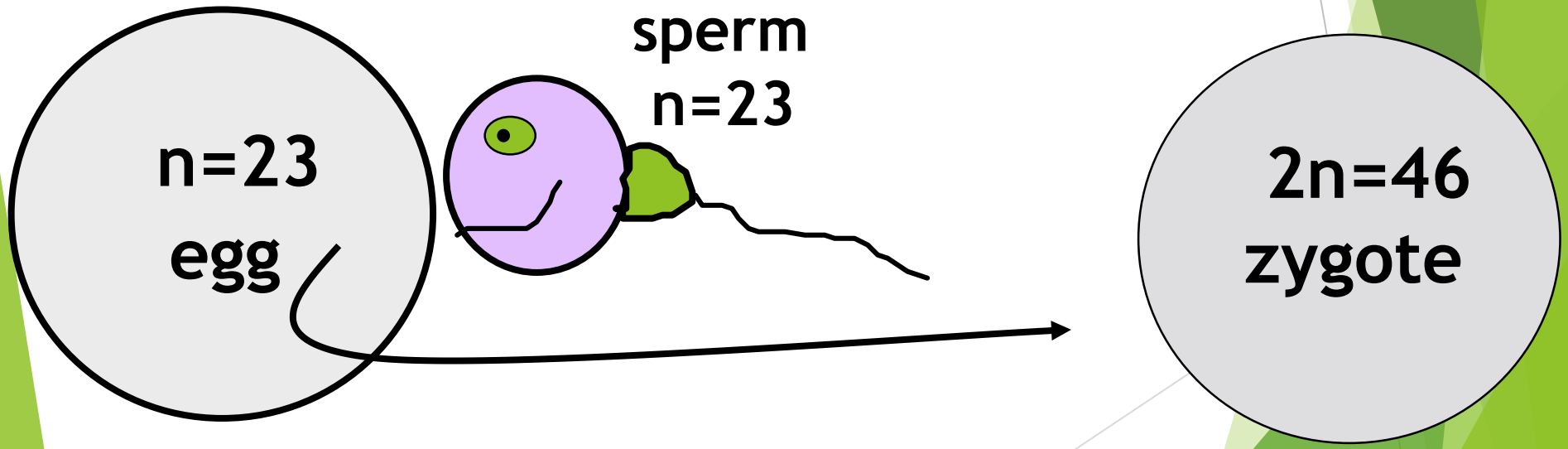
- **Sex cells** divide to produce **gametes (sperm or egg)**.
- **Gametes** have **half** the # of **chromosomes**.
- **Occurs only in gonads (testes or ovaries).**

  Male: spermatogenesis

  Female: oogenesis
- **Meiosis** is similar to **mitosis** with some chromosomal differences.

Fertilization

- The fusion of a **sperm** and **egg** to form a **zygote**.
- A zygote is a fertilized egg



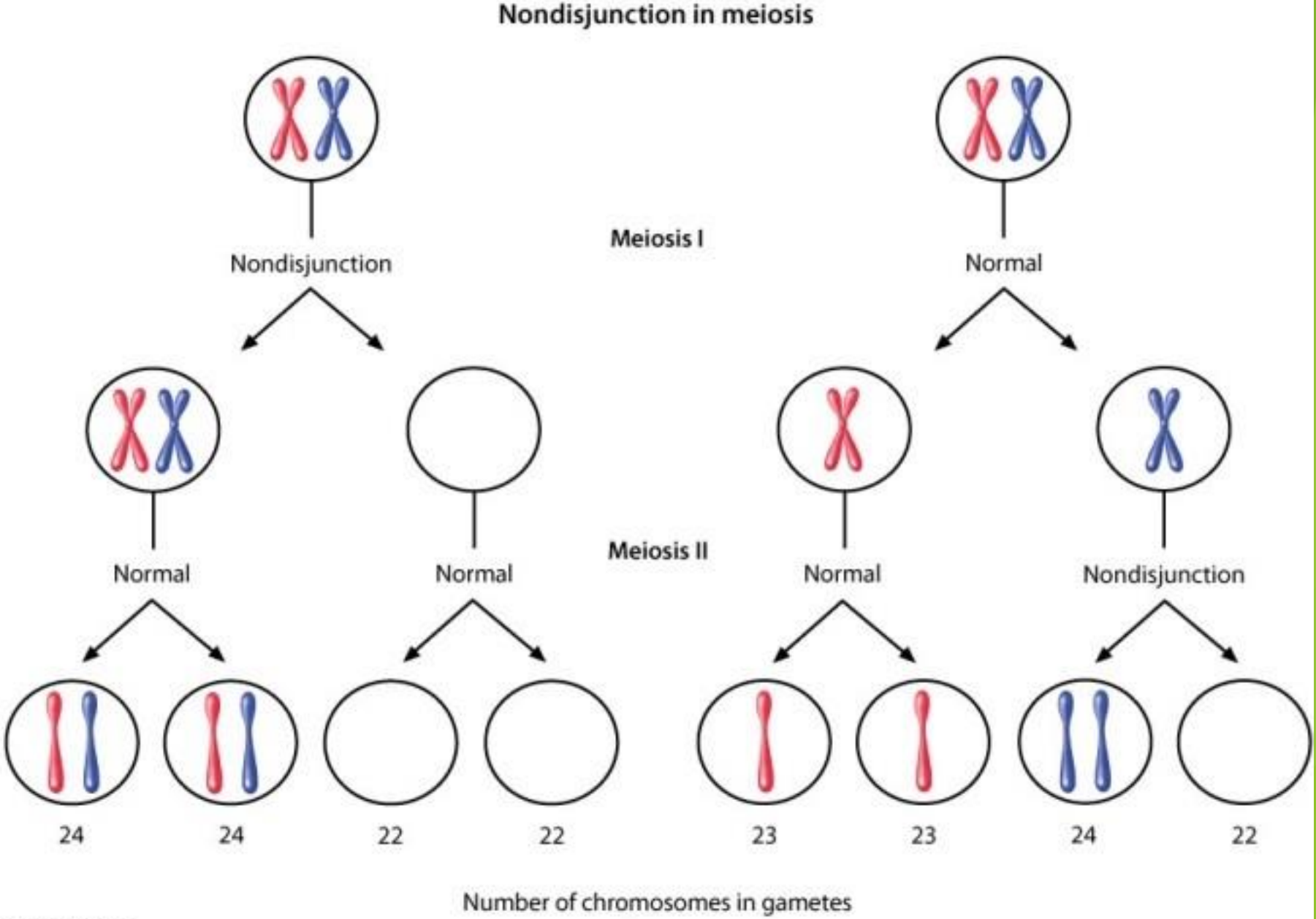
These cells are now ready to become gametes; ex. sperm are made in the process of spermatogenesis and eggs are made in oogenesis.

Nondisjunction

Occurs when chromosomes fail to separate.

Nondisjunction

- Can occur during **Anaphase I** or **Anaphase II** of Meiosis
- Result: eggs or sperm with **incorrect** number of chromosomes
- If the mutated egg or sperm is fertilized, the child will have abnormalities.
- Note: It may also occur in anaphase of **Mitosis**, but usually the abnormal cells die and the whole organism is not affected.


Nondisjunction in meiosis
Nondisjunction
Normal
Meiosis I
Normal
Normal
Normal
Meiosis II
Normal
Nondisjunction
24
24
22
22
23
23
24
22
Number of chromosomes in gametes
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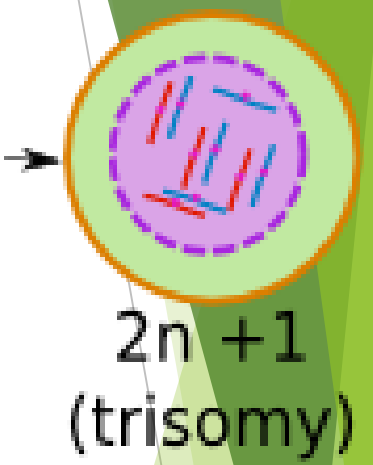
Nondisjunction results in chromosomal abnormalities

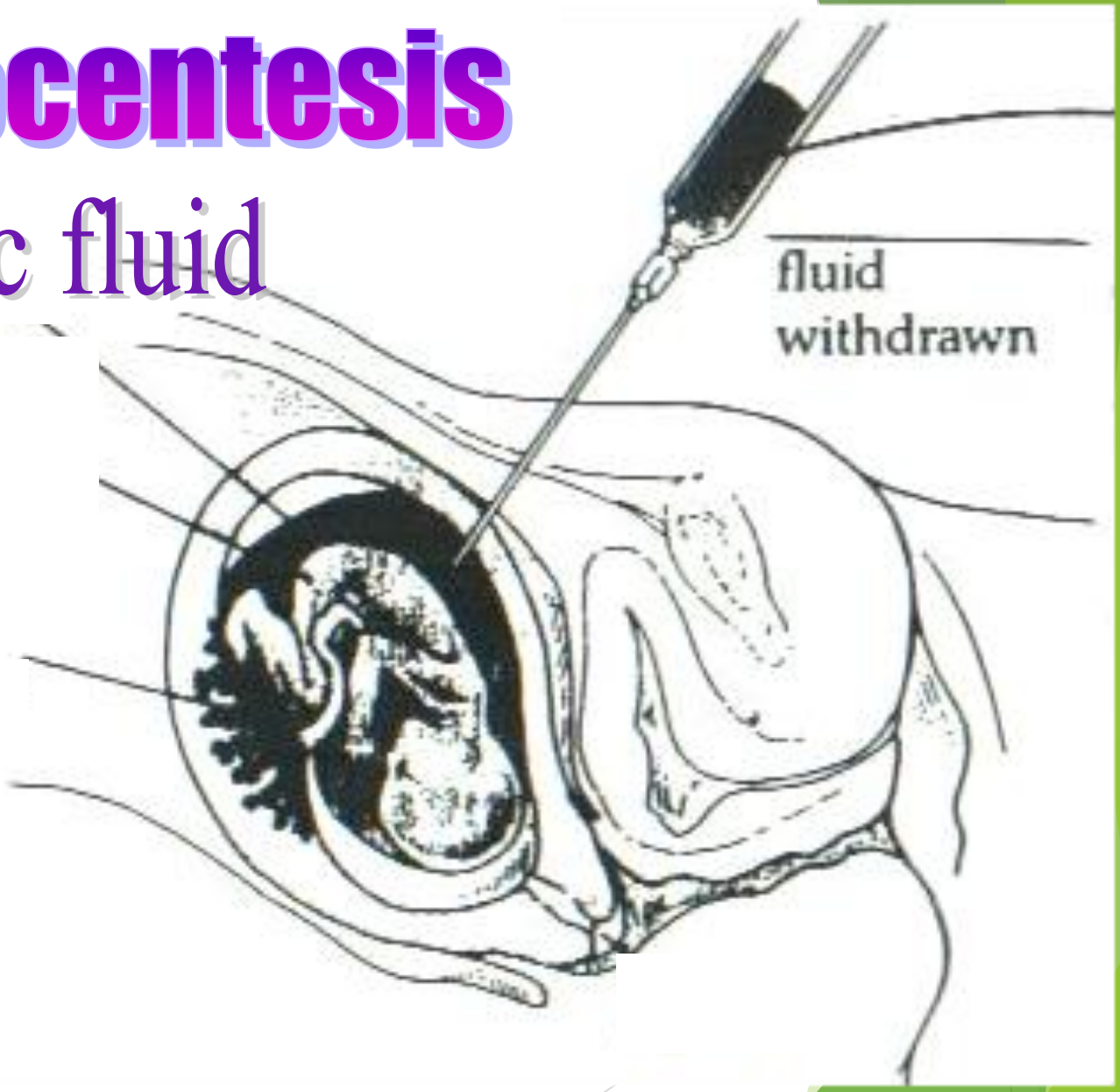
- Trisomy: Each cell has an extra chromosome

- Monosomy: Each cell has one less chromosome



Amniocentesis

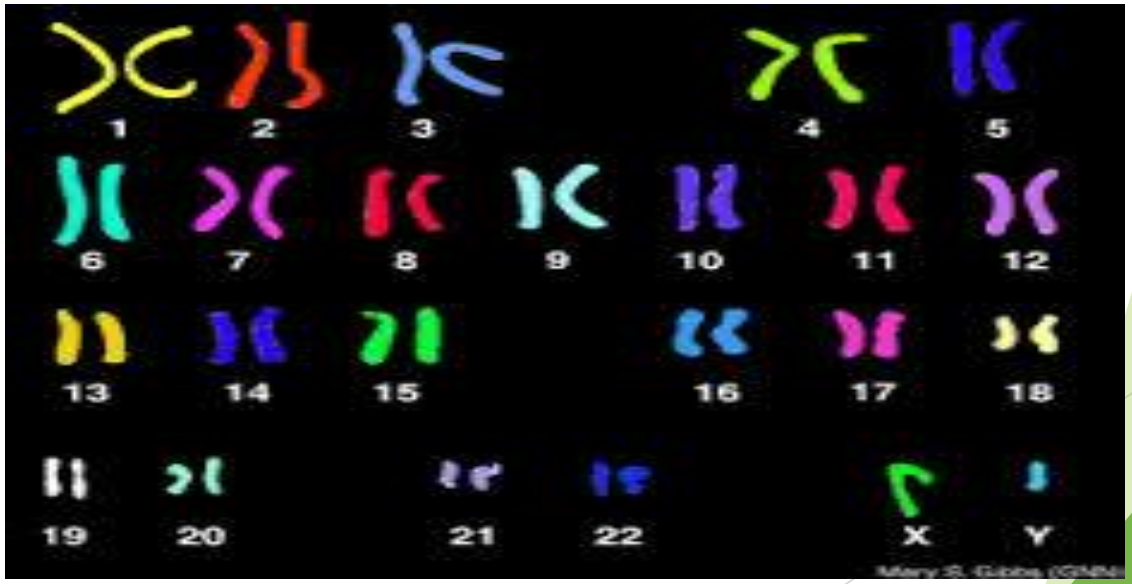
- amniotic fluid
- fetus
- 14-16 weeks




Several
weeks later
Karyotyping

Karyotypes can detect chromosomal abnormalities

- Chromosomes are photographed, cut, and matched based on size

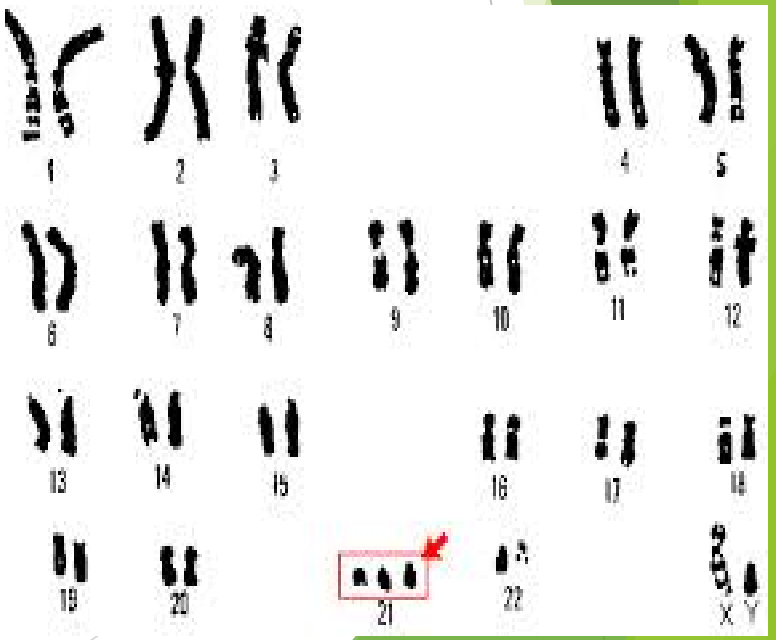


Examples:

- In humans, nondisjunction results in a person having more or less than 46 chromosomes.
- **Trisomy 21** → Down Syndrome- 1 in 691 babies born in US are born with DS (alters course of development, low muscle tone)
- **Trisomy 13** → Patau Syndrome (~1 in 9,500 births); many with this diagnosis will not make it to birth or will survive on average 10 days (clefts, improper brain formation, extra digits)
- **Monosomy –Turner Syndrome**→ only has an X in pair 23 (missing another sex chromosome); 1 in 2,000 female births; delayed puberty, hearing/ear issues; infertility
- **Trisomy- Klinefelter Syndrome** → has XXY (an extra sex chromosome); 1 in 500 to 1 in 1,000 male births; small testes (less testosterone)

Trisomy 21: Down Syndrome

- **Three copies** of chromosome 21
- Occurrence: 1 in 700 births, increased chances when **mother is over 40**.
- Shorter average life span (35 yrs)
- Common facial characteristics



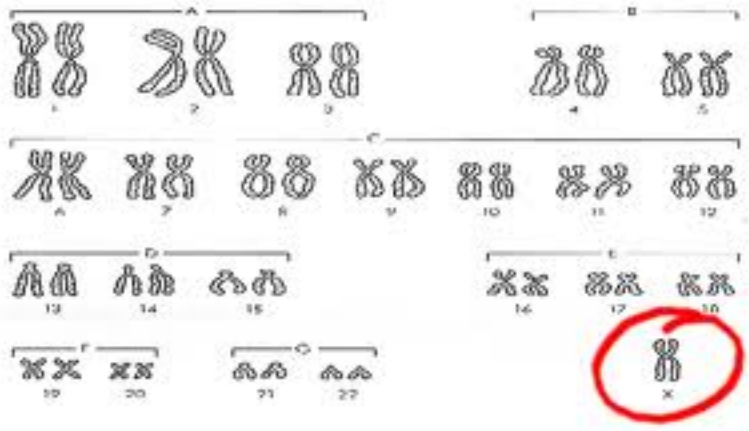
Trisomy 13: Patau Syndrome

- **Extra copy** of Chromosome 13
- Occurrence: 1 in 10,000 births
- Characteristics:
  - Cleft lip and palate
  - Mentally handicapped
  - **Polydactyl**

- Usually on live about 3 months, 80% die within the first year

Monosomy: Turner Syndrome

- Missing a **sex chromosome**
- 1 in 2,000 births
- Usually cannot tell **before puberty**
- Sex organs do not fully develop
- Webbed neck



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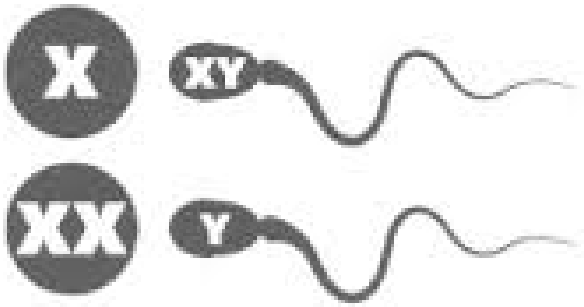
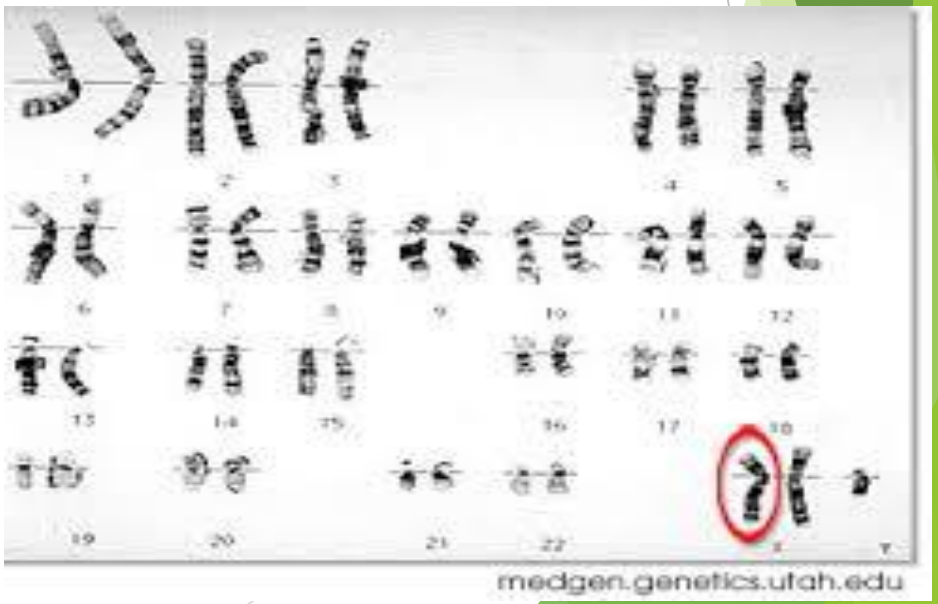
Trisomy: Klinefelter Syndrome (XXY)

- Caused by an **extra X chromosome**
- 1 in 1,000 males
- Underdeveloped testes, taller, may have breast development, sterile





Stages of Meiosis

Meiosis I

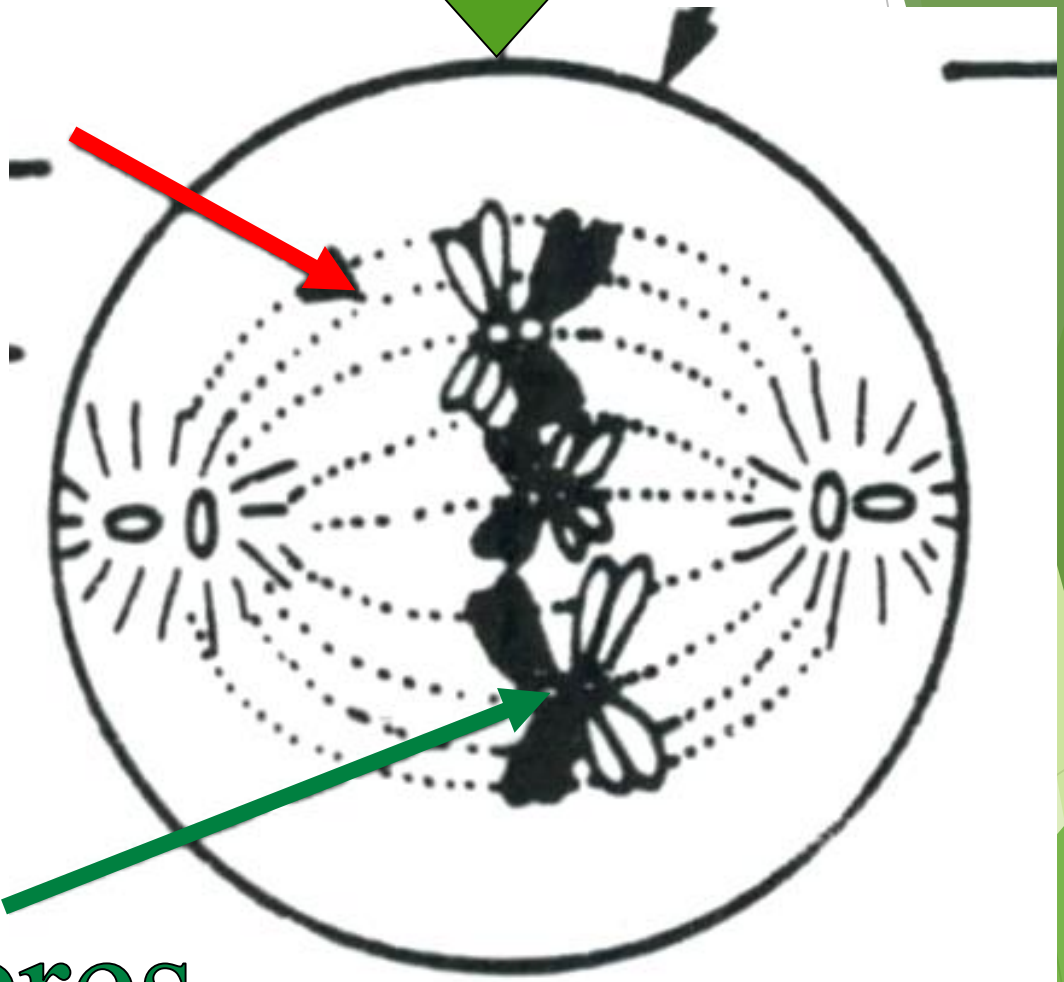
chromosome reduction occurs

Prophase I

homologous chromosomes

equator
(midline)

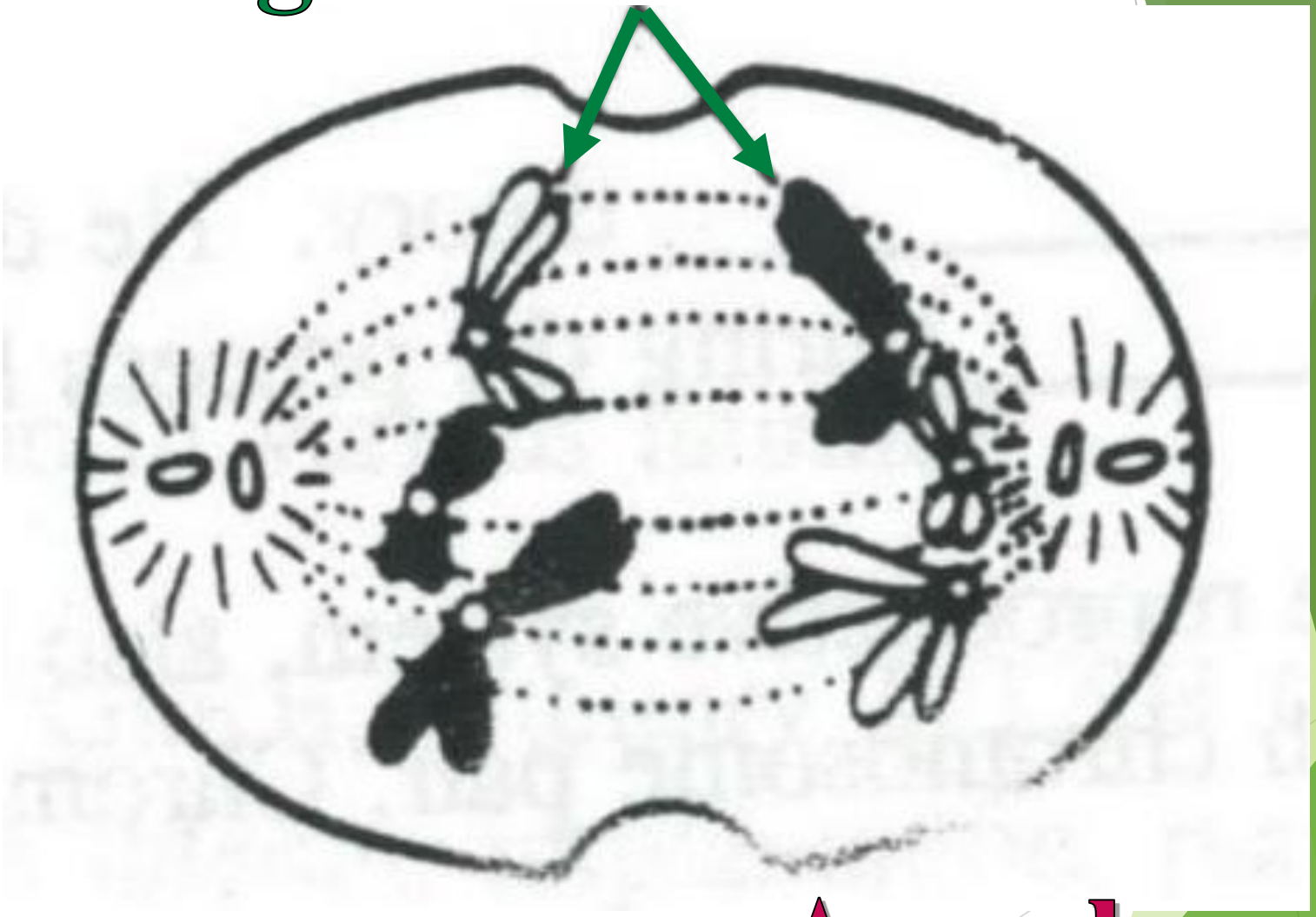
spindle
fibers



centromeres

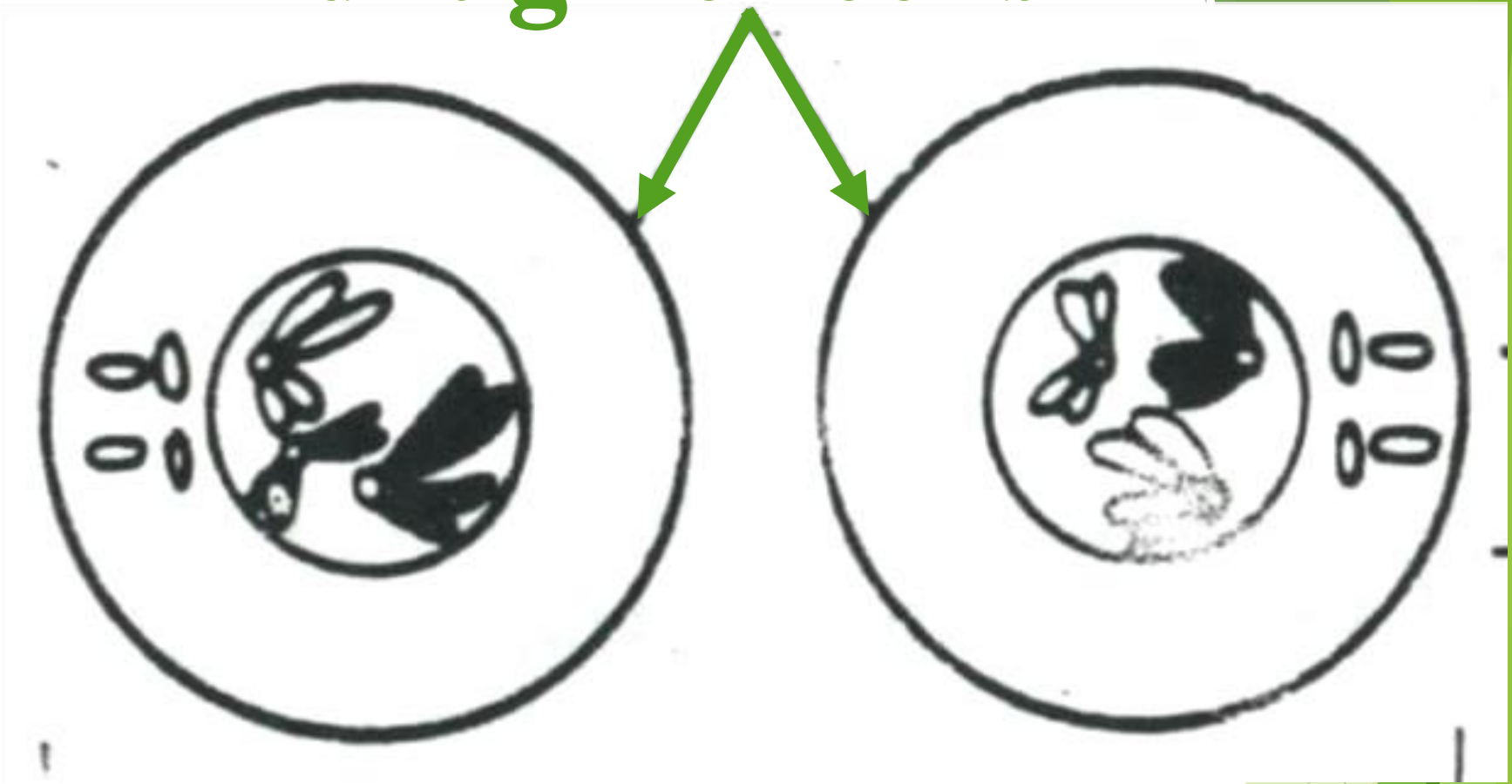
Metaphase I

homologous chromosomes



Anaphase I

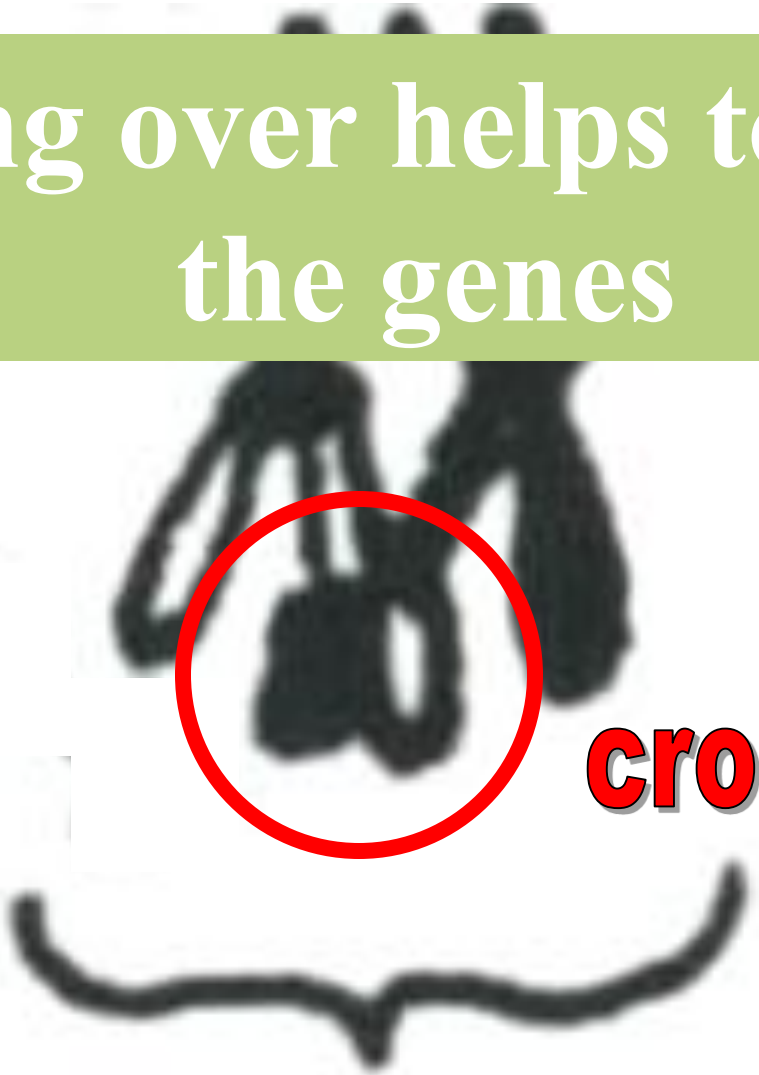
daughter cells



haploid
n = 23

Telophase I

crossing over helps to shuffle the genes



crossing over

homologous chromosomes

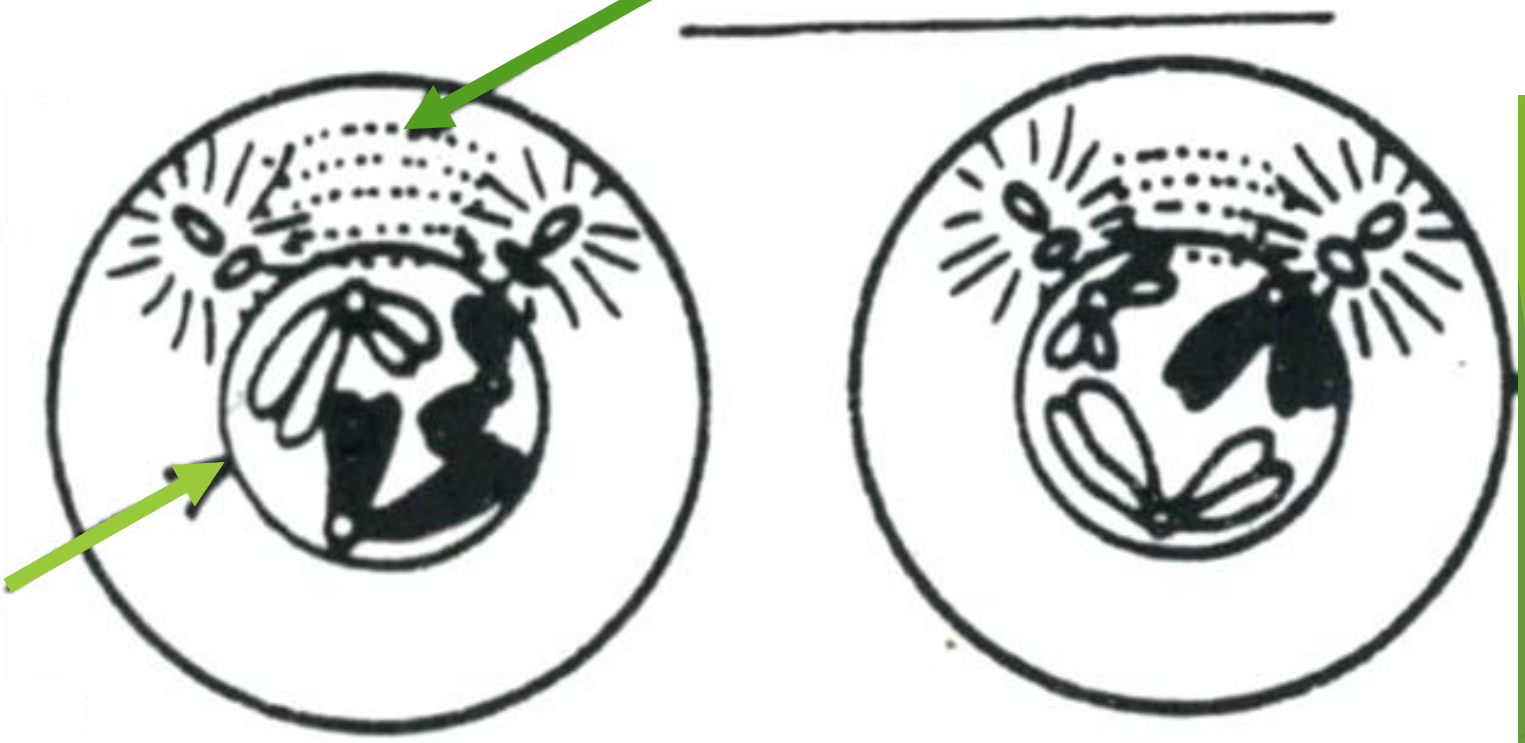
Stages of Meiosis

Meiosis II

chromosomes separate as they do in mitosis

spindle

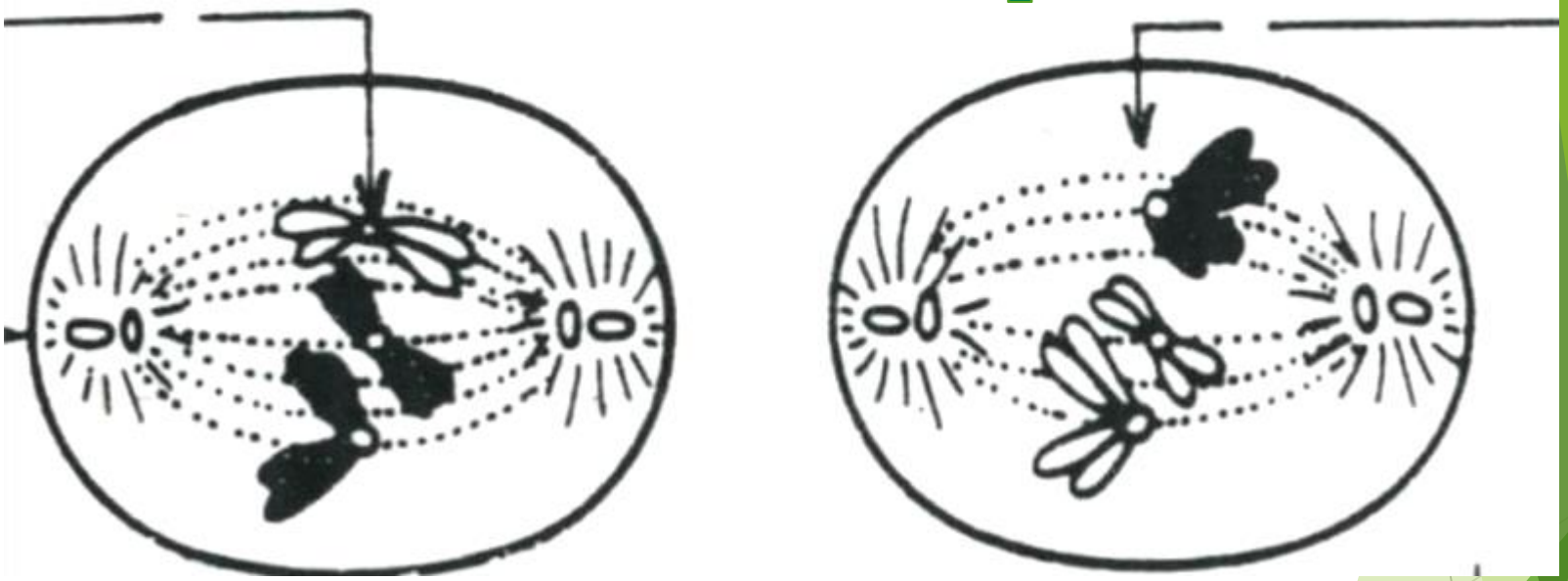
nuclear membrane



Prophase II

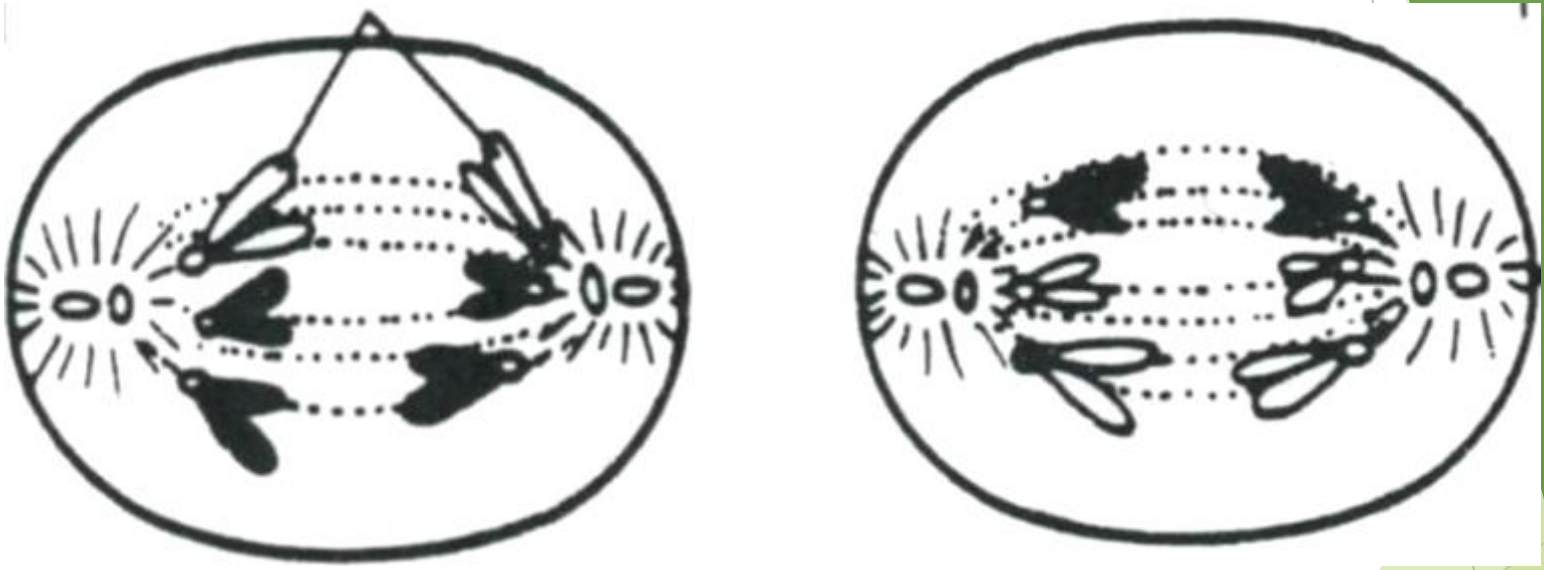
centromere

equator



Metaphase II

sister chromatids



Anaphase II

haploid
n = 23

Telophase II