Meiosis

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Cell Biology, 1st Semester/W8

Organisms that reproduce Sexually are made up of two different types of cells.

1. **Somatic Cells** are "body" cells and contain the normal number of chromosomes ….called the "Diploid" number (the symbol is **2n**). Examples would be … skin cells, brain cells, etc.

2. **Gametes** are the "sex" cells and contain only ½ the normal number of chromosomes…. called the "Haploid" number (the symbol is **n**)….. Sperm cells and ova are gametes.

n = number of chromosomes in the set… so….2n means 2 chromosomes in the set…. Polyploid cells have more than two chromosomes per set… example: 3n (3 chromosomes per set)

Gametes

- The **Male Gamete** is the **Sperm** and is produced in the male gonad the **Testes**.

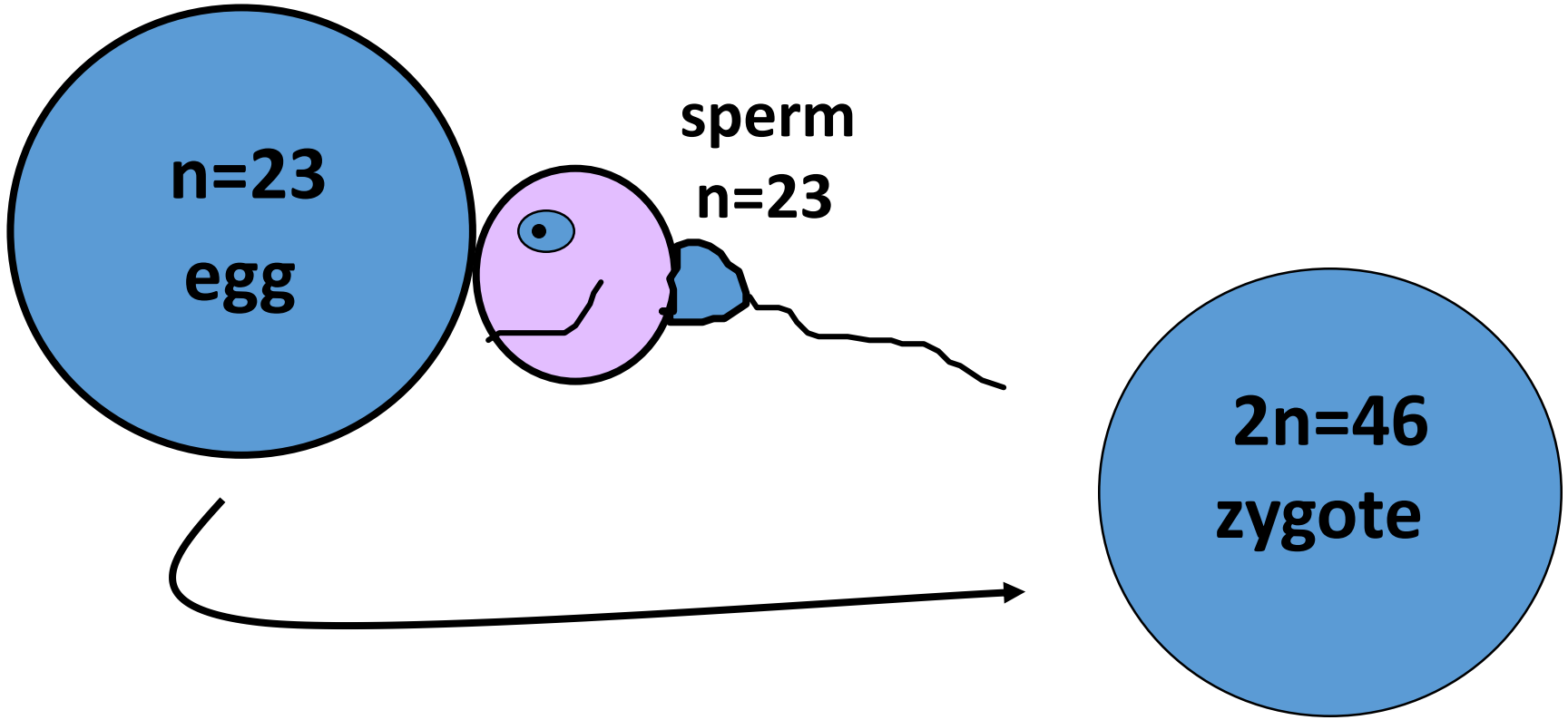
- The **Female Gamete** is the **Ovum (ova = pl.)** and is produced in the female gonad the **Ovaries**.

During **Ovulation** the ovum is released from the ovary and transported to an area where **fertilization**, the joining of the sperm and ovum, can occur fertilization, in humans, occurs in the Fallopian tube. Fertilization results in the formation of the **Zygote**. (fertilized egg)

Sperm + Ovum (egg) —fertilization→ **Zygote**

Fertilization

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



Chromosomes

- If an organism has the Diploid number (2n) it has two matching homologues per set. One of the homologues comes from the mother (and has the mother's DNA).... the other homologue comes from the father (and has the father's DNA).
- Most organisms are diploid. Humans have 23 sets of chromosomes… therefore humans have 46 total chromosomes….. The diploid number for humans is 46 (46 chromosomes per cell).

Homologous Chromosomes

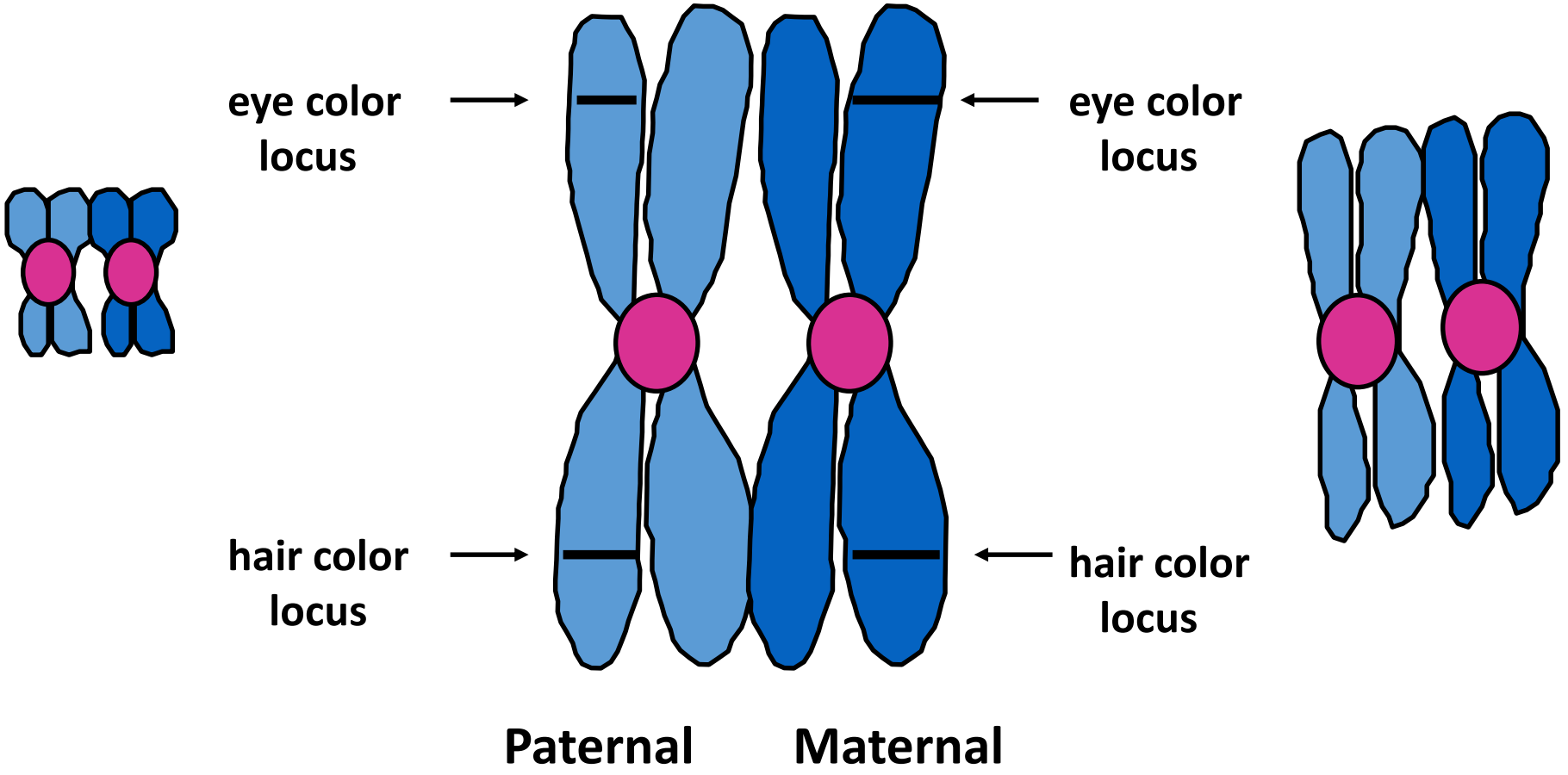
- Pair of chromosomes (maternal (mother) and paternal (father)) that are similar in shape and size.
- Homologous pairs (tetrads) carry genes controlling the same inherited traits.
- Each locus (position of a gene) is in the same position on homologues.
- Humans have 23 pairs of homologous chromosomes.

22 pairs of autosomes

1 pair of sex chromosomes

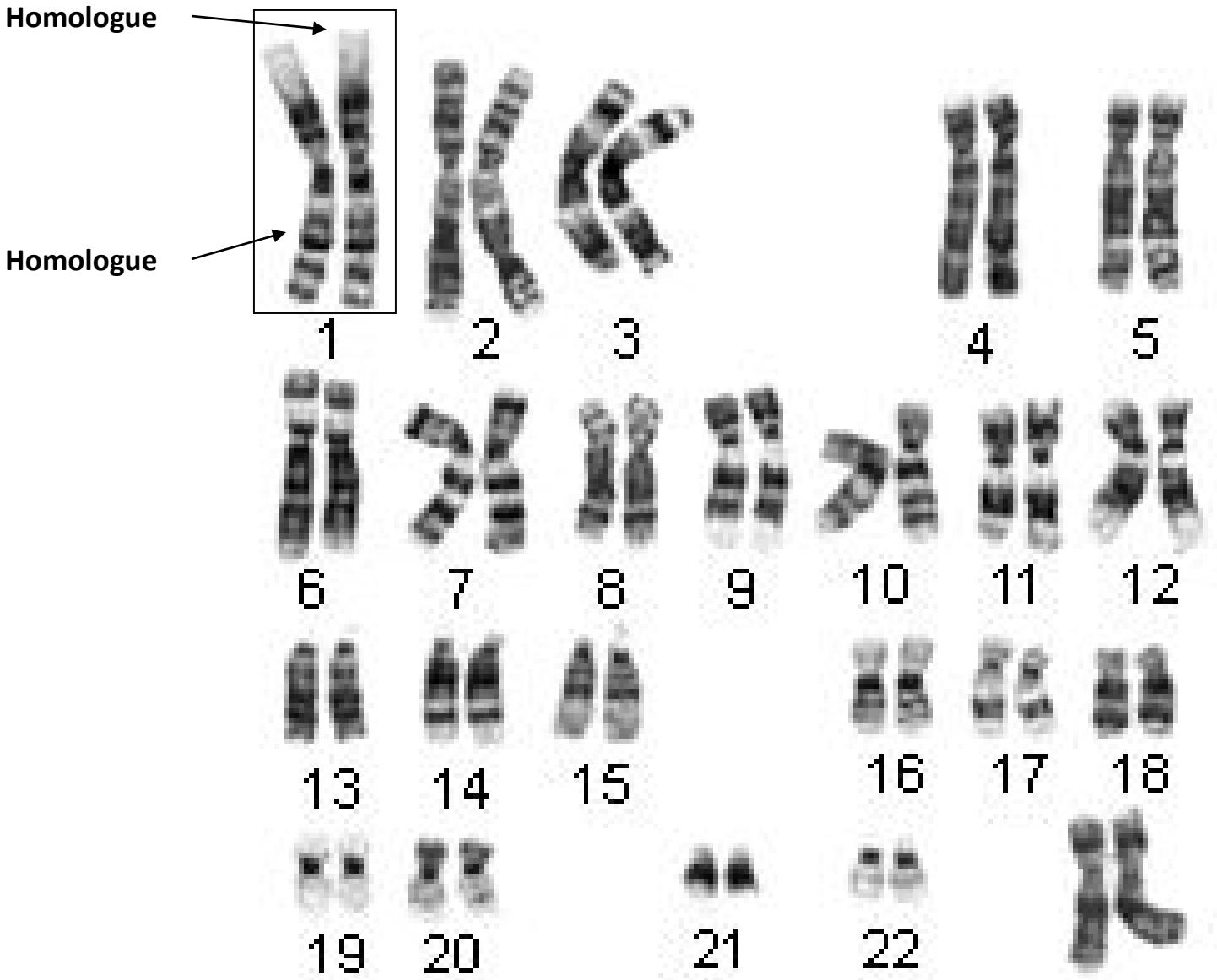
Homologous Chromosomes

(because a homologous pair consists of 4 chromatids it is called a “Tetrad”)



Humans have 23 Sets of Homologous Chromosomes

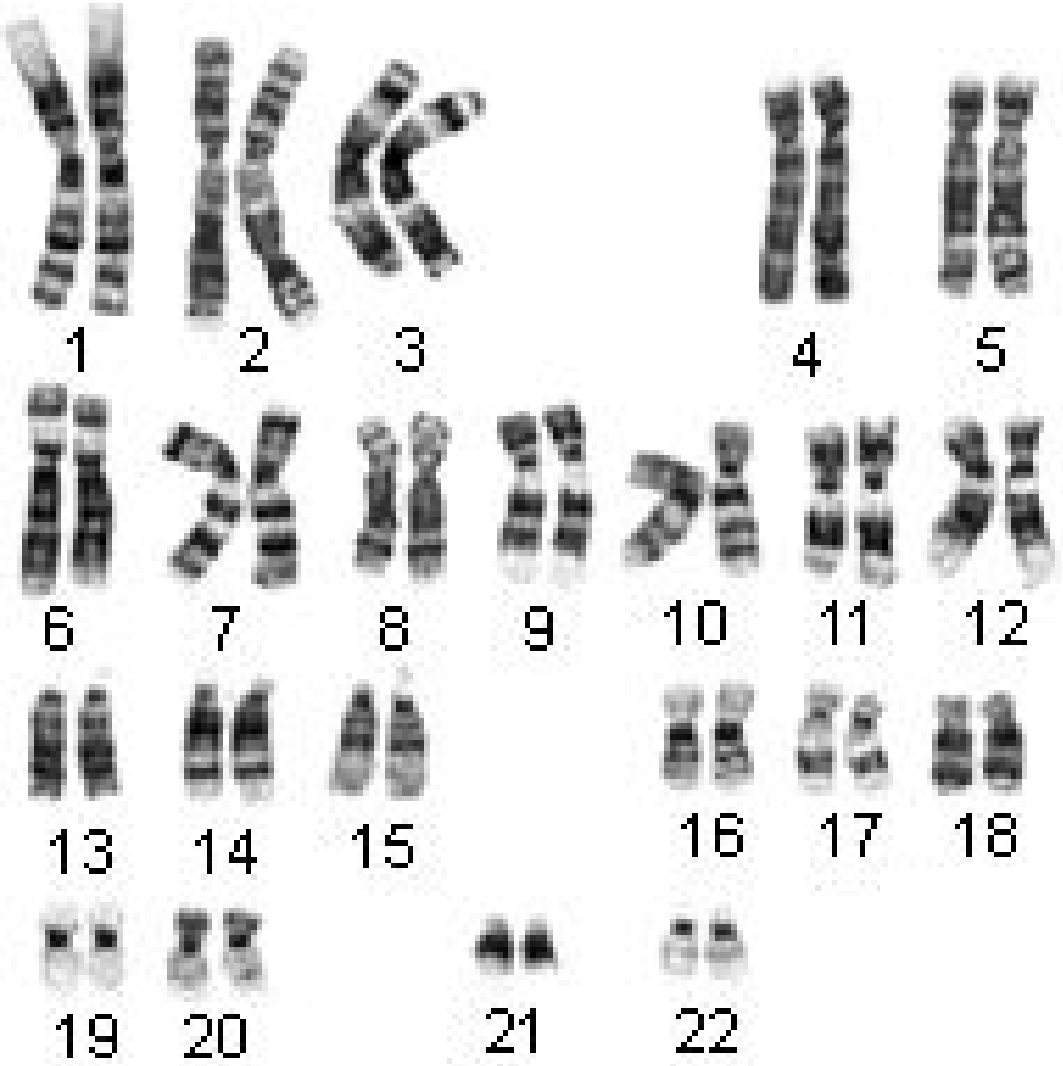
Each Homologous set is made up of 2 Homologues.



Autosomes

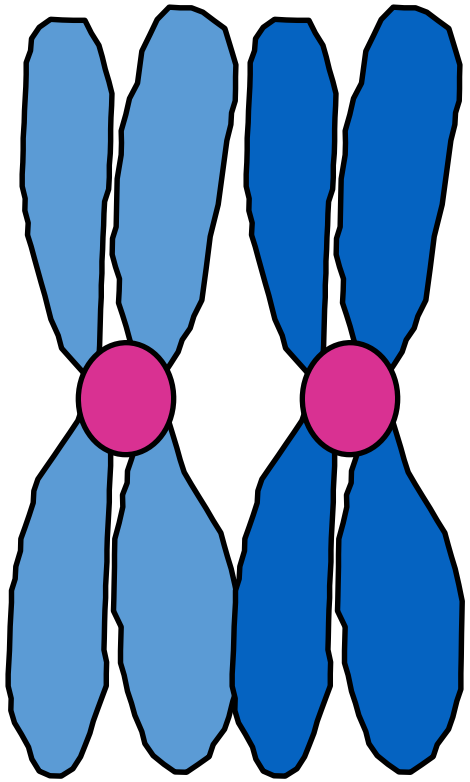
(The Autosomes code for most of the offspring's traits)

In Humans the "Autosomes" are sets 1 - 22



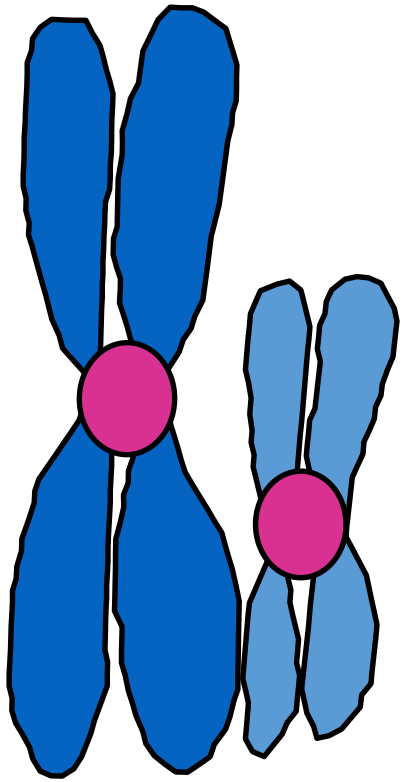
Sex Chromosomes

The Sex Chromosomes code for the sex of the offspring.
** If the offspring has two "X" chromosomes it will be a female.
** If the offspring has one "X" chromosome and one "Y" chromosome it will be a male.



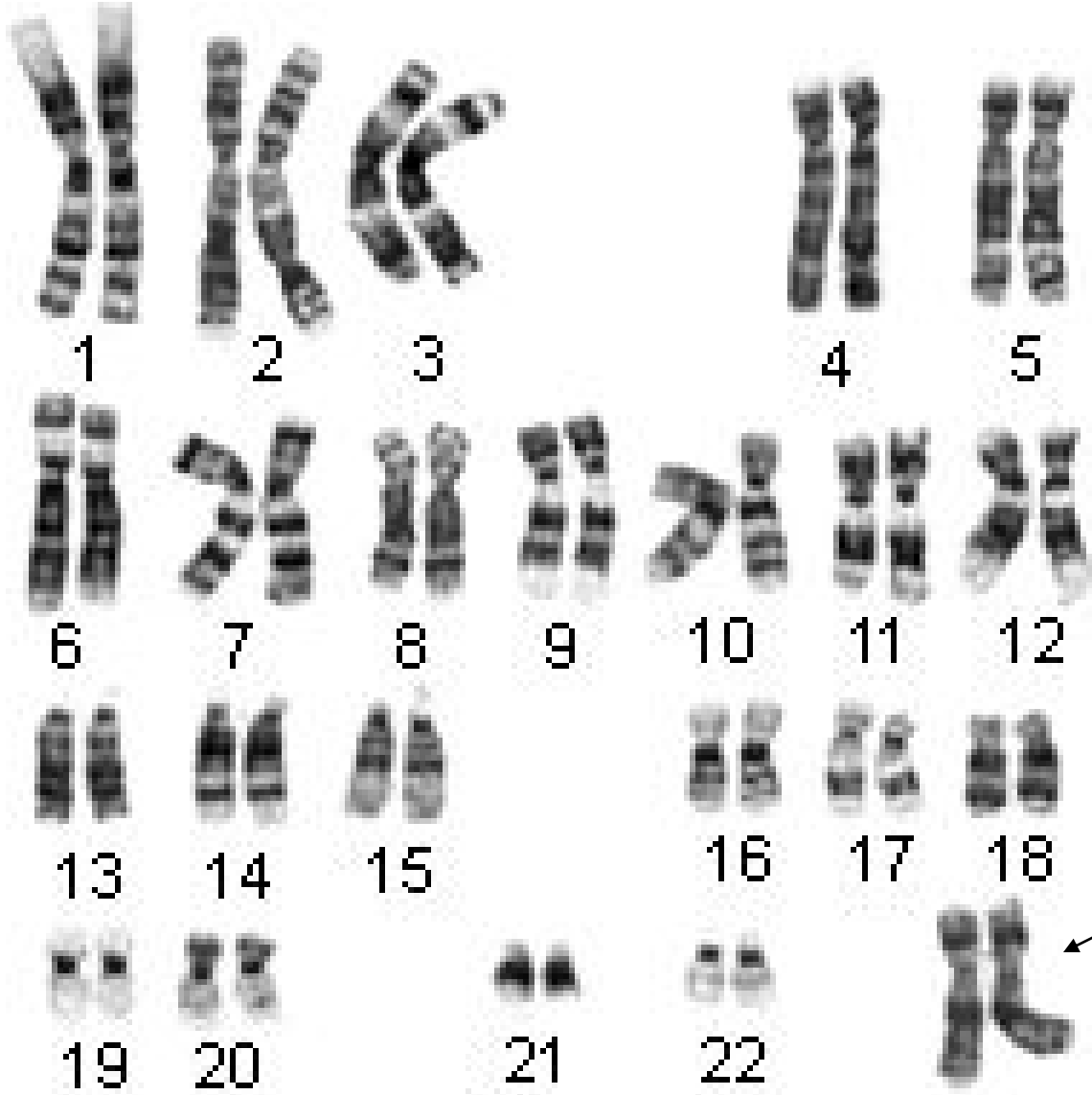
XX chromosome - female

In Humans the "Sex Chromosomes" are the 23rd set



XY chromosome - male

Sex Chromosomes



"Sex Chromosomes" .....the 23rd set

This person has 2 "X" chromosomes... and is a female.

Meiosis

is the process by which "gametes" (sex cells) , with half the number of chromosomes, are produced.

During Meiosis diploid cells are reduced to haploid cells

Diploid (2n) → Haploid (n)

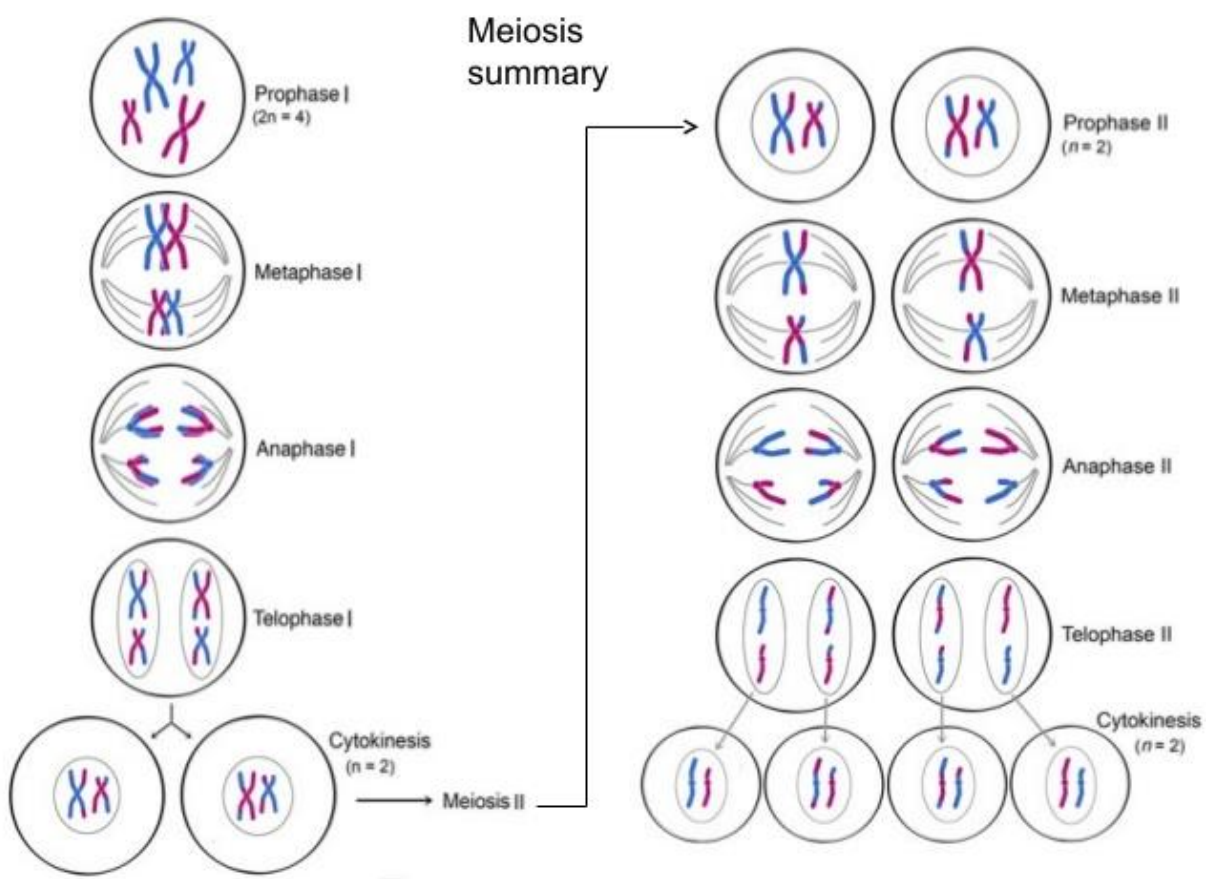
If Meiosis did not reduce the chromosome number in each new generation would double…. The offspring would die.

Meiosis

Meiosis is Two cell divisions

(called meiosis I and meiosis II)

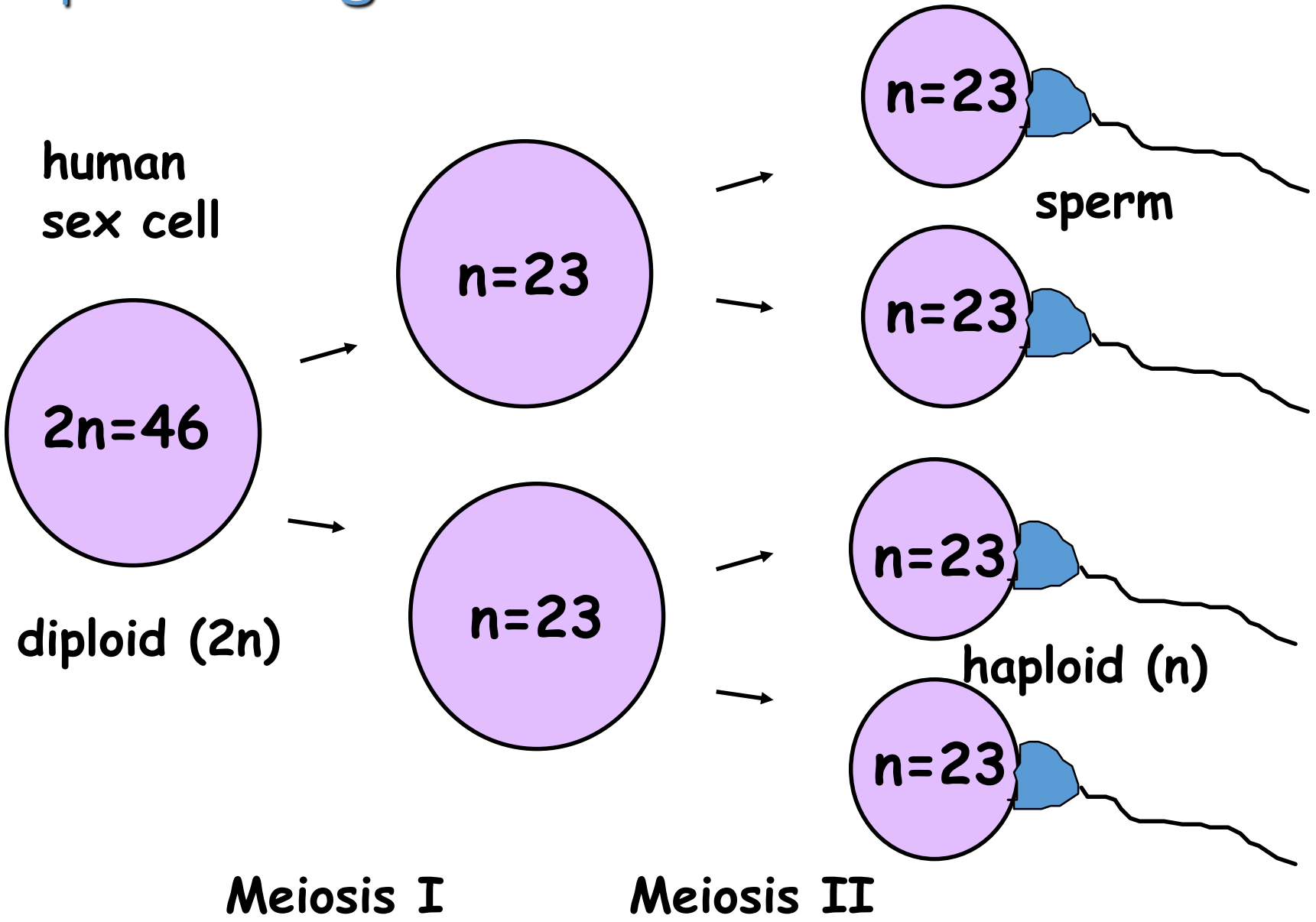
with only one duplication of chromosomes.


Meiosis summary
Prophase I
(2n = 4)
Metaphase I
Anaphase I
Telophase I
Cytokinesis
(n = 2)
Meiosis II
Prophase II
(n = 2)
Metaphase II
Anaphase II
Telophase II
Cytokinesis
(n = 2)

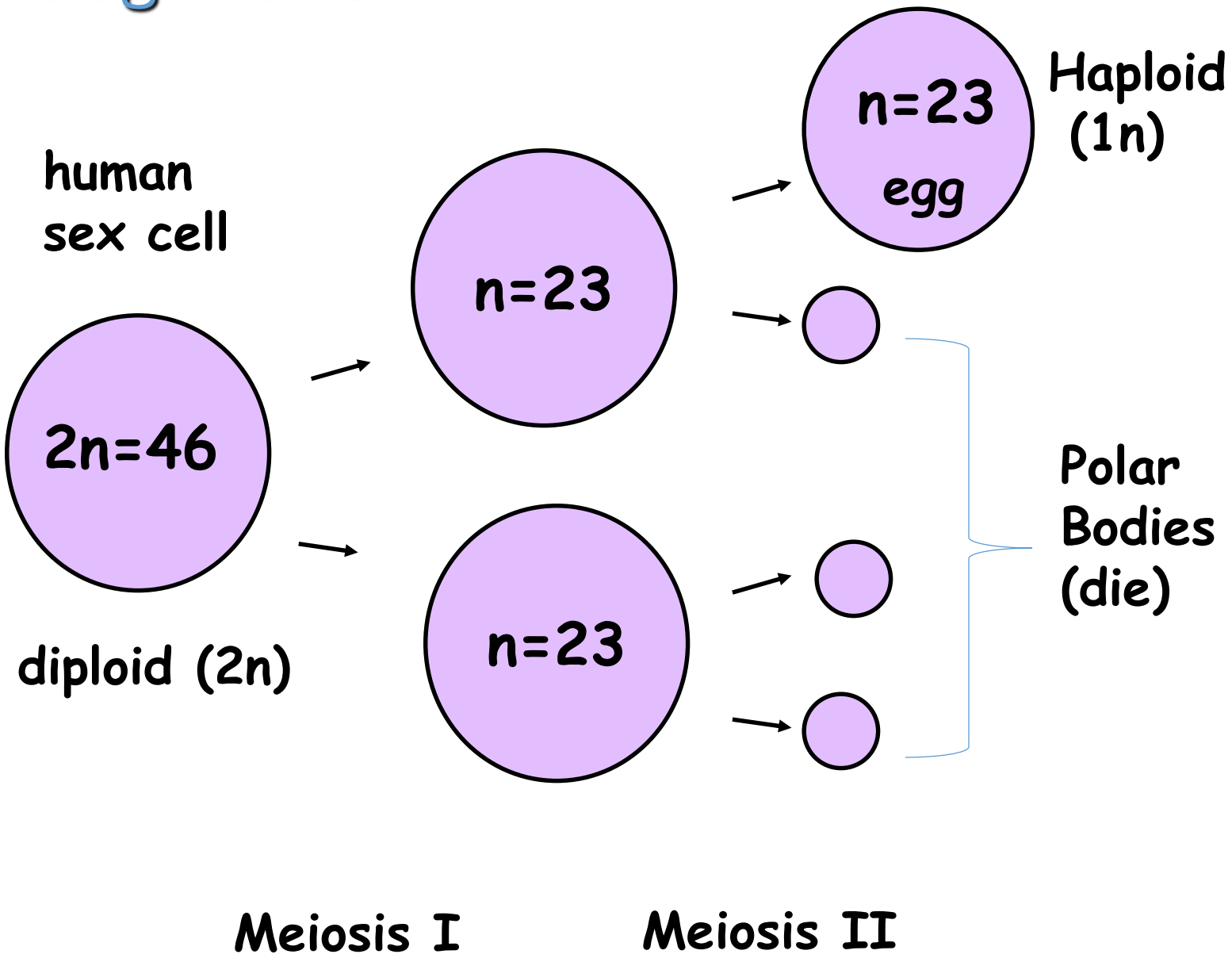
Meiosis in males is called spermatogenesis and produces sperm.

Meiosis in females is called oogenesis and produces ovum.

Spermatogenesis

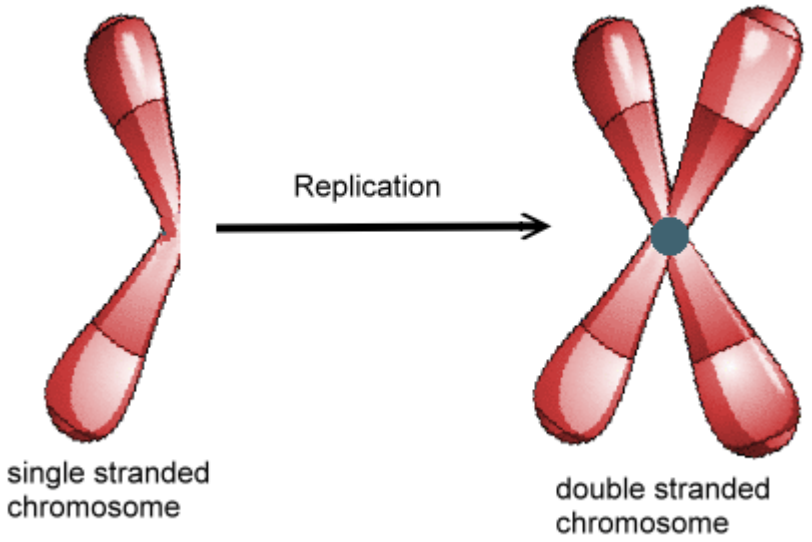


Oogenesis


human
sex cell
2n=46
diploid (2n)
n=23
n=23
n=23
egg
Haploid
(1n)
Polar
Bodies
(die)
Meiosis I
Meiosis II

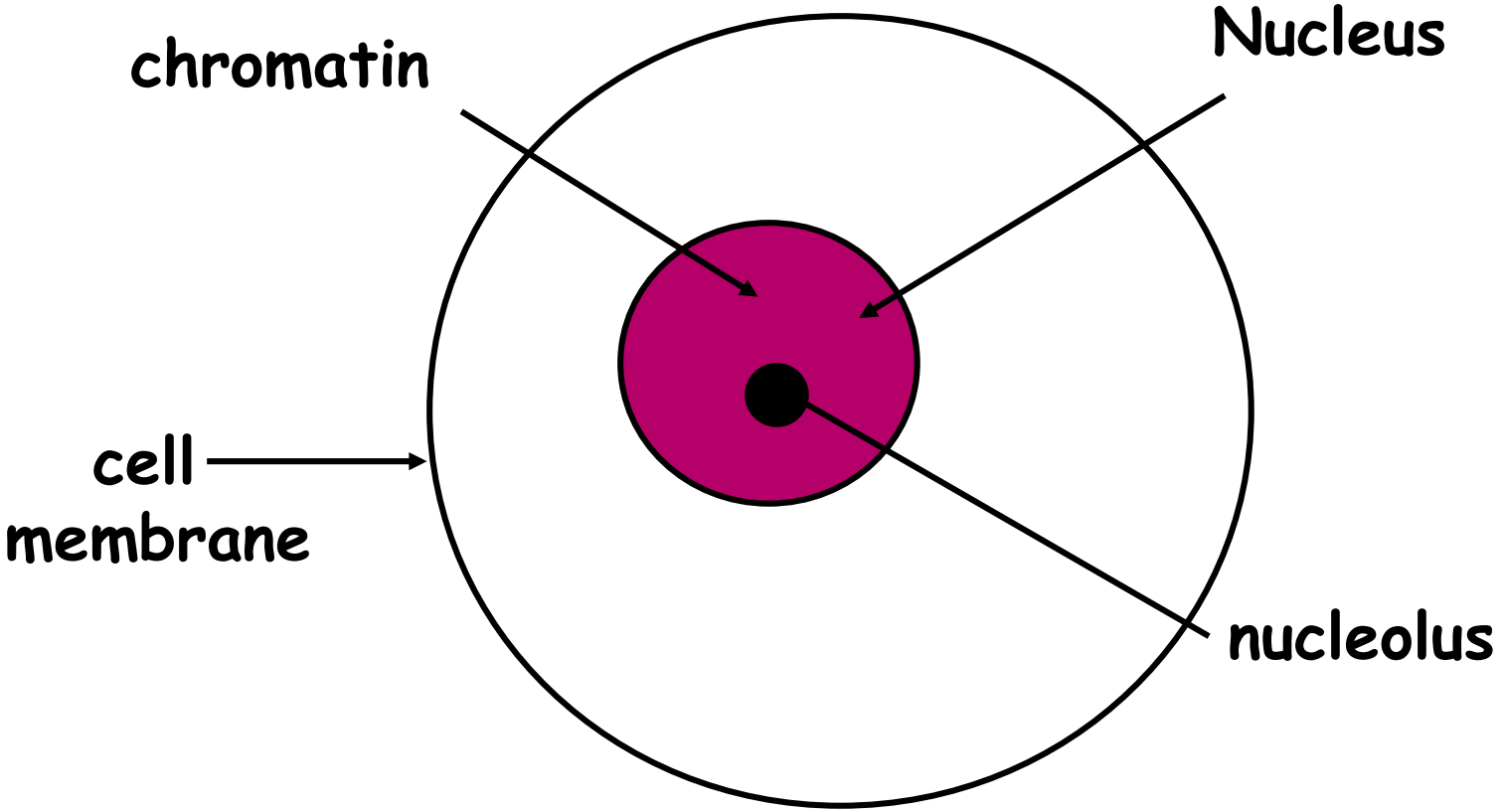
Interphase I

- **Similar to mitosis interphase.**
- **CHROMOSOMES (DNA)** replicate in the **S phase**
- Each duplicated **chromosome** consist of **two identical SISTER CHROMATIDS** attached at their **CENTROMERES**.
- **CENTRIOLE** pairs also replicate.



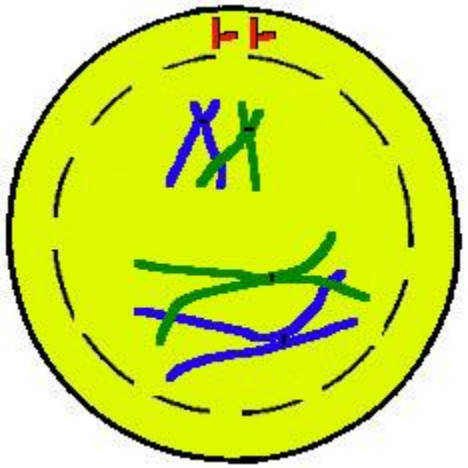
Interphase I

- **Nucleus and nucleolus visible.**



Meiosis I (four phases)

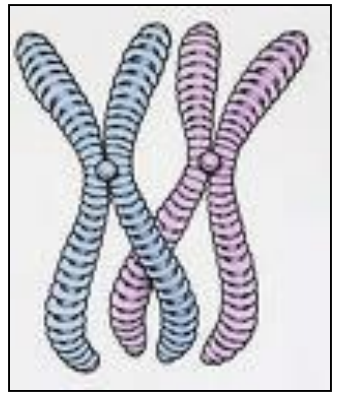
- **Cell division** that reduces the **chromosome number** by **one-half.**
- **Four phases**:
  a. **Prophase I**
  b. **Metaphase I**
  c. **Anaphase I**
  d. **Telophase I**



Prophase I

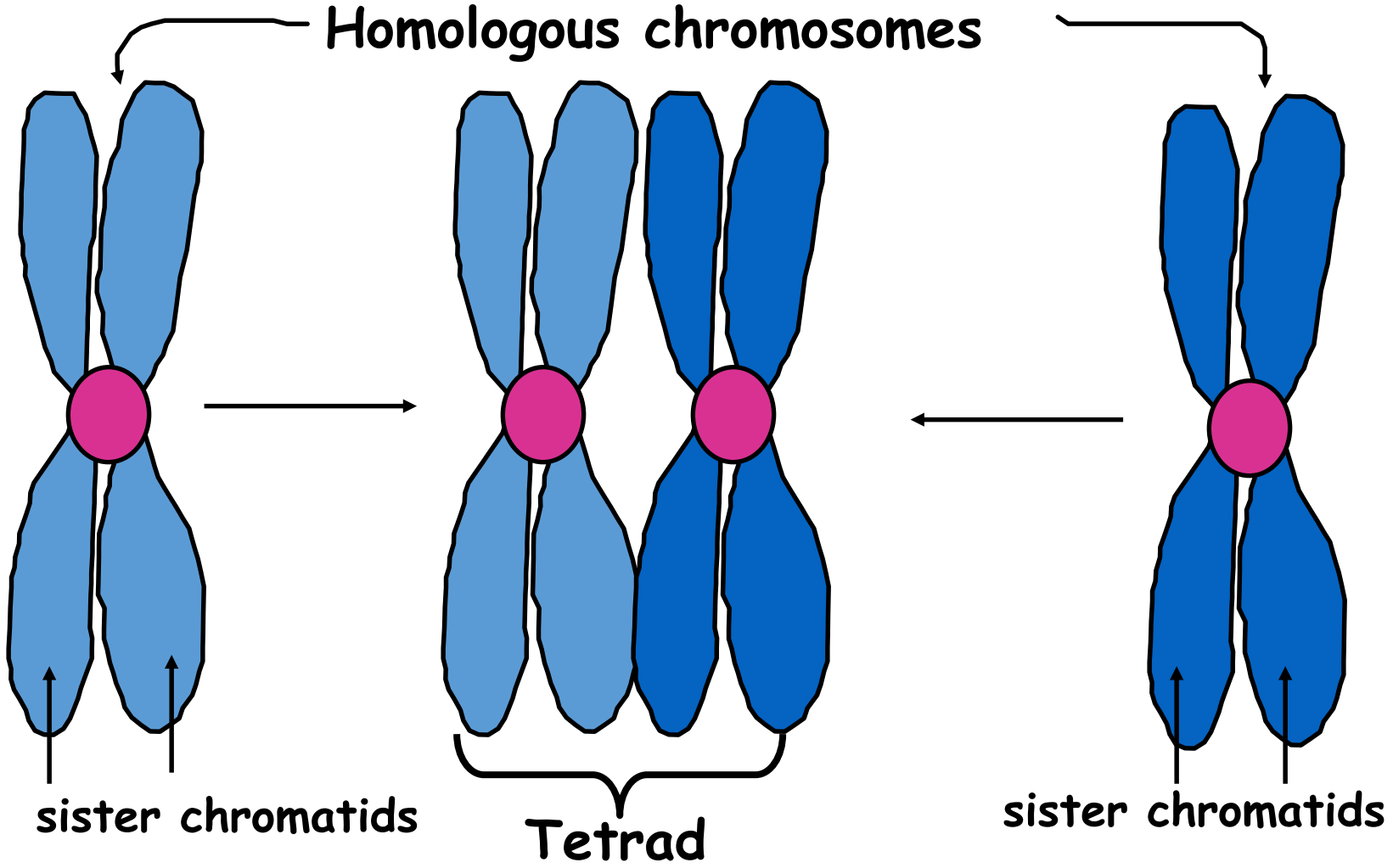
Prophase I

- **Longest and most complex phase (90%).**
- **Chromosomes condense.**
- **Synapsis occurs - Homologous chromosomes come together to form a tetrad.**



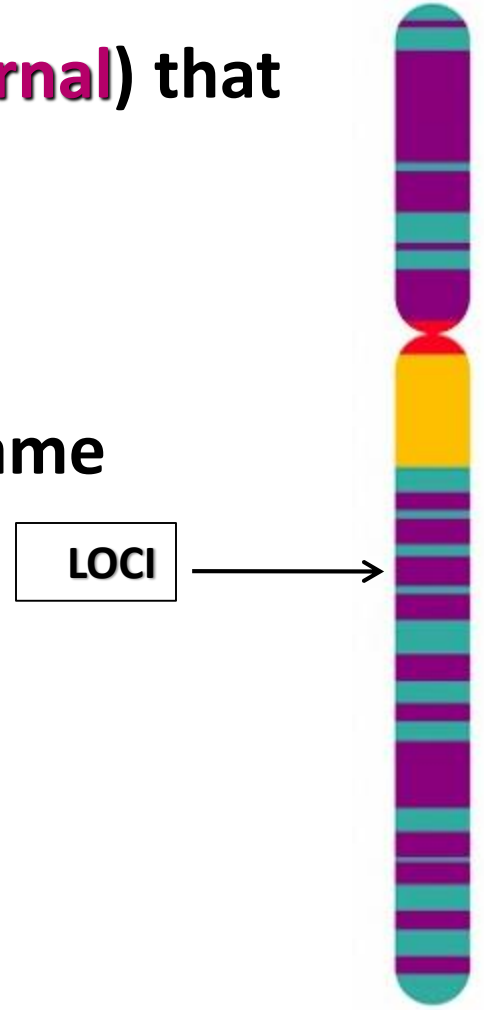
- **Tetrad is two chromosomes or four chromatids (sister and non-sister chromatids).**

Prophase I - Synapsis



Homologous Chromosomes

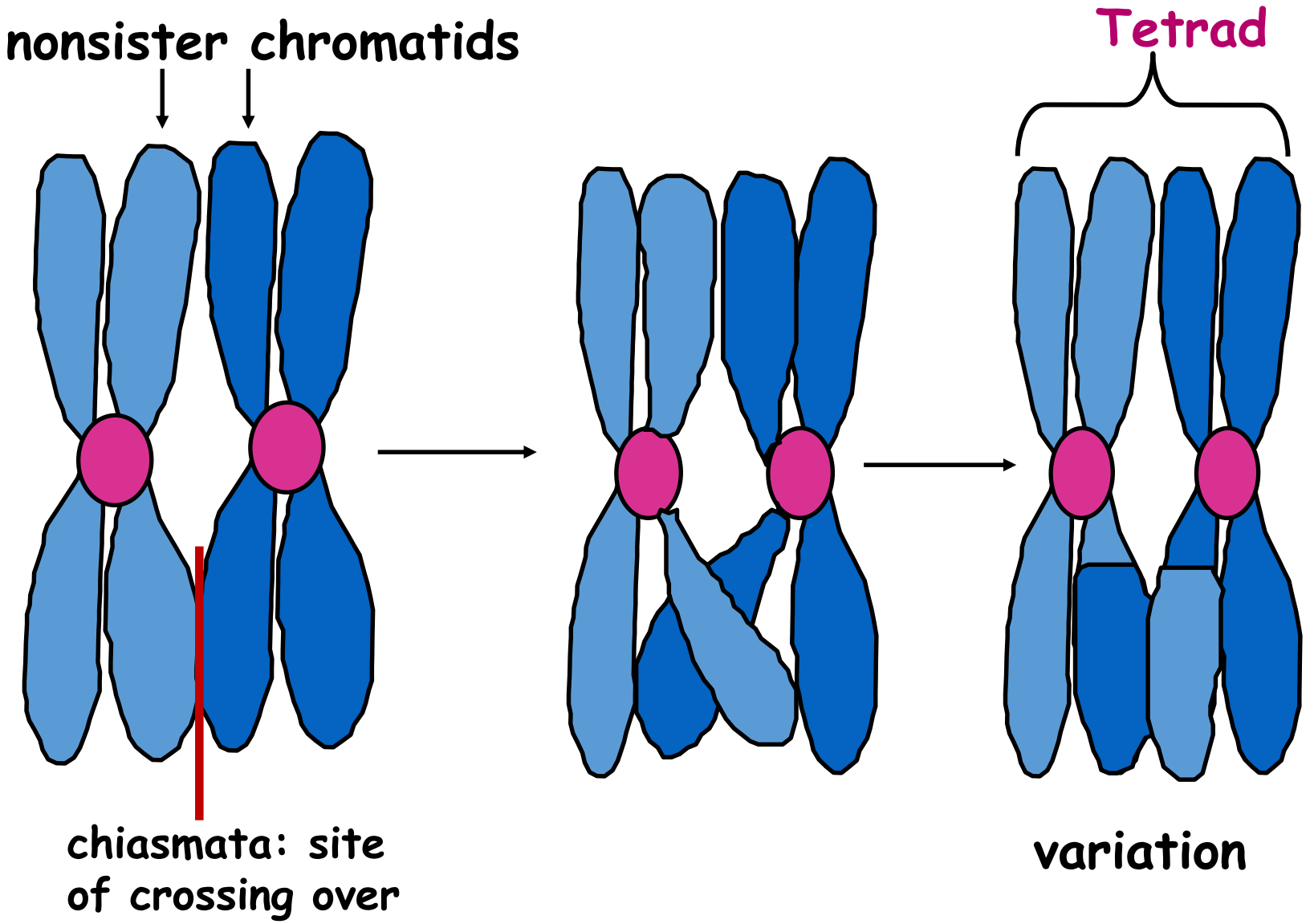
- Pair of **chromosomes** (**maternal** and **paternal**) that are **similar in shape and size.**
- Homologous pairs (**tetrads**) carry GENES controlling the SAME inherited traits.
- Each **locus (position of a gene)** is in the same position on homologues.
- **Humans** have **23 pairs** of **homologous chromosomes:**
  a. First 22 pairs of **autosomes**
  b. Last pair of **sex chromosomes**



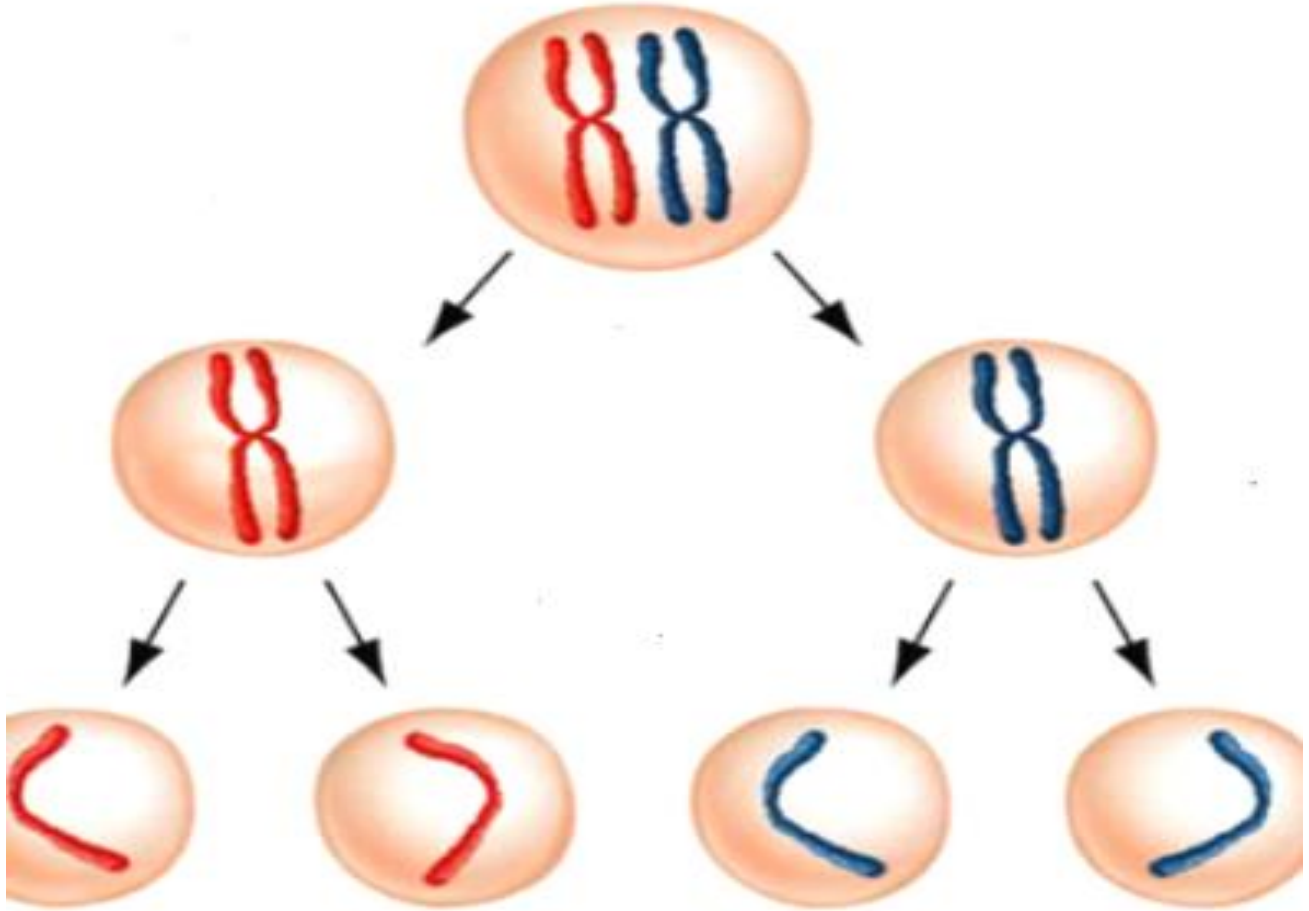
Crossing Over

- **Crossing over** may occur between non-sister **chromatids** at sites called **chiasmata**.
- **Crossing over**: segments of nonsister **chromatids** break and reattach to the other **chromatid**.
- **Chiasmata (chiasma)** are where chromosomes touch each other and **exchange genes** (**crossing over**.)
- Causes **Genetic Recombination**

Genetic Recombination

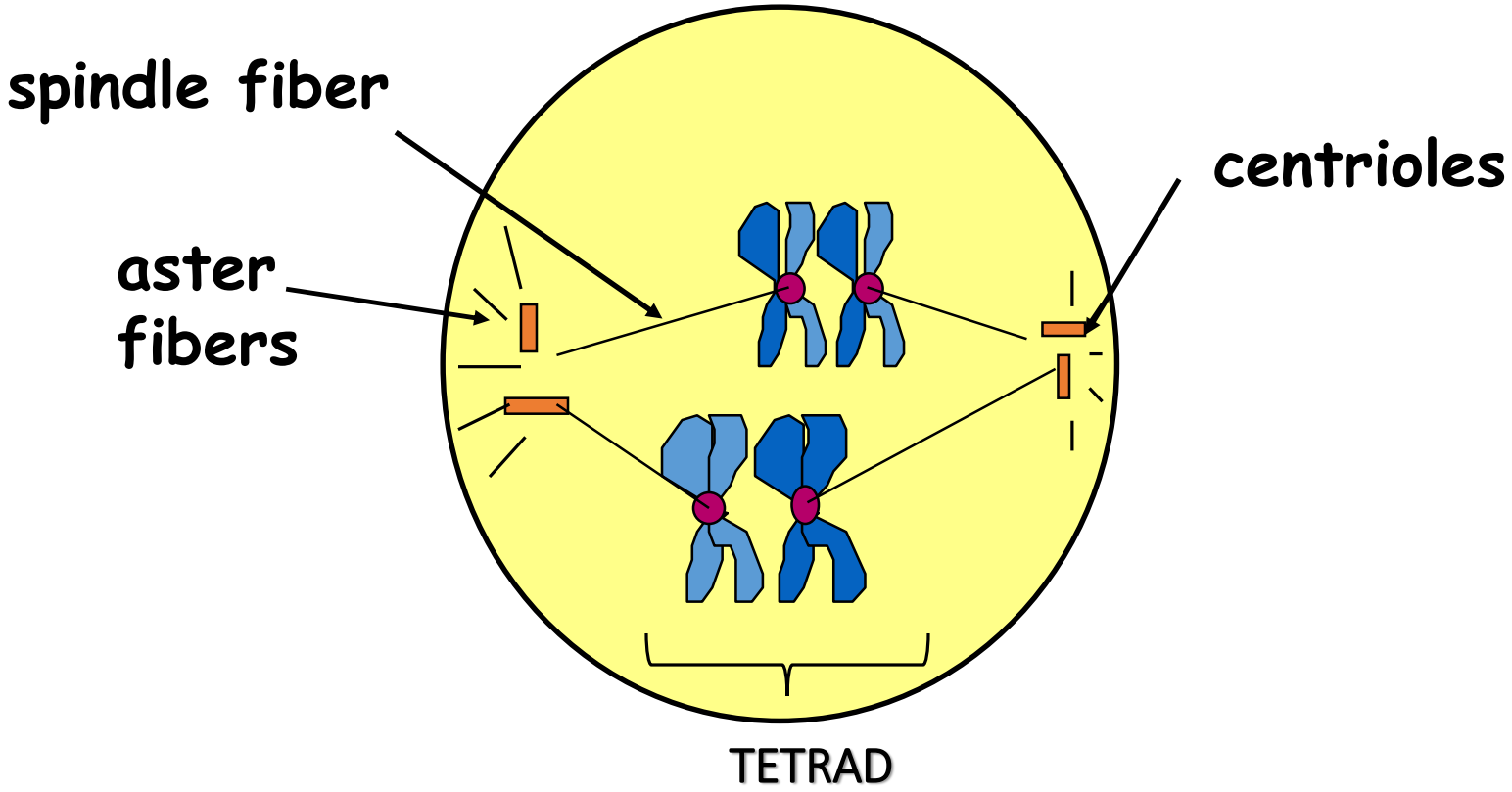


Meiosis I



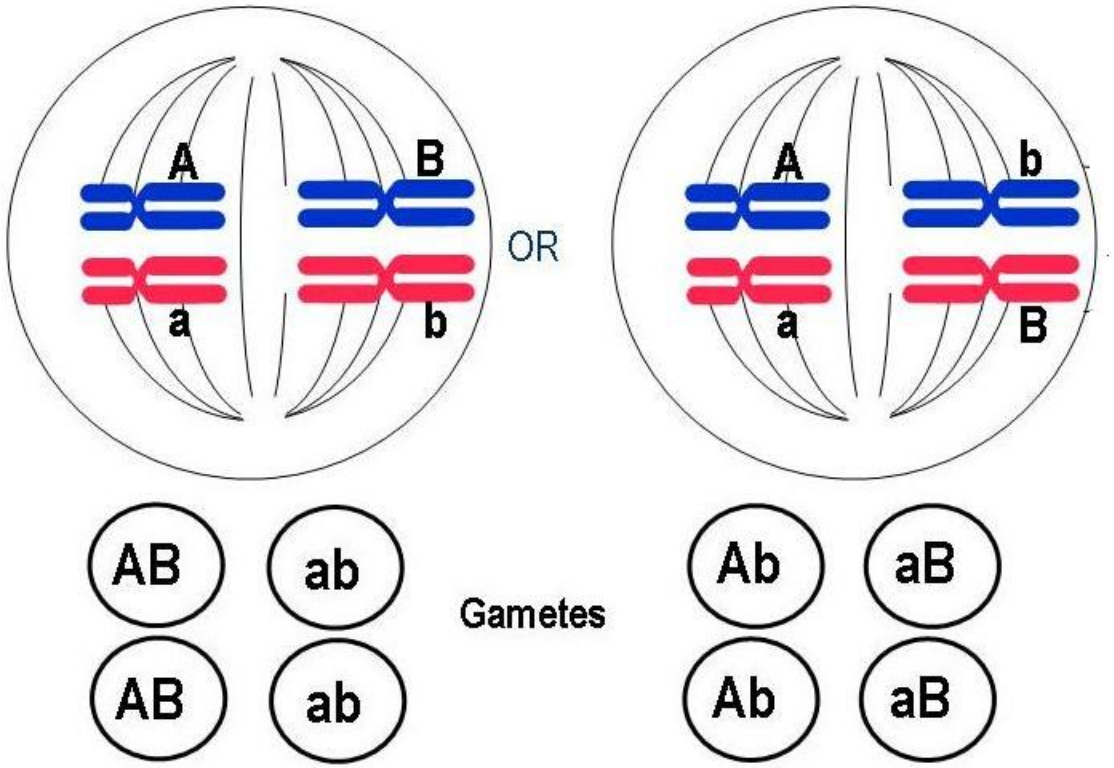
Prophase I

- **Nucleus & Nucleolus** disappear
- **Spindle** forms
- Chromosomes **coil** & **Synapsis** (pairing) occurs
- **Tetrads** form & *Crossing over* Occurs

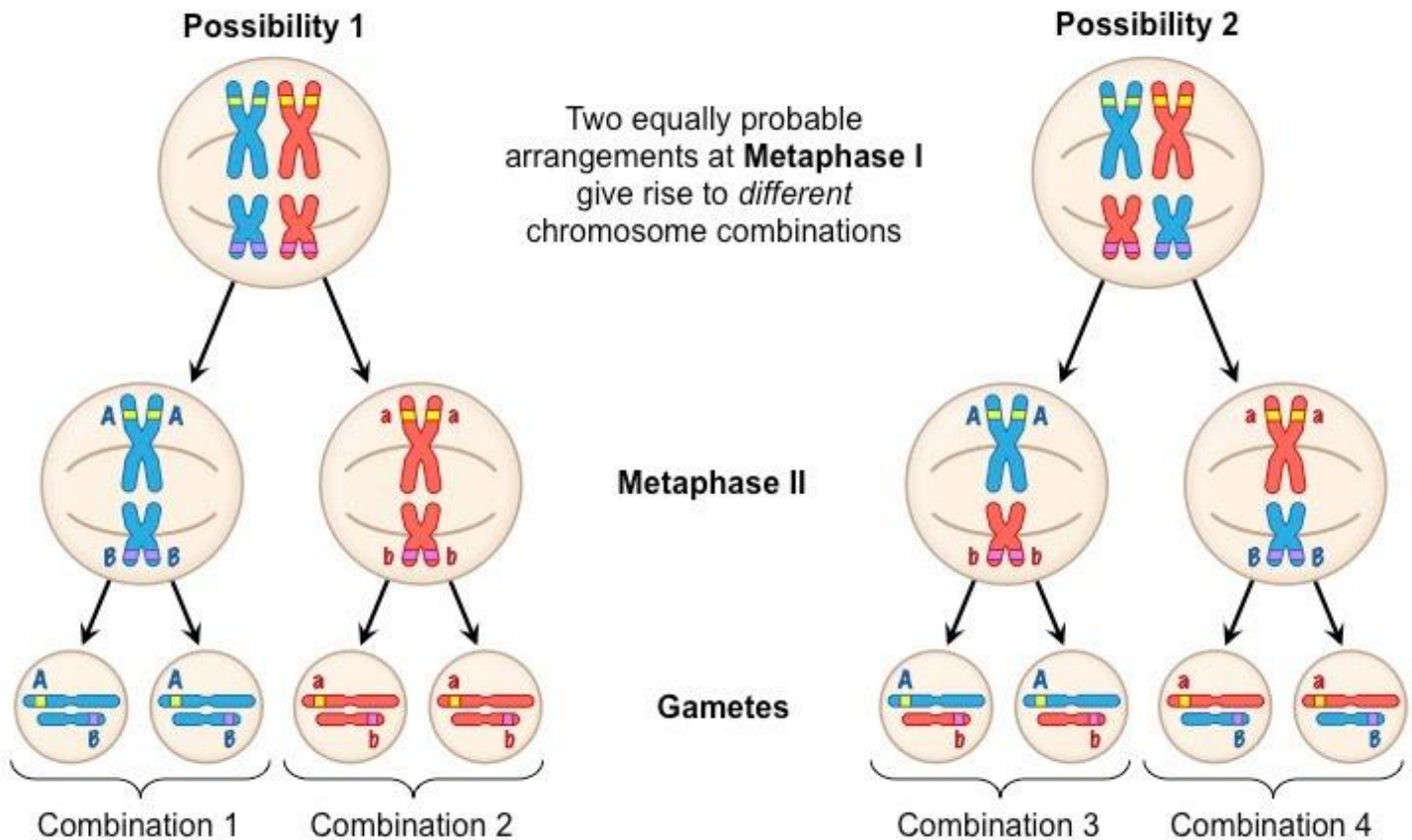


Metaphase I

- **Shortest** phase
- **Tetrads** align on the **equator**.
- **Independent assortment** occurs – chromosomes separate randomly causing GENETIC RECOMBINATION

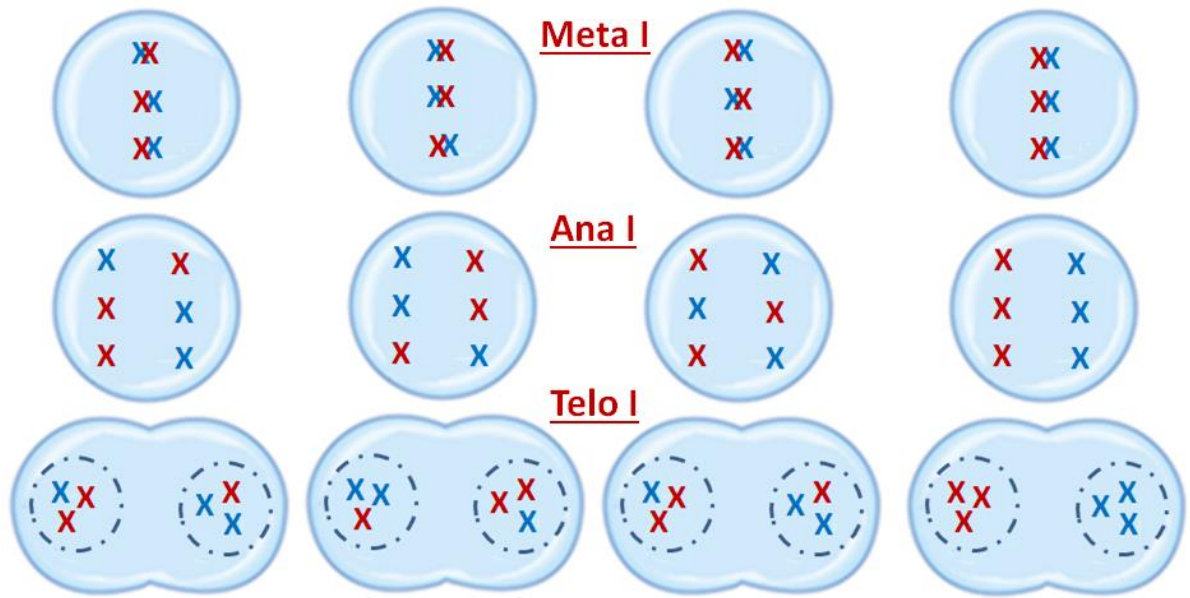


Independent Assortment of Genes via the Random Separation of Homologous Chromosomes



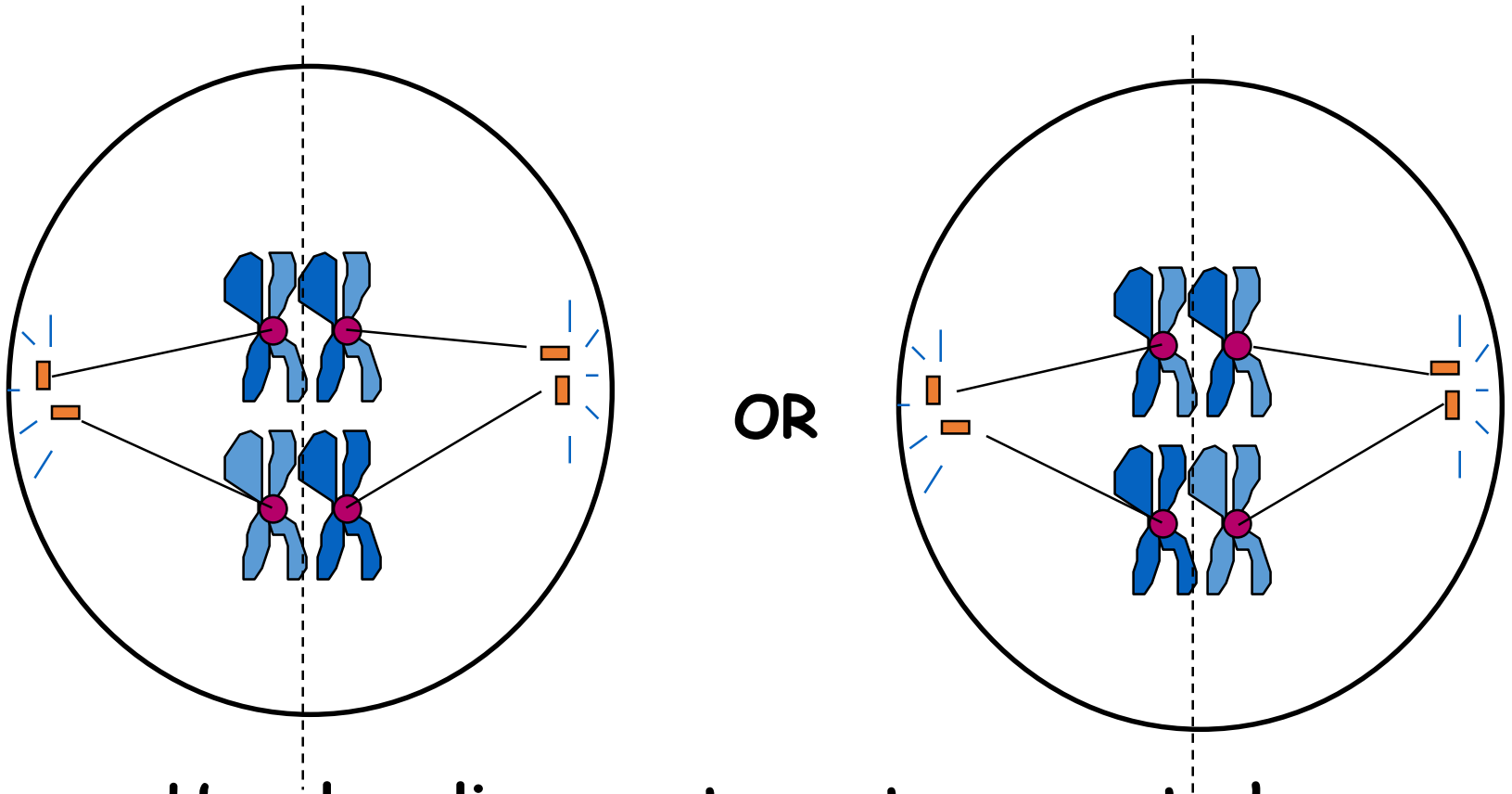
Independent assortment in Anaphase I

leads to different combinations of chromosomes in gametes



Each gamete can be a different combination of maternal and paternal chromosomes depending on the orientation of homologous pairs in metaphase I

Metaphase I

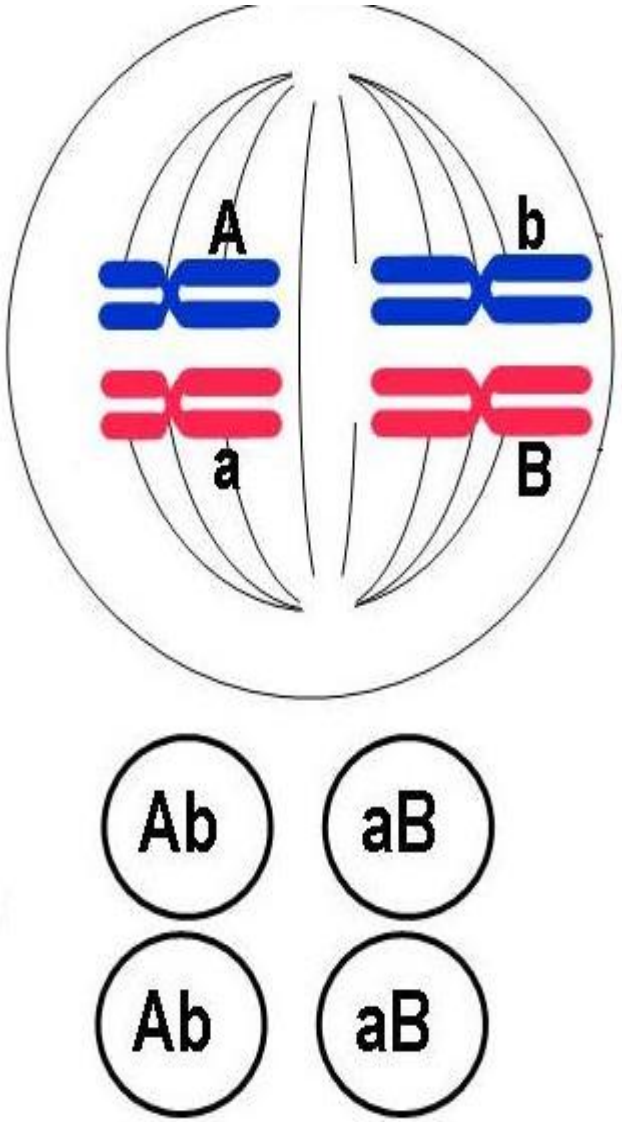


Homologs line up at equator or metaphase plate

- **Formula: 2^n**
- **Example: 2n = 4**

  then 1n = 2

  thus $2^2 = 4$ combinations



Question:

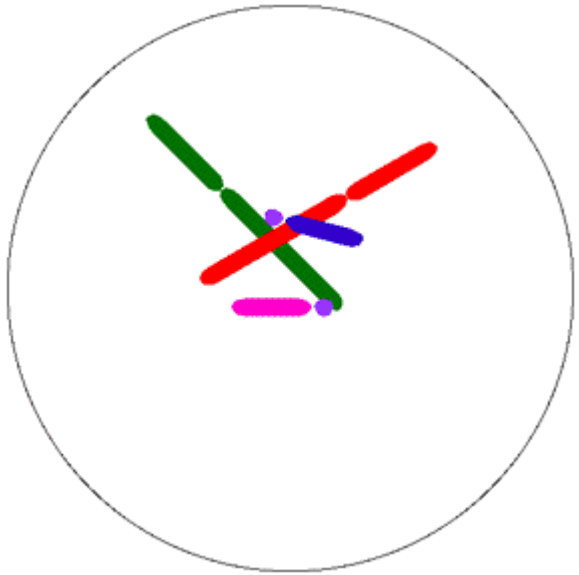
- **In terms of Independent Assortment -how many different combinations of sperm could a human male produce?**

Answer

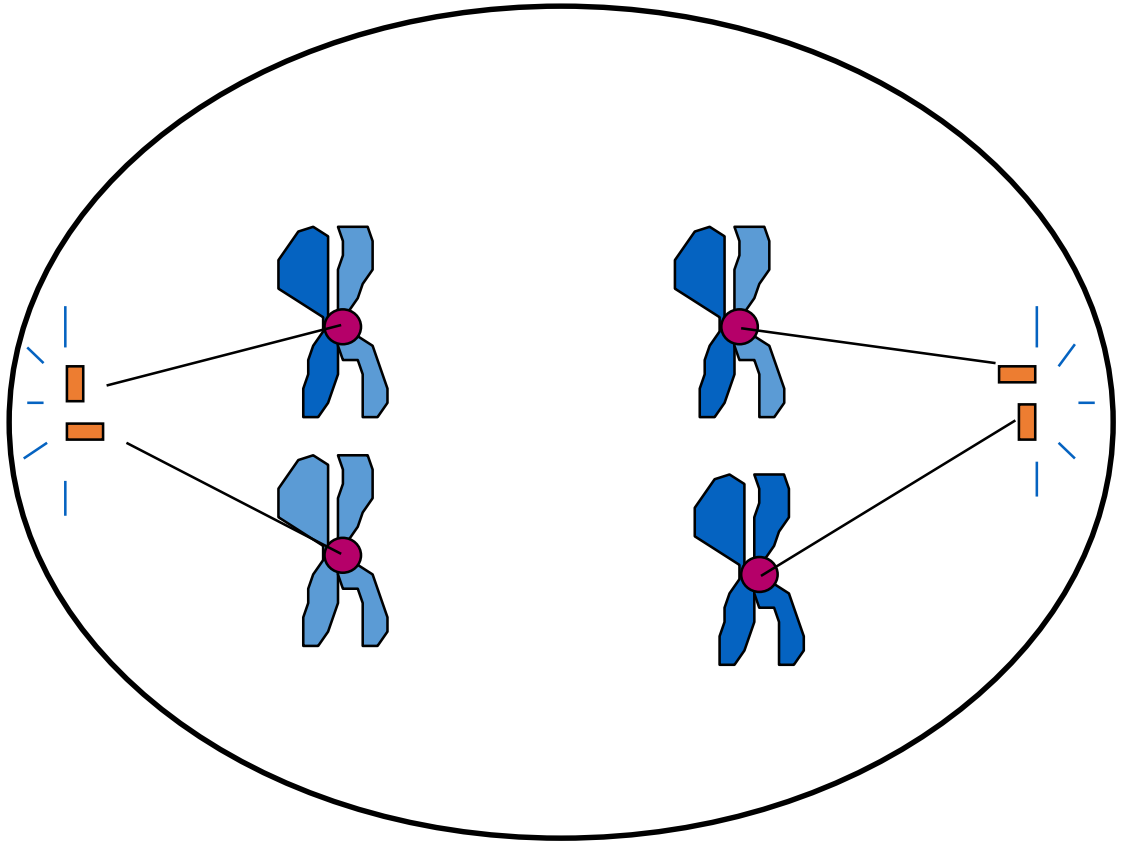
- **Formula: 2^n**
- **Human chromosomes: 2n = 46**
- **n = 23**
- **2^{23} = ~8 million combinations**

Anaphase I

- **Homologous chromosomes** separate and move towards the poles.
- **Sister chromatids remain attached** at their **centromeres**.



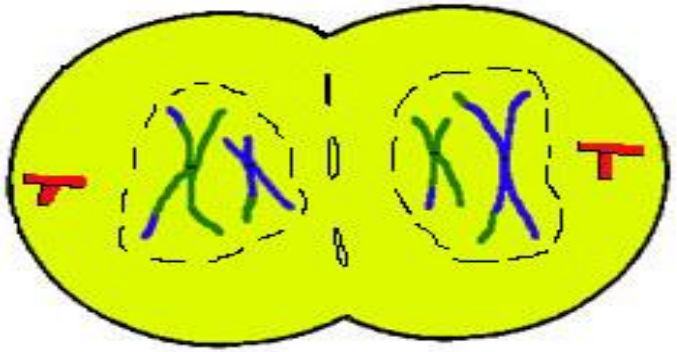
Anaphase I



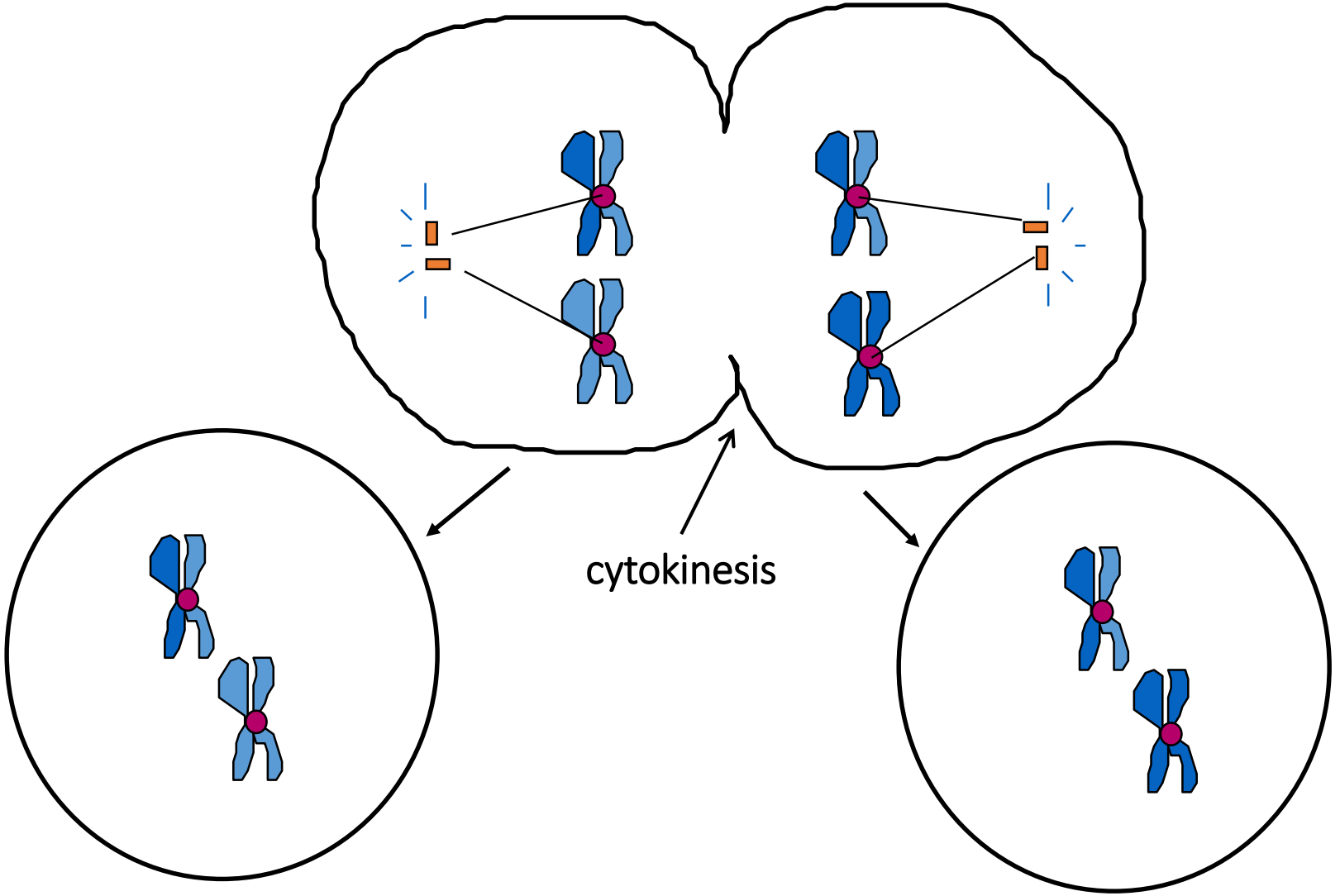
Homologs separate

Telophase I

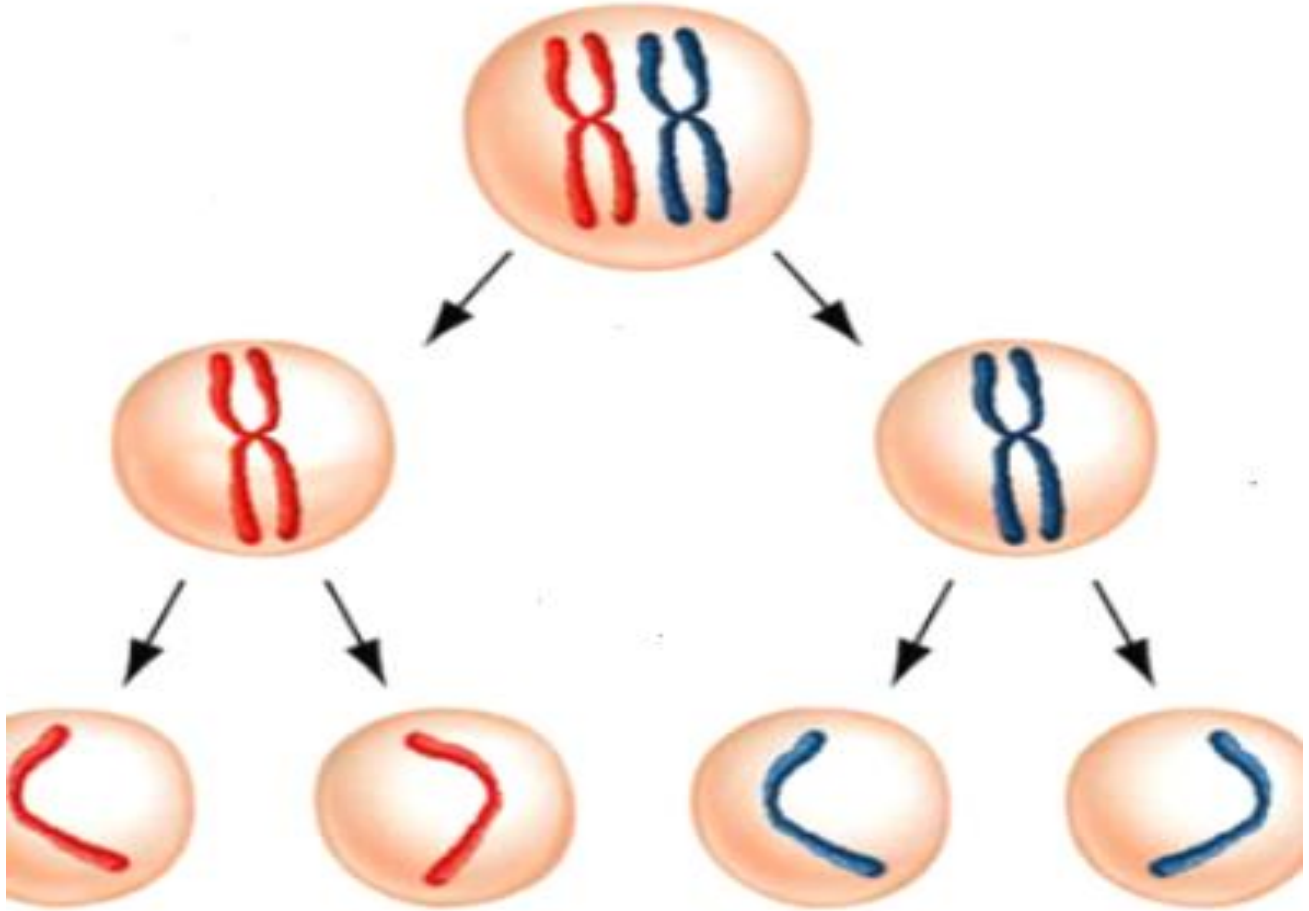
- Each pole now has **haploid** (1n) set of **chromosomes**.
- **Cytokinesis** occurs and two haploid daughter cells are formed.



Telophase I

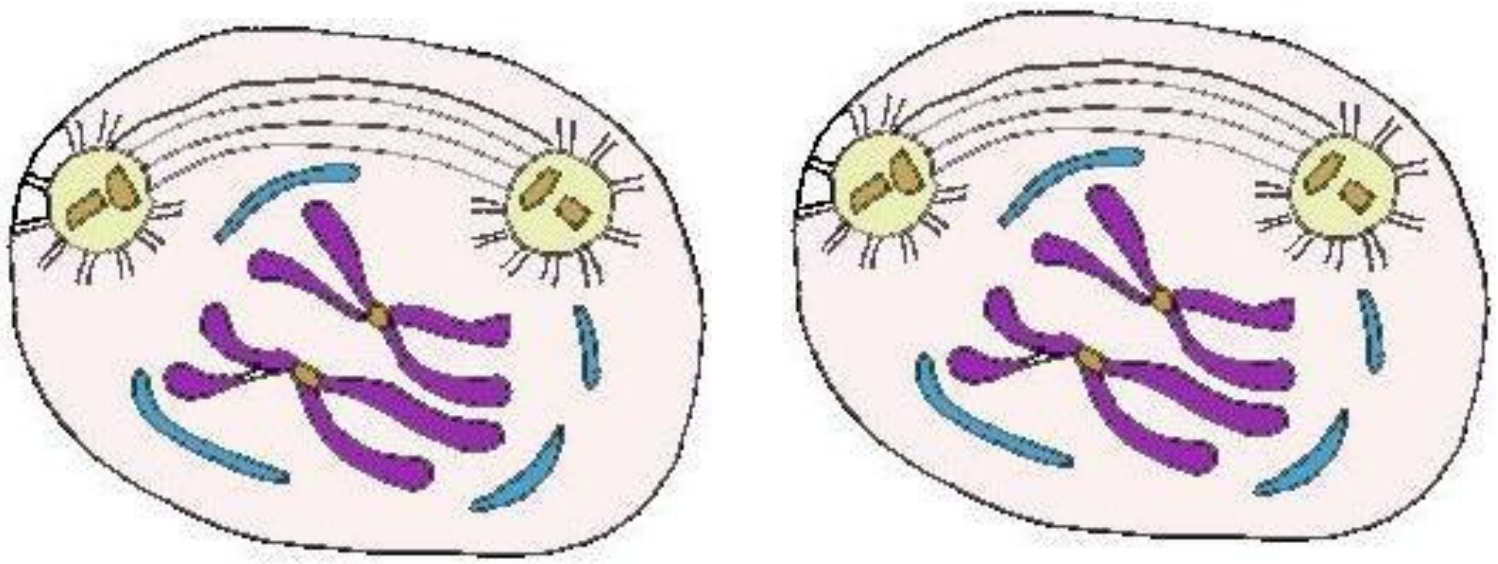


Meiosis II



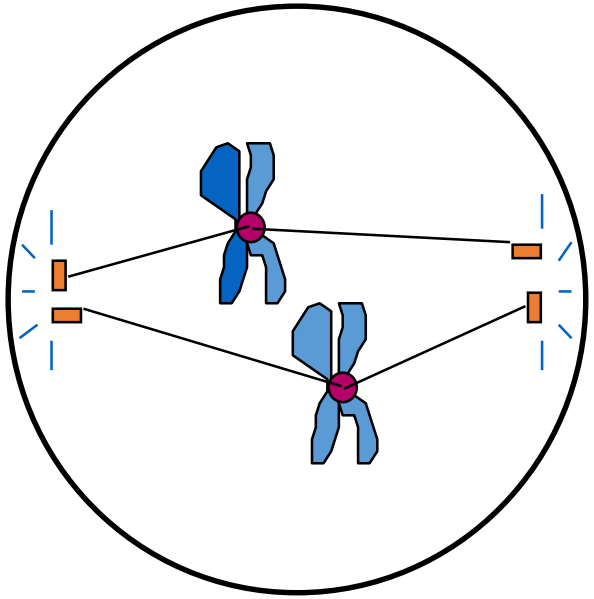
Meiosis II

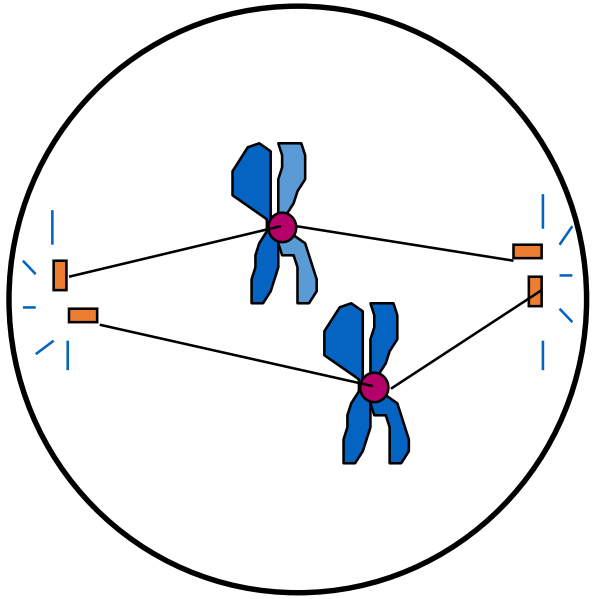
- **No Interphase II or very short**
- **No DNA Replication**
- **Remember: Meiosis II is similar to mitosis**



Prophase II

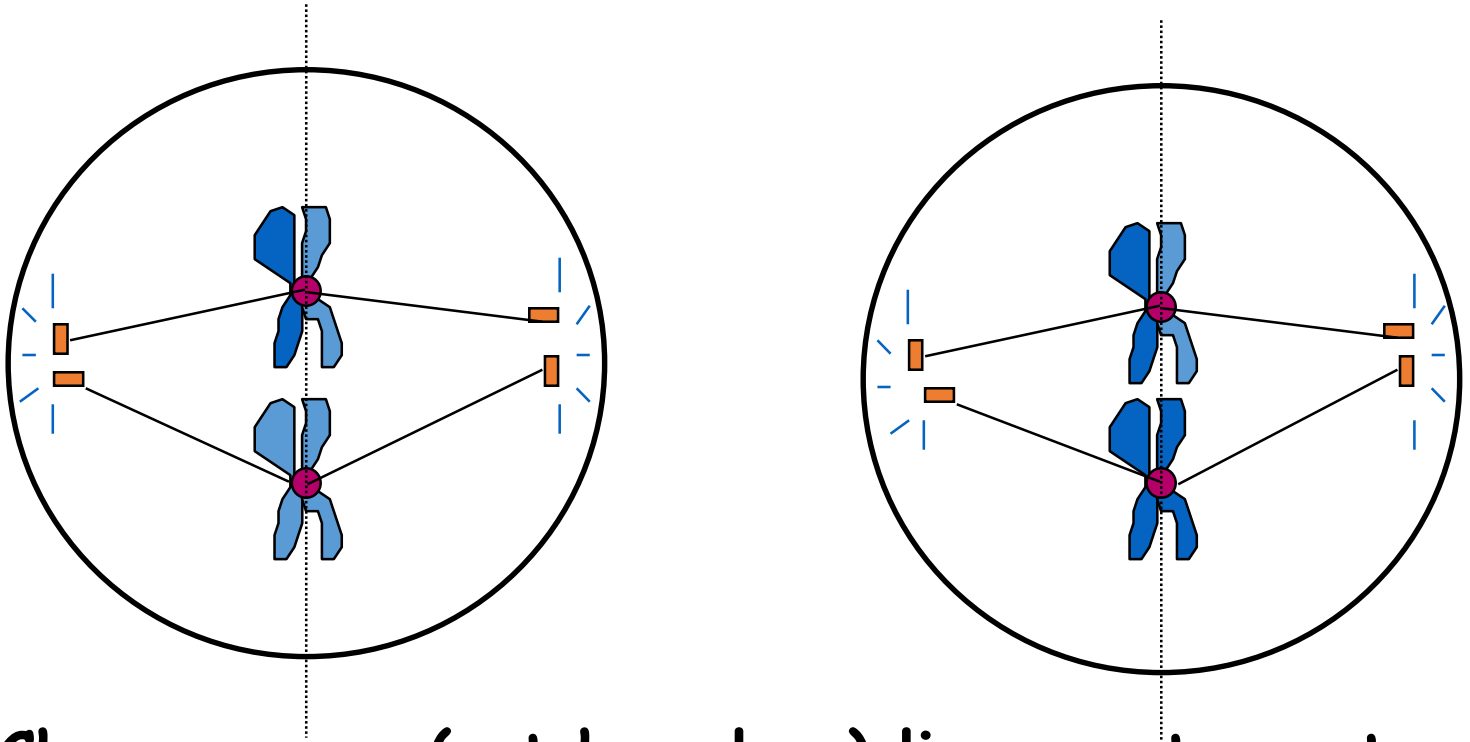
- **Same as Prophase in mitosis**
  - **Nucleus & nucleolus disappear**
  - **Chromosomes condense**
  - **Spindle forms**





Metaphase II

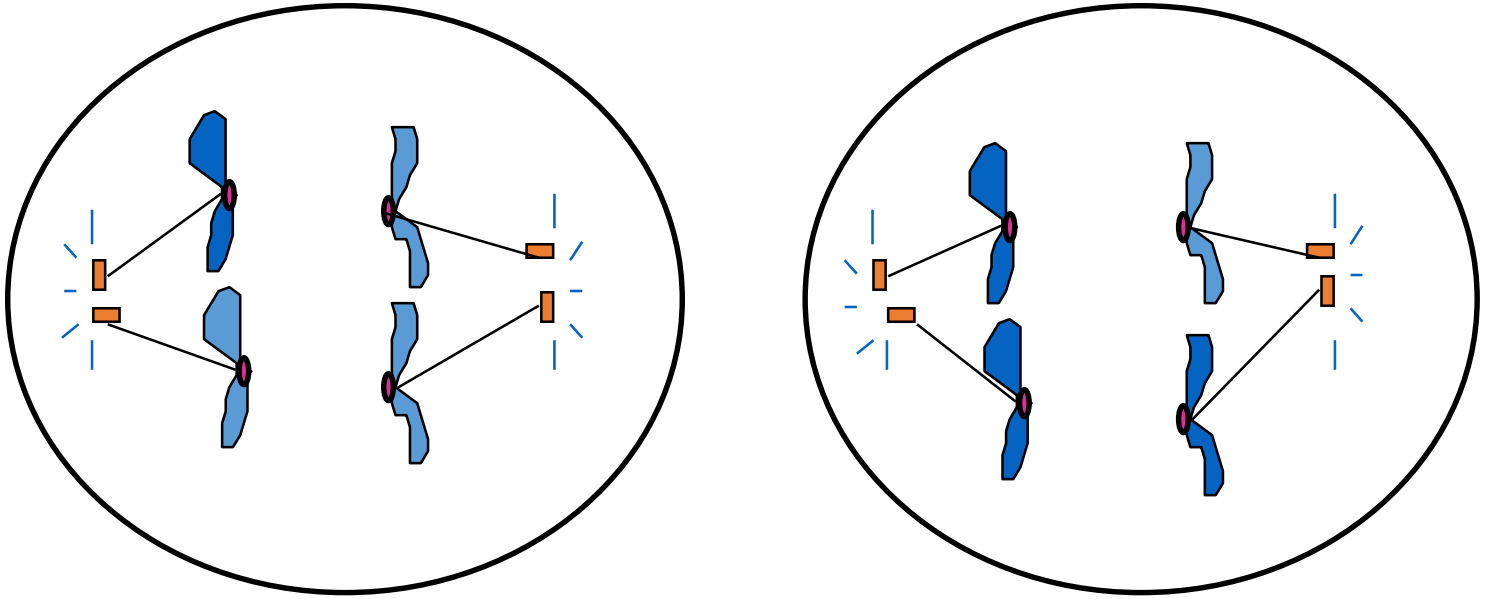
- **Same as Metaphase in mitosis**



Chromosomes (not homologs) line up at equator

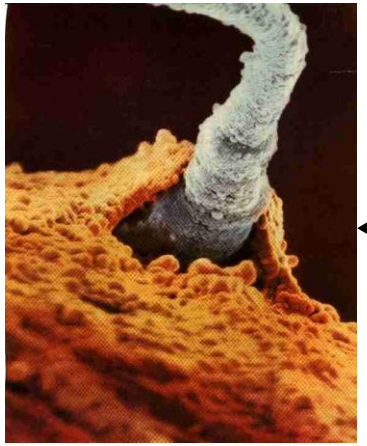
Anaphase II

- Same as **Anaphase** in **mitosis**
- **SISTER CHROMATIDS separate**



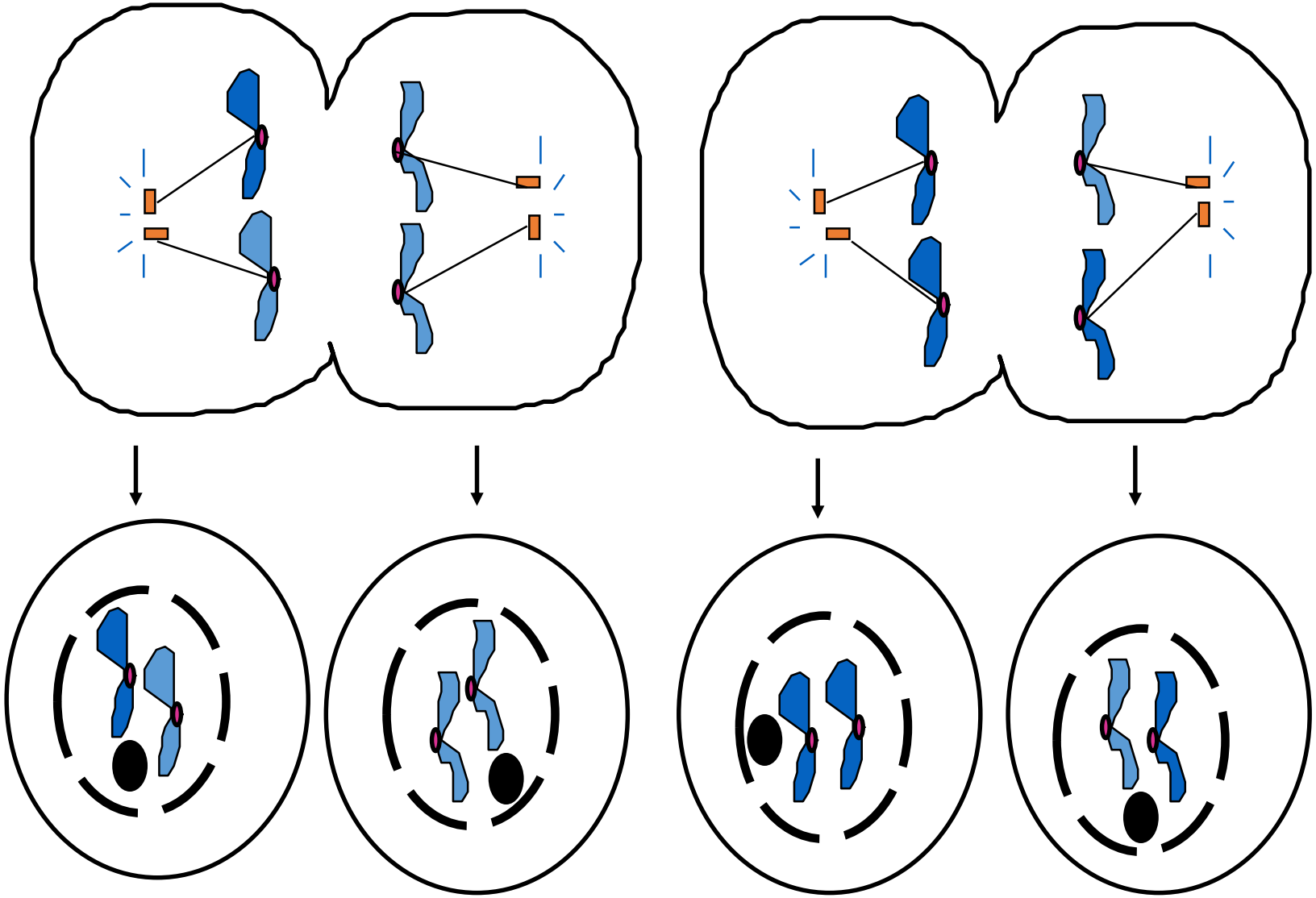
Telophase II

- Same as **Telophase** in mitosis.
- **Nuclei and Nucleoli** reform, spindle disappears
- **CYTOKINESIS** occurs.
- Remember: **FOUR HAPLOID** DAUGHTER cells are produced.
- Called **GAMETES** (eggs and sperm)



1n Sperm cell fertilizes 1n egg
to form 2n zygote

Telophase II



Variation- genetic recombination

- **Non-disjunction is one of the Two major occurrences of Meiosis. The other is Crossing Over**
- **Non-disjunction is the failure of homologous chromosomes, or sister chromatids, to separate during meiosis (metaphase I).**
- **Non-disjunction results with the production of zygotes with abnormal chromosome numbers…… remember…. An abnormal chromosome number (abnormal amount of DNA) is damaging to the offspring.**

Non-disjunctions usually occur in one of two fashions.

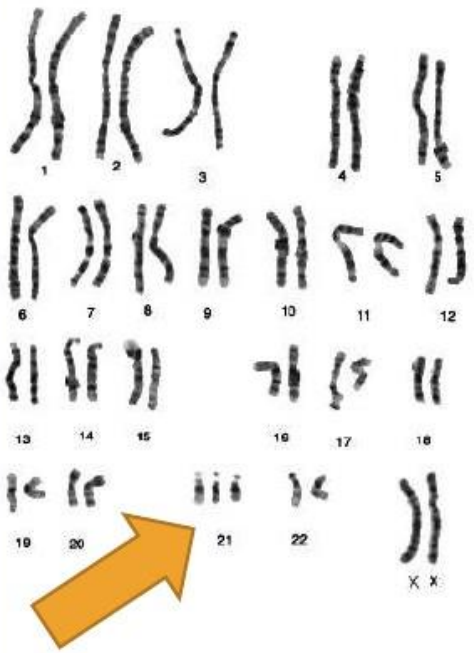
- The first is called **Monosomy**, the second is called **Trisomy**. If an organism has Trisomy 18 it has three chromosomes in the 18^{th} set, Trisomy 21…. Three chromosomes in the 21^{st} set. If an organism has Monosomy 23 it has only one chromosome in the 23^{rd} set.

Common Non-disjunction Disorders

- **Down's Syndrome – Trisomy 21**
- **Turner's Syndrome – Monosomy 23 (X)**
- **Kleinfelter's Syndrome – Trisomy 23 (XXY)**
- **Edward's Syndrome – Trisomy 18**

Down Syndrome is also called

Trisomy 21



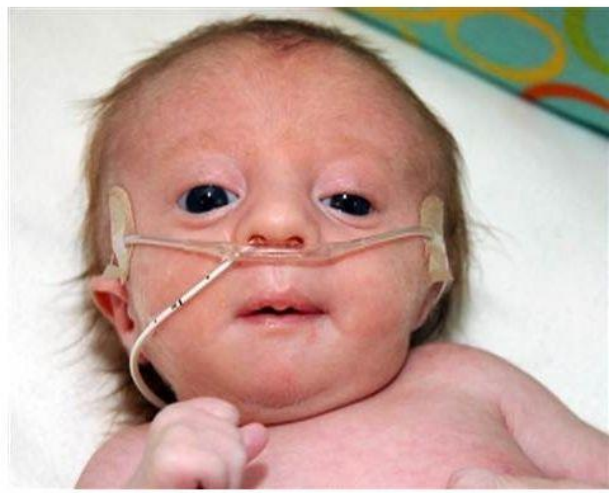
- Trisomy 21 is a congenital condition that makes an extra copy of the 21st chromosome.
- This extra chromosome causes mental and physical developmental delays.

- **Turner syndrome,** a condition that affects only females, results when one of the X chromosomes (sex chromosomes) is missing or partially missing. Turner syndrome can cause a variety of medical and developmental problems, including short height, failure of the ovaries to develop and heart defects.
- **Klinefelter syndrome** XXY or XXY, is the set of symptoms that result from two or more X chromosomes in males. The primary features are infertility and small testicles. Often, symptoms may be subtle and many people do not realize they are affected.

Teacher Notes (Page 37.C)

Trisomy 18 – Edwards Syndrome

- 2nd most common trisomy
- 80% female
- Majority die before birth
- Low survival rate
  - heart abnormalities, kidney malformations, etc.
- Symptoms: small head , malformed ears, widely spaced eyes, clenched hands

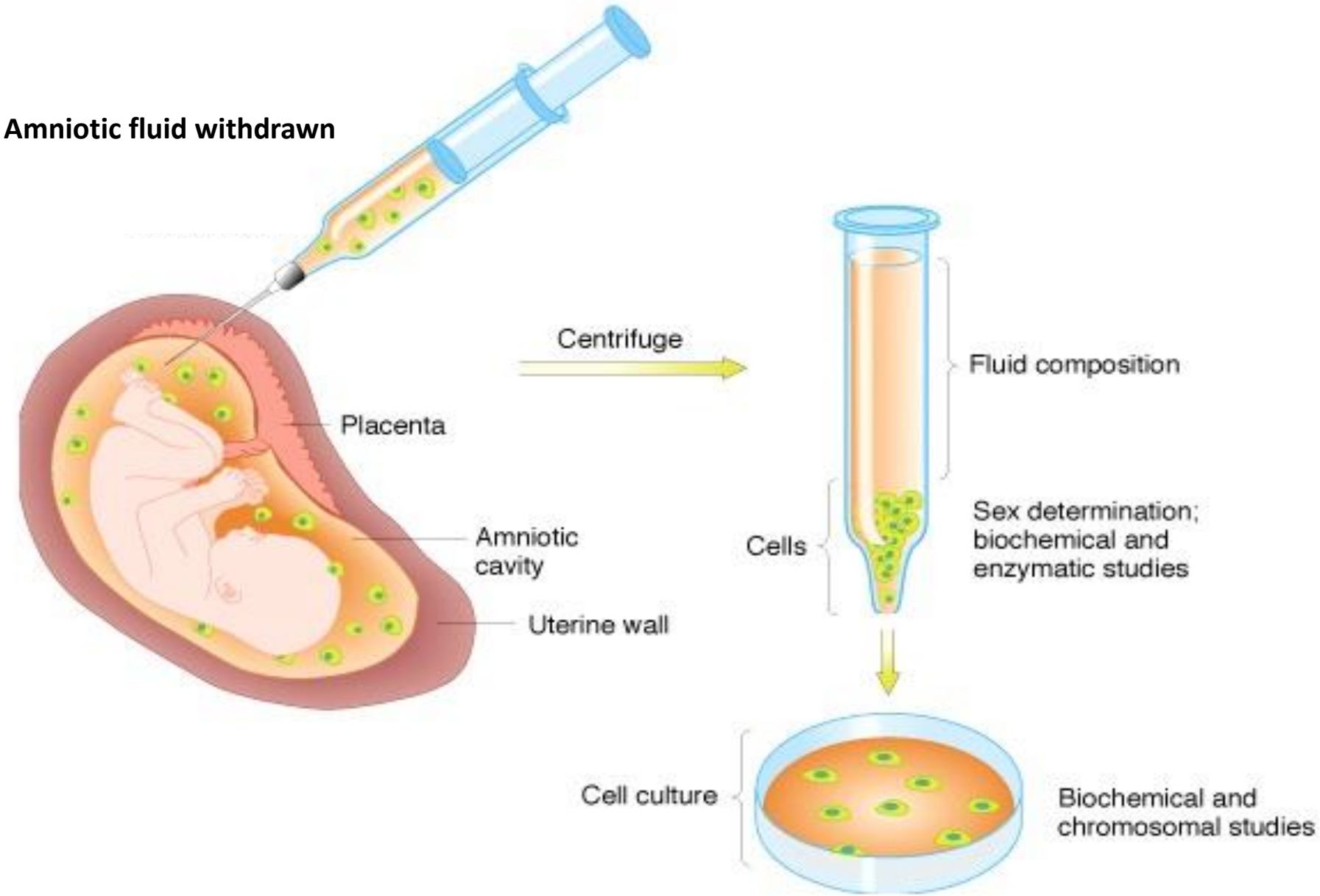


Amniocentesis

- An Amniocentesis is a prrocedure a pregnant woman can have in order to detect some genetics disorders…..such as non-disjunction.

Amniocentesis

Amniotic fluid withdrawn



Karyotype

(picture of an individual's chromosomes)

One of the ways to analyze the amniocentesis is to make a Karyotype

What genetic disorder does this karyotype show?

Trisomy 21….Down's Syndrome