Human Heredity
Chapter 2
Chromosomes, Mitosis, and Meiosis

2:1 Chromosomes

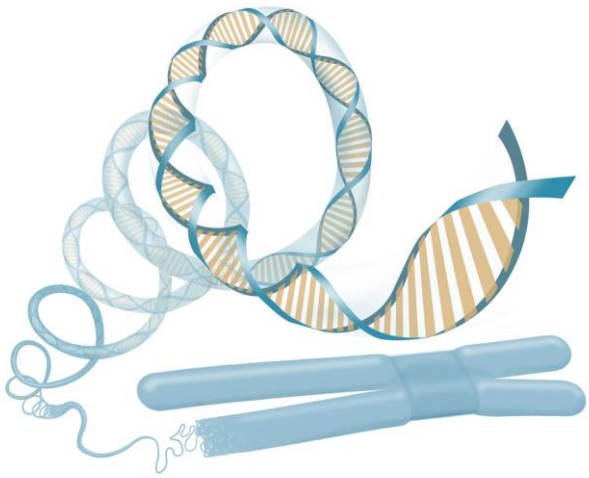
DNA → Genes → Chromatin → Chromosomes

CHROMATIN: nuclear material in non-dividing cell, composed of DNA/protein in thin uncoiled strands

How does chromatin become chromosomes?

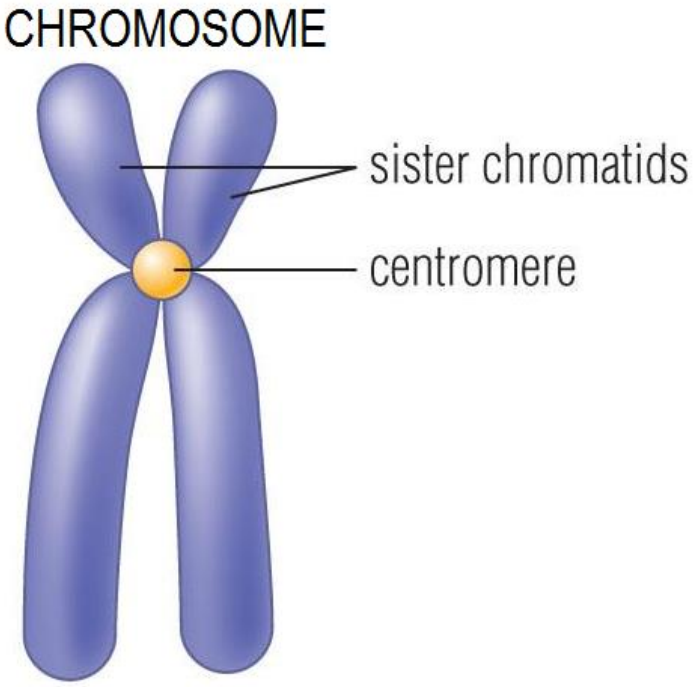
1. Prior to cell division, DNA replicates.
2. Replicated strands of DNA begin to coil; DNA becomes tightly wrapped around HISTONES: a group of special protein molecules.
3. DNA and histones in coiled form can be seen as rod-shaped structure (chromosome).
4. Only the physical arrangement of DNA changes in the transition from chromatin to chromosome. Chemically, chromatin and chromosomes are the same.

CHROMOSOME: nuclear material in dividing cell composed of DNA/protein in coiled, rod-shaped form.



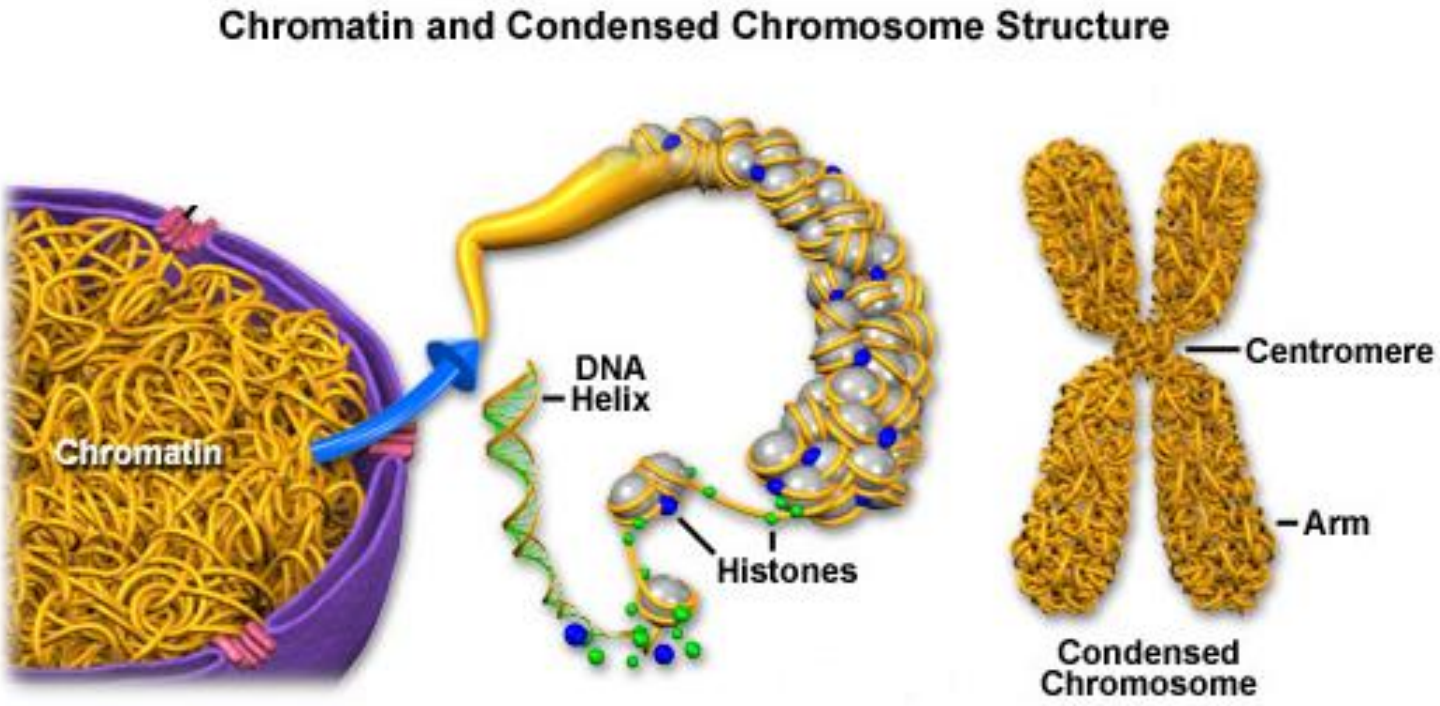
CHROMATID: (sister chromatids) one of two identical parts of a chromosome, found after DNA replication but prior to cell division

CENTROMERE: point at which sister chromatids are attached



SUMMARY

1. Chromatin: DNA in thin uncoiled strands
2. DNA replicates
3. DNA coils around histones
4. Chromosome: DNA in 2 identical chromatids

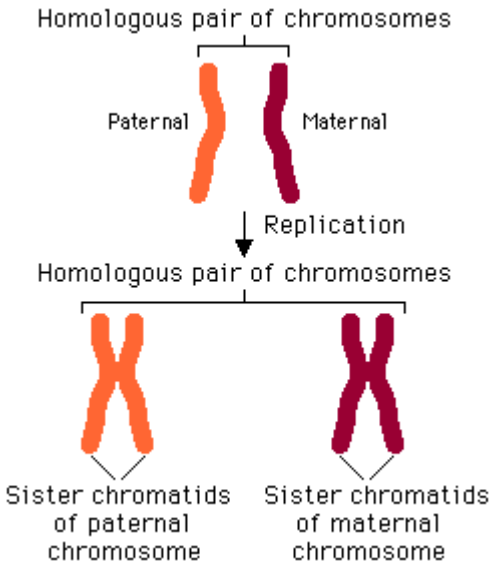


Chromosome Number

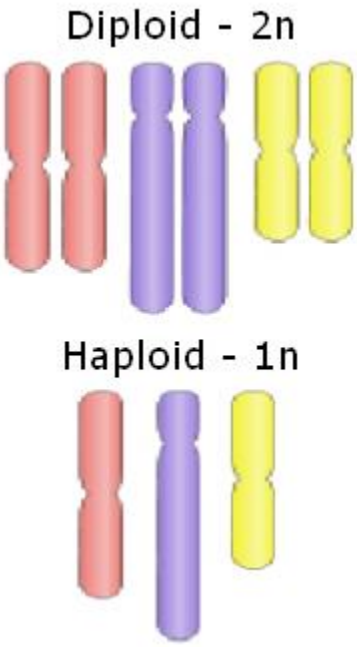
Every species has a characteristic number of chromosomes. The number varies among species.

e.g.	nematode worm	2
	protozoan	300
	human	46

In all sexually reproducing organisms chromosomes occur in pairs called HOMOLOGOUS CHROMOSOMES: (homologues) two members of a pair of chromosomes with the same size and shape



n: number of pairs of homologous chromosomes in a particular species



DIPLOID (2n): total chromosome number in a body or somatic cell, has both chromosomes of the homologous pair

e.g. Diploid (2n) for a human body cell is 46, or 23 homologous pairs.

HAPLOID (1n): chromosome number of egg or sperm cell with only one chromosome from each homologous pair

e.g. Haploid (1n) for a human gamete is 23, there are no homologous chromosomes.

2:2 The Cell Cycle

CELL CYCLE: sequence of events that occurs in a cell from mitosis to mitosis

Five Events of the Cell Cycle

1. G1 period
2. S period
3. G2 period
4. Mitosis
5. Cytokinesis

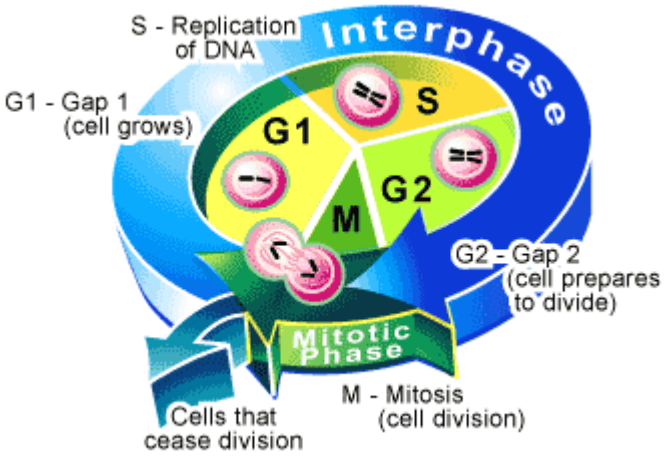
INTERPHASE

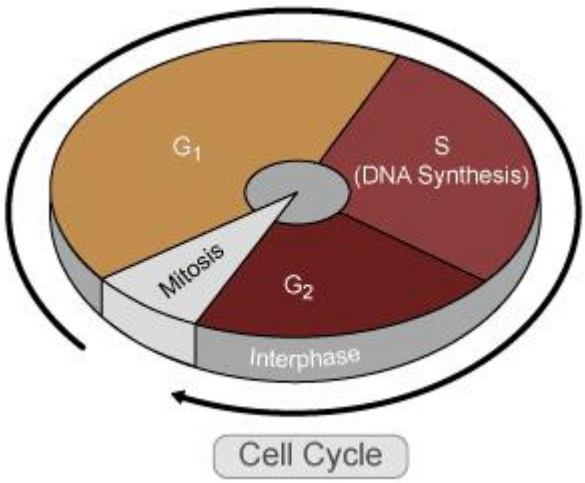
CELL DIVISION

INTERPHASE: period of cell growth and development that precedes mitosis and follows cytokinesis

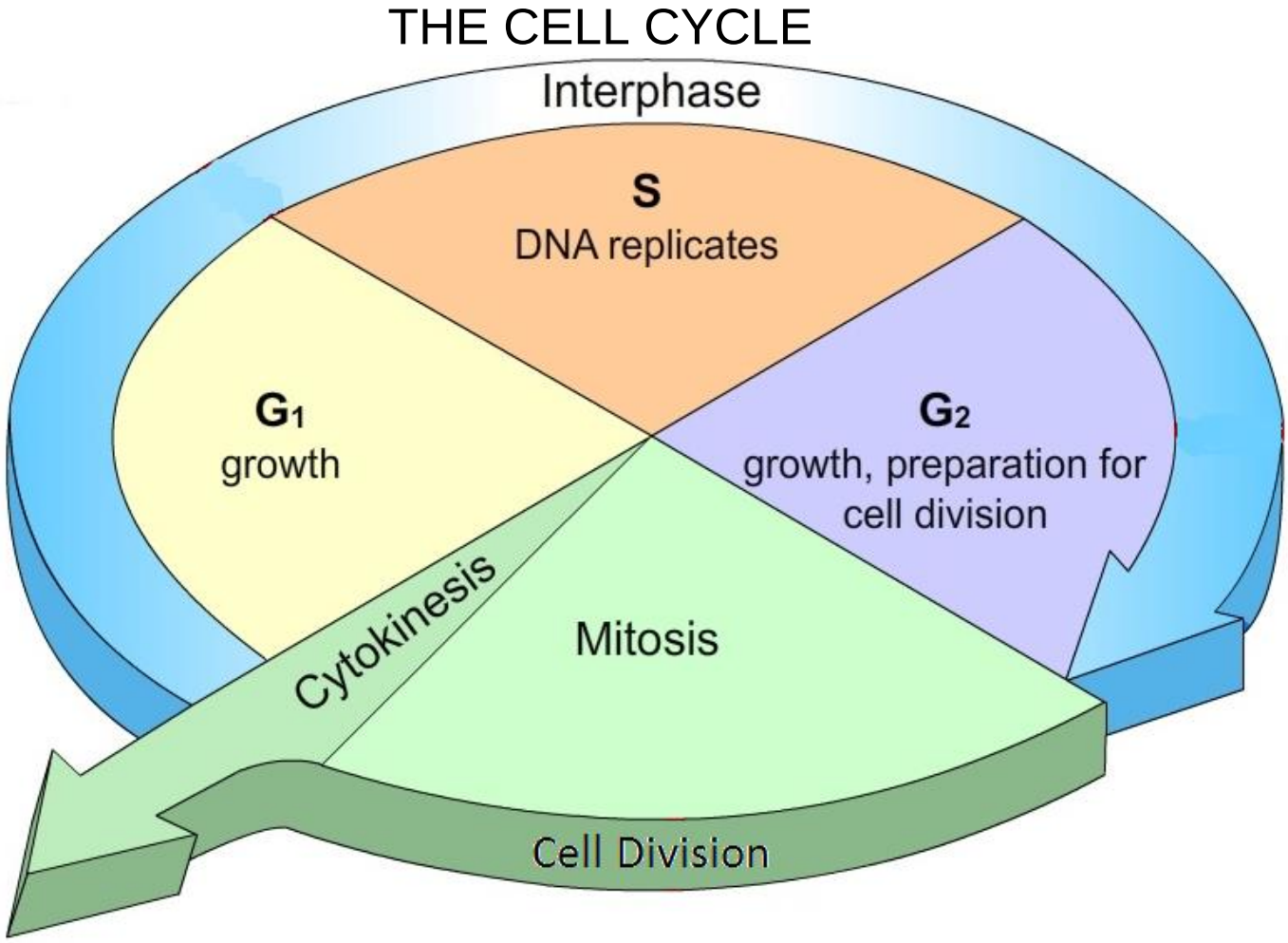
MITOSIS: the division of the cell nucleus in which the chromosomes in the parent cell divide into two identical sets

CYTOKINESIS: the division of the cytoplasm of a parent cell and its contents into two daughter cells





The three periods of interphase constitute the largest part of the cell cycle. Cells spend most of their time in interphase.

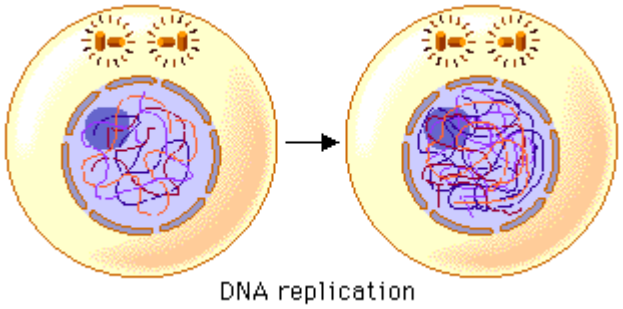


Interphase is G1, S, and G2 period.

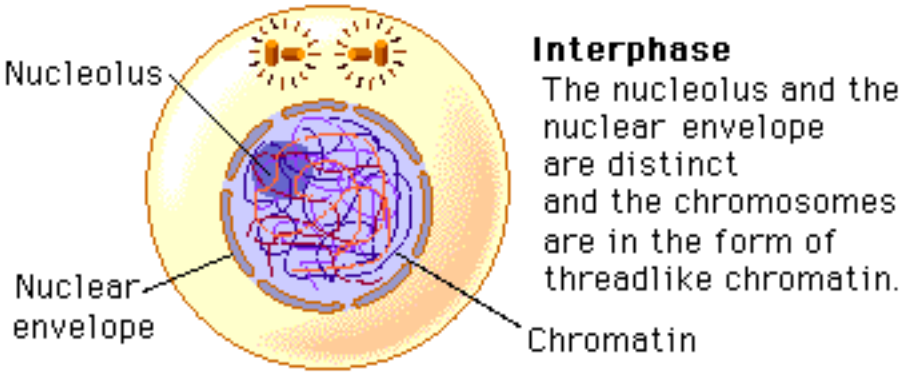
The Periods of Interphase

1. G1 PERIOD: first period of interphase; the cell doubles in size, enzymes, and organelles double in number

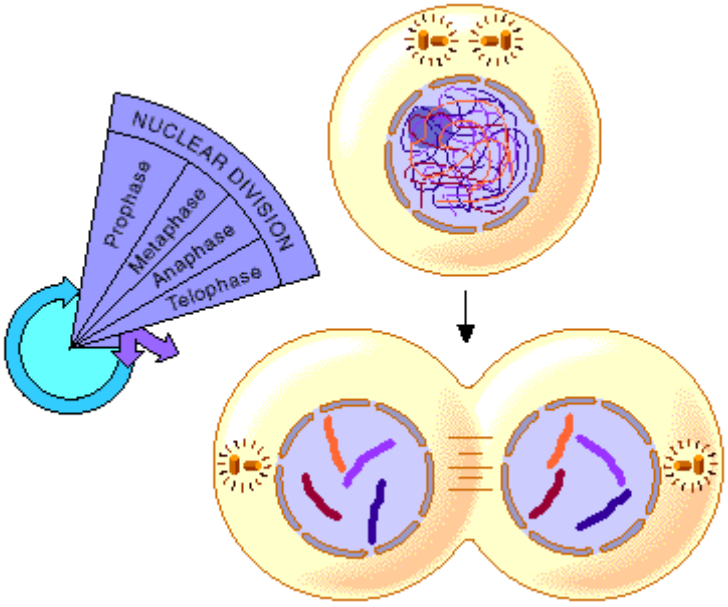
2. S PERIOD: second period of interphase; the DNA that makes up the chromatin replicates



3. G2 PERIOD: third period of interphase; cell undergoes rapid growth, synthesizes necessary enzymes and structures in preparation for mitosis



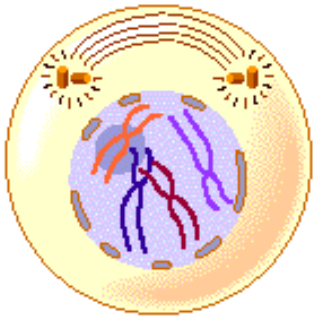
Mitosis produces two identical nuclei with the same chromosome number as the parent cell.



The Phases of Mitosis

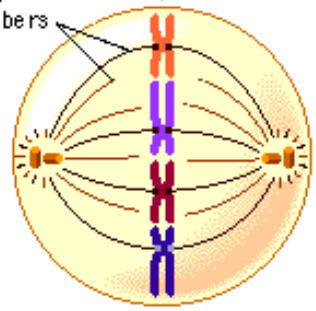
1. PROPHASE
   - Chromatin coils and forms chromosomes
   - Nucleolus and nuclear membrane break down and disappear
   - In organisms other than plants, CENTRIOLES (two small dark cylindrical bodies that anchor spindle fibers) move away from each other toward opposite poles of the cell

- SPINDLE FIBERS (microtubules of protein) develop
  Two Types of Spindle Fibers
  POLAR FIBERS: microtubules extending across cell from centriole to centriole
  KINETOCHORE FIBERS: microtubules extending from centromeres of chromosomes to centrioles.
- ASTERS (protein fibers that radiate from each centriole) form in all but plant cells



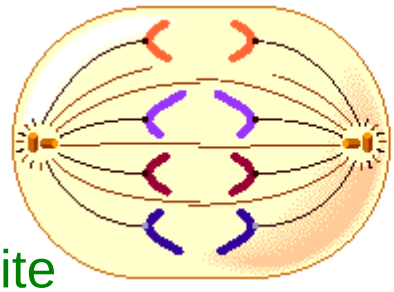
Prophase
The chromosomes appear condensed, and the nuclear envelope is not apparent.

2. METAPHASE
   - Kinetochore fibers move the chromosomes to center (equator) of the cell



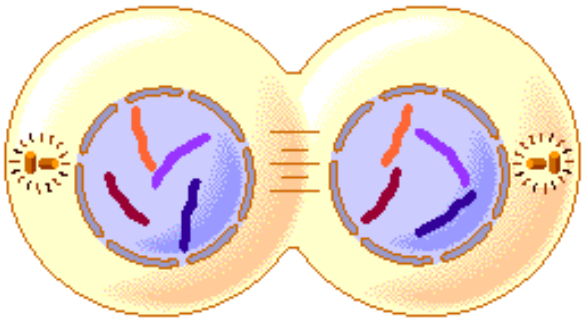
Metaphase
Thick, coiled chromosomes are lined up in the center of the cell on the metaphase plate. Spindle fibers are attached to the chromosomes.

3. ANAPHASE
   - The centromere of each chromosome divides
   - The chromatids separate and are rapidly moved toward opposite poles of the cell by the spindle fibers.



Anaphase
The chromosomes have separated and are moving toward the poles.

4. TELOPHASE

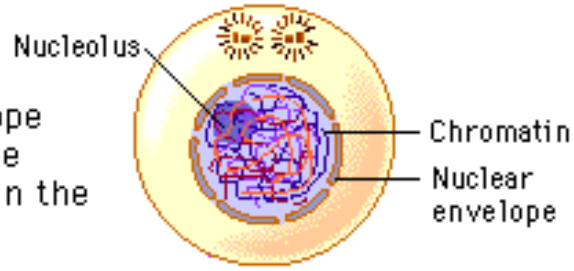


Telophase
The chromosomes are at the poles, and are becoming more difuse. The nuclear envelope is reforming. The cytoplasm may be dividing.

- Two identical sets of chromosomes are clustered at opposite poles
- Centrioles and spindle fibers disappear
- Chromosomes unwind and elongate into threadlike structure of DNA (chromatin)
- Nuclear membrane forms around each mass of chromatin, nucleolus appears

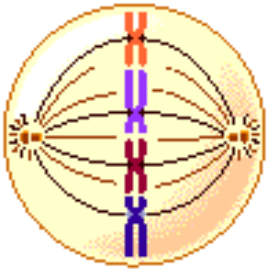
MITOTIC PHASE	CHROMOSOMES	SPINDLE
Prophase	Condense from chromatin	Appears
Metaphase	Line up at equator	Attaches to chromosomes
Anaphase	Move to poles	Shortens
Telophase	Unwind into chromatin	Disappears

Interphase
The nucleolus and the nuclear envelope are distinct and the chromosomes are in the form of threadlike chromatin.

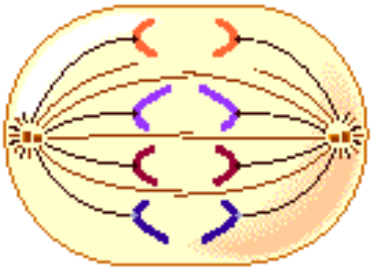


Prophase
The chromosomes appear condensed, and the nuclear envelope is not apparent.

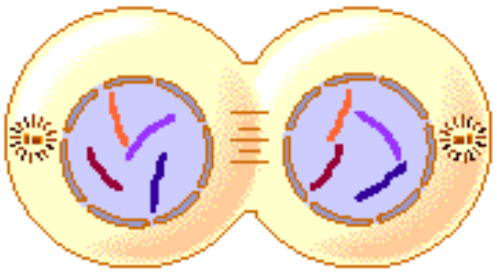
Metaphase
Thick, coiled chromosomes, each with two chromatids, are lined up on the metaphase plate.



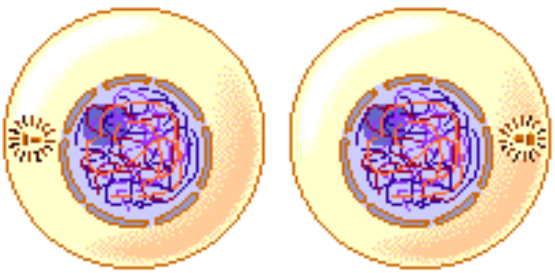
Anaphase
The chromatids of each chromosome have separated and are moving toward the poles.



Telophase
The chromosomes are at the poles, and are becoming more diffuse. The nuclear envelope is reforming. The cytoplasm may be dividing.

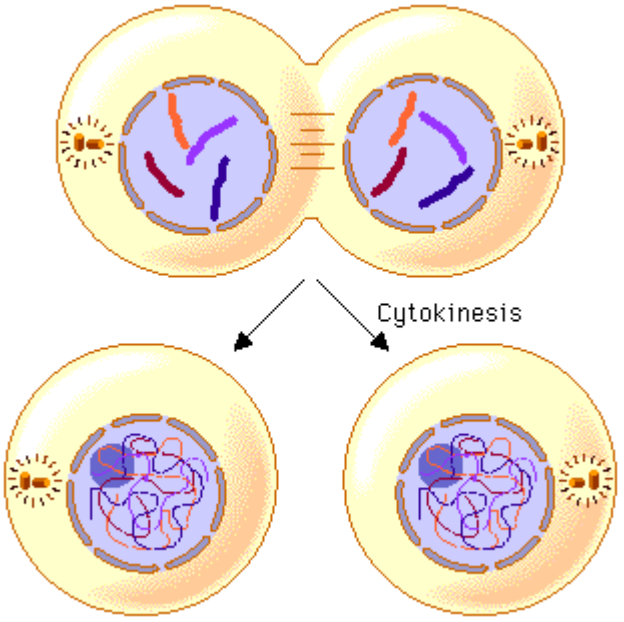


Cytokinesis
Division into two daughter cells is completed.



Events of Cytokinesis

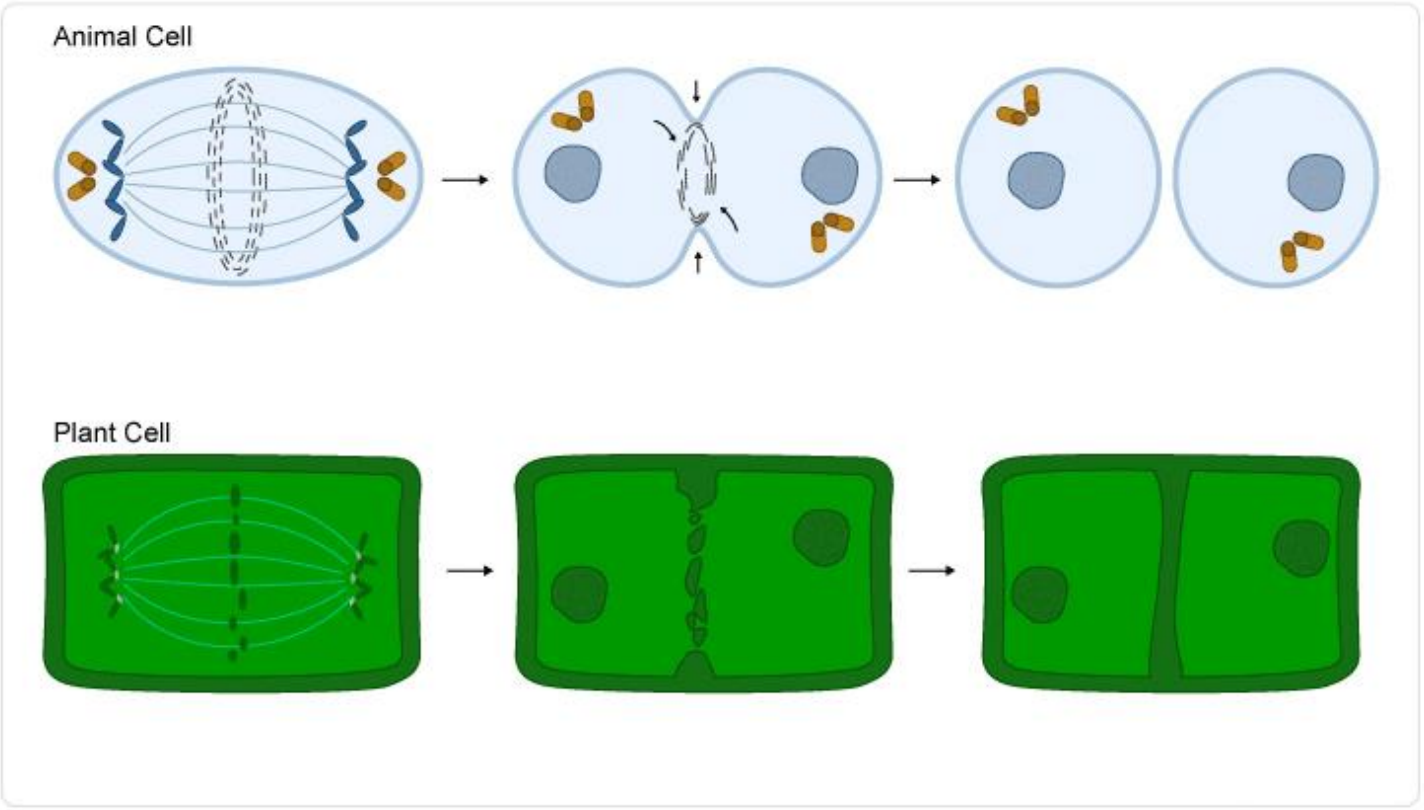
1. Cytoplasm from original cell splits and forms two new cells.
2. Each newly formed cell houses one of the two nuclei from mitotic division
3. Other cell structures are evenly distributed into two new cells, cells are even in size



Cytokinesis in Plant and Animal Cells Differs

Animal: During early anaphase cell membrane pinches in, after telophase cell divides

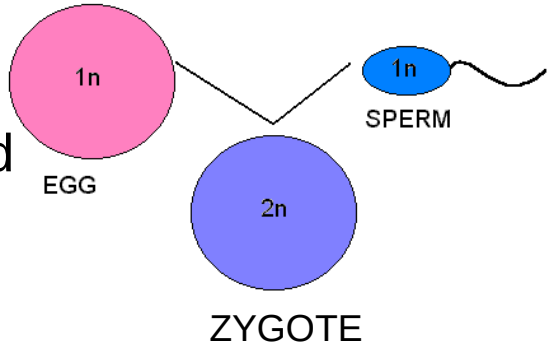
Plant: Vesicles formed by Golgi bodies fuse at equator and form CELL PLATE: barrier across the middle of the cell

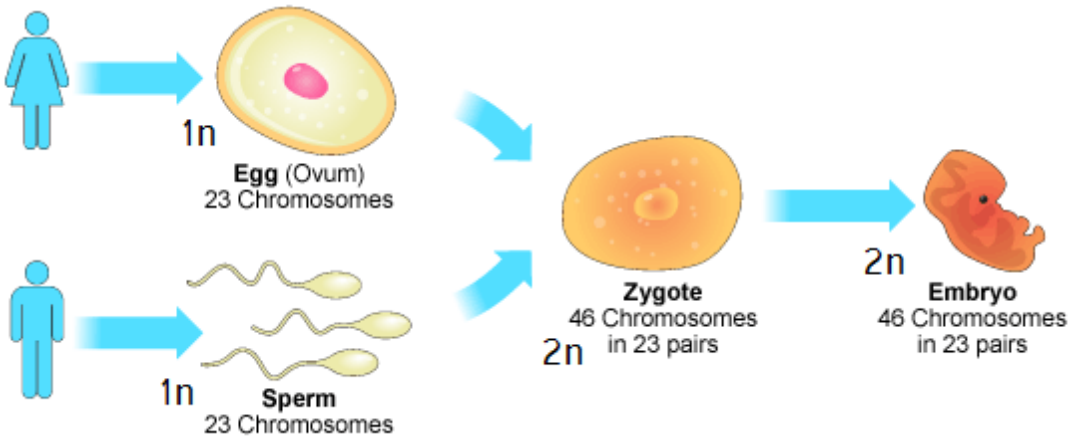


2:3 MEIOSIS

MEIOSIS: the process of nuclear division that reduces the number of chromosomes by half for sexual reproduction.

Meiosis produces haploid (1n) egg cells and haploid (1n) sperm cells that fuse during fertilization to form a diploid (2n) zygote.





PHASES OF MEIOSIS: (two nuclear divisions)

MEIOSIS I: homologous chromosomes are separated into two cells.

MEIOSIS II: the chromatids of each chromosome are segregated into separate cells.

Since meiosis I follows interphase, DNA has been replicated. The chromosomes are two identical chromatids

RESULTS OF MEIOSIS → 4 daughter cells with half the number of chromosomes as the parent cell.

MEIOSIS I

1. PROPHASE I:
   - DNA strands coil, shorten, and thicken into chromosomes
   - Spindle fibers appear; nuclear membrane and nucleolus disappear
   - Chromosome lines up next to its homologue during SYNAPSIS: pairing of homologous chromosomes
   - Homologous chromosomes twist around each other forming a TETRAD: group of 4 chromatids that form 2 chromosomes.
   - Tetrads may exchange genes during CROSSING OVER: when portions of chromatids (either homologues or sister chromatids) exchange portions of genetic material.

2. METAPHASE I:
   - Tetrads are moved by spindle fibers to the equator of the cell, homologous pairs stay together.

3. ANAPHASE I:
   - The homologous pairs of chromosomes separate, and are pulled by spindle fibers to opposite poles.
   - Each chromosome is still composed of two chromatids joined by a centromere.

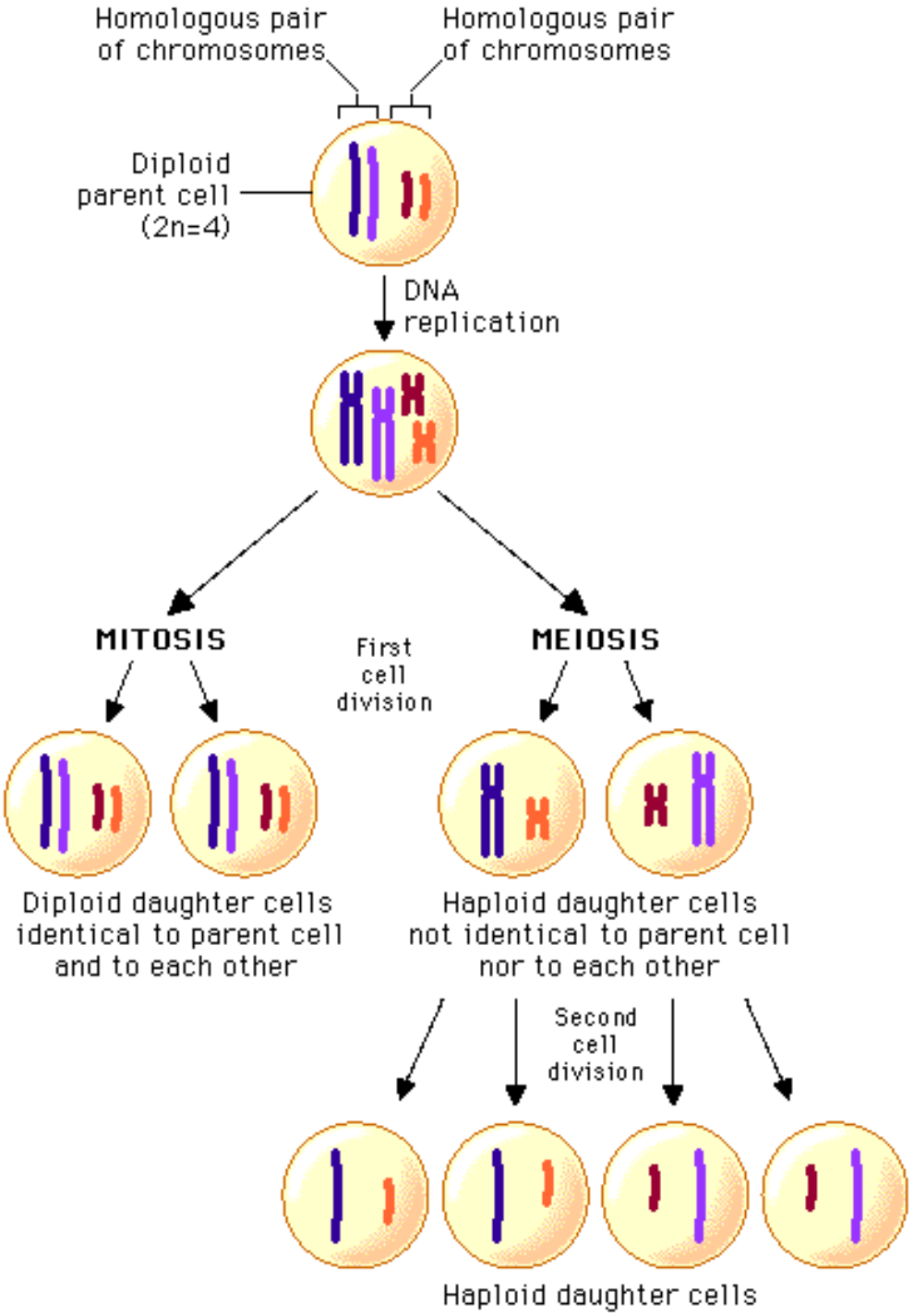
4. TELOPHASE I:
   - Cytoplasm divides, forming two haploid daughter cells.

MEIOSIS II:

1. PROPHASE II:
   - New spindle fibers form.
2. METAPHASE II:
   - Chromosomes (2 chromatids joined by a centromere) are moved to equator by the spindle fibers.
3. ANAPHASE II:
   - The centromeres of each chromosome divide, freeing sister chromatids.
   - Each sister chromatid is moved by spindle fibers to the opposite pole.
4. TELOPHASE II:
   - Spindle fibers dissolve
   - Nuclear membrane forms around the chromosomes (single chromatids) in each of the 4 daughter cells.

SUMMARY

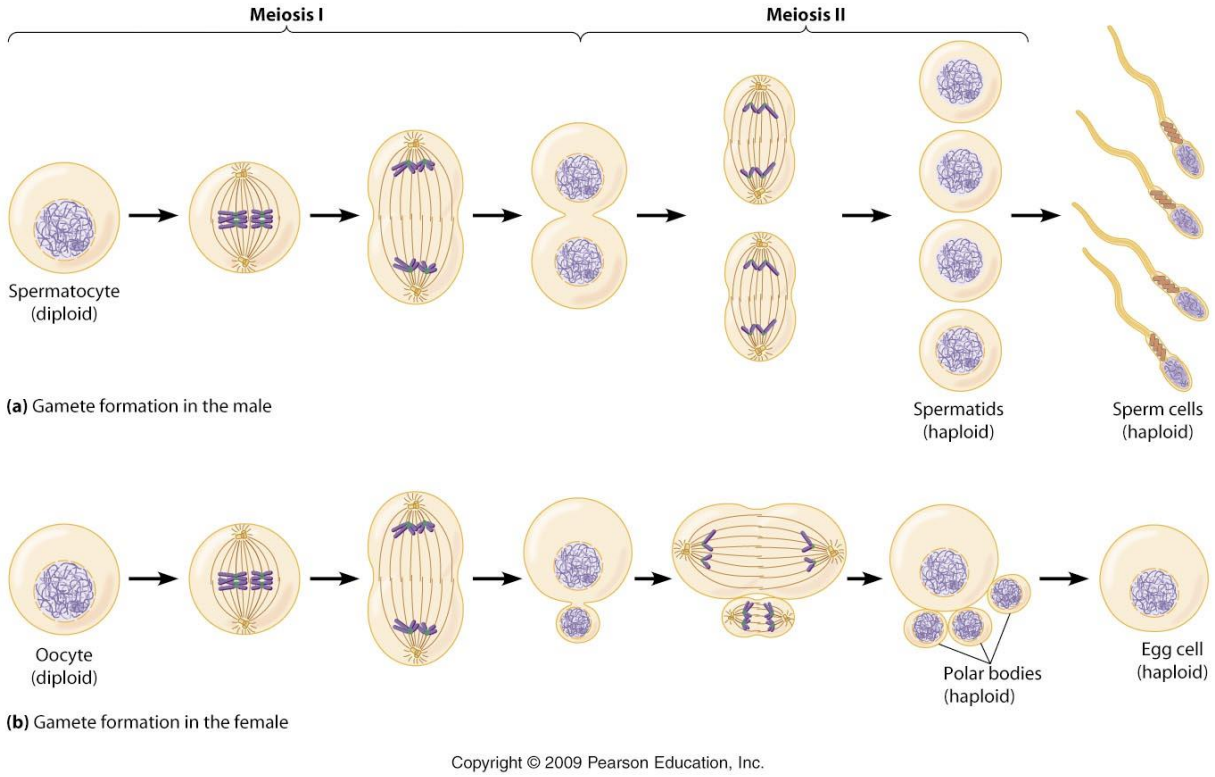
MEIOTIC PHASE	MEIOSIS I	MEIOSIS II
PROPHASE	Spindle appears, tetrads form	New spindles form
METAPHASE	Tetrads move to cell equator	Chromosomes (2 sister chromatids) move to equator
ANAPHASE	Homologous pairs separate	Chromatids separate
TELOPHASE	Cytoplasm divides	Nuclear membrane surrounds 4 daughter nuclei


Homologous pair of chromosomes
Homologous pair of chromosomes
Diploid parent cell (2n=4)
DNA replication
MITOSIS
First cell division
MEIOSIS
Diploid daughter cells identical to parent cell and to each other
Haploid daughter cells not identical to parent cell nor to each other
Second cell division
Haploid daughter cells

2:4 Formation of Egg and Sperm

When meiosis occurs in male reproductive organs, all 4 new cells become sperm because many sperm are needed to ensure fertilization.

SPERMATOGENESIS: the production of sperm through meiotic cell division



When meiosis occurs in female reproductive organs, the cytoplasm divides unequally, with one of the four cells receiving almost all of the cytoplasm. This is because it is easier for humans to carry only one baby at a time.

OOTID: the egg cell that receives almost all the cytoplasm in meiosis

POLAR BODIES: three cells that receive little cytoplasm during meiosis and eventually disintegrate

OOGENESIS: the production of one egg (ootid) and 3 polar bodies through meiotic cell division

2:5 Sexual Reproduction

SEXUAL REPRODUCTION: the production of offspring through meiosis and the fusion of gametes

Steps of Sexual Reproduction

1. Organisms produce GAMETES: haploid sex cells. Female gametes are eggs, male gametes are sperm.
2. Egg and sperm unite forming ZYGOTE: diploid fertilized egg resulting from fusion of gametes, capable of developing into new organism.
3. Zygote develops into mature organism by mitosis.