NATIONAL PHARMACEUTICAL UNIVERSITY

DEPARTMENT OF VETERINARY MEDICINE AND PHARMACY

Lecture on Biology and genetics principles specialty 226 Pharmacy

Mitosis and meiosis. Cell cycle regulation

Lecturer: associate professor Department of Veterinary medicine and pharmacy Ph.D. Dotsenko Roman Valeryevich

LECTURE PLAN

- **Introduction**
- **History Note**
- **Function**
- **Structural Component**
- **Mitosis**
- **Meiosis.**
- **Cell cycle regulation**

Recommended literature

Maloshtan L.M., Filiptsova O.V. 2011. Biology and genetics principles, Publisher house of NUPh, Kharkiv, pp. 4-18,56-68.

https://www.britannica.com/list/6-cell-organelles

Craig, Nancy (2014). Molecular Biology, Principles of Genome Function. ISBN 978-0-19-965857-2.

Darwin, Charles (1859). *On the Origin of Species*, John Murray.

"biology, n". Oxford English Dictionary online version. Oxford University Press. September 2011. Retrieved 1 November 2011.

Bruce Alberts: Molecular.Biology.Of.The.Cell.5th.Ed

Arthur C. Guyton; John E. Hall. Text book of Medical Physiology. Tenth edition

Cell Division

- ✓ All cells are derived from pre-existing cells
- ✓ New cells are produced for growth and to replace damaged or old cells
- ✓ Differs in prokaryotes (bacteria) and eukaryotes (protists, fungi, plants, & animals)

Keeping Cells Identical

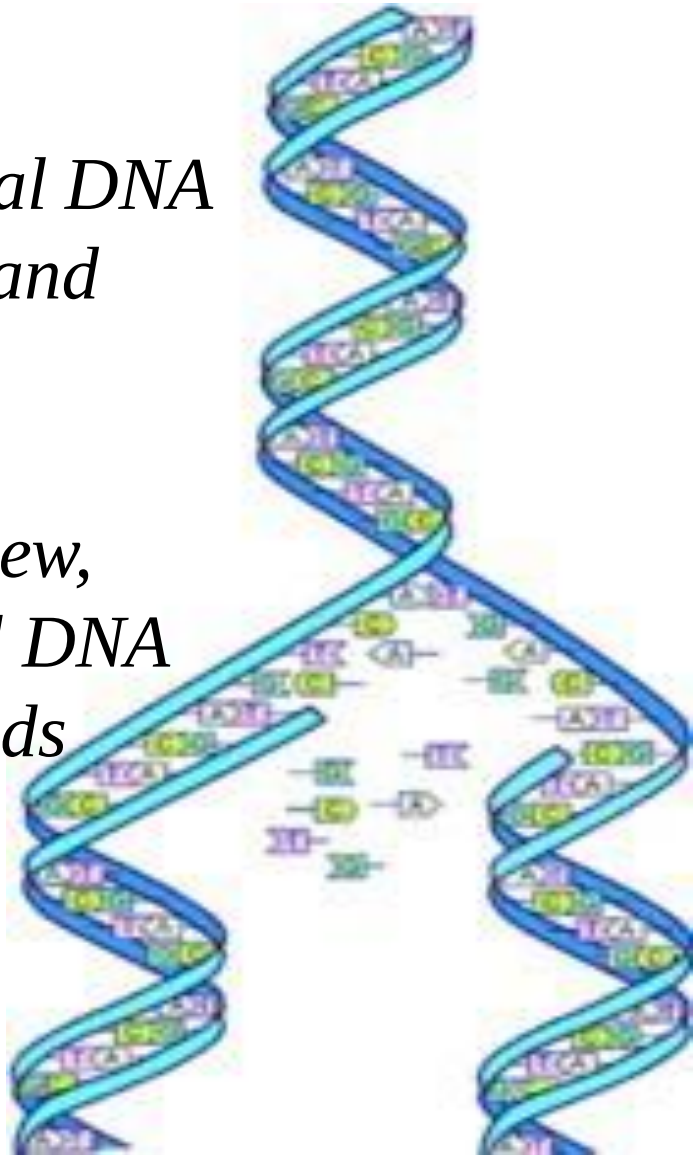
The instructions for making cell parts are encoded in the DNA, so each new cell must get a complete set of the DNA molecules

DNA Replication

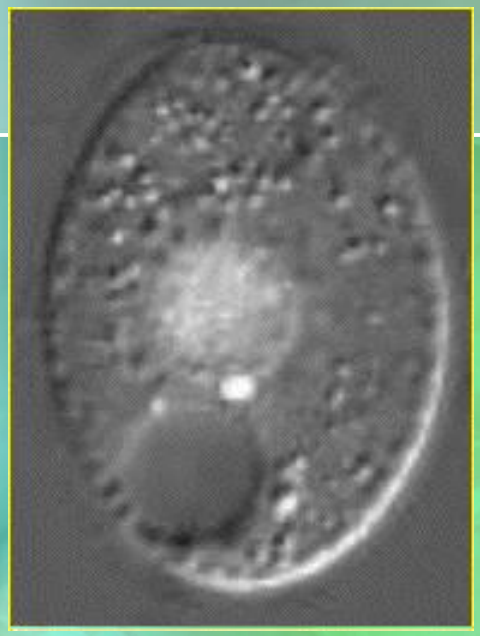
- ✓ DNA must be copied or replicated before cell division
- ✓ Each new cell will then have an identical copy of the DNA

Original DNA strand

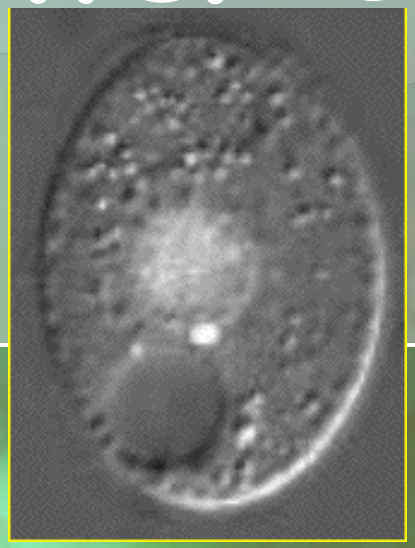
Two new, identical DNA strands

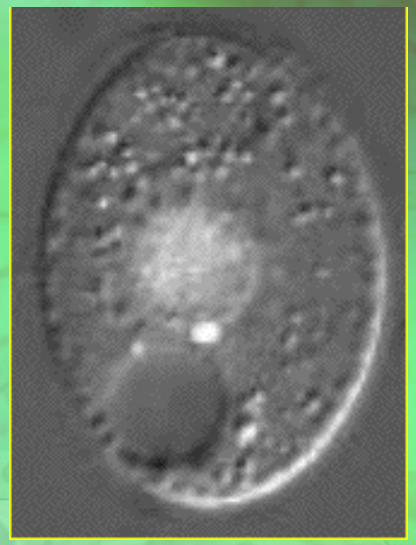


Identical Daughter Cells



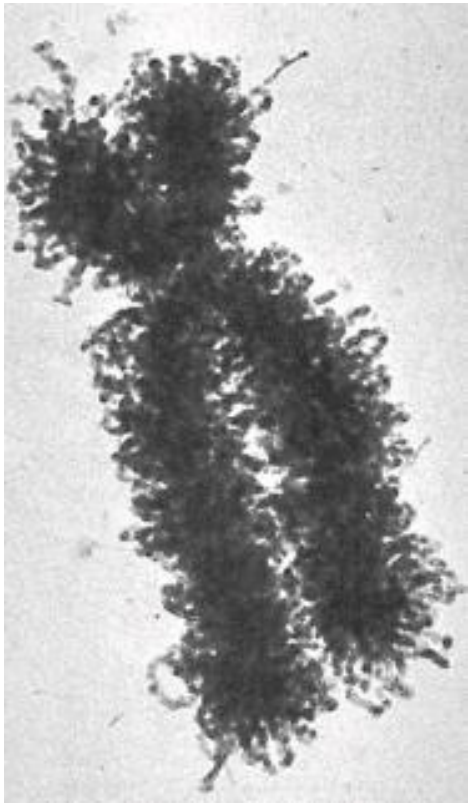
Parent Cell





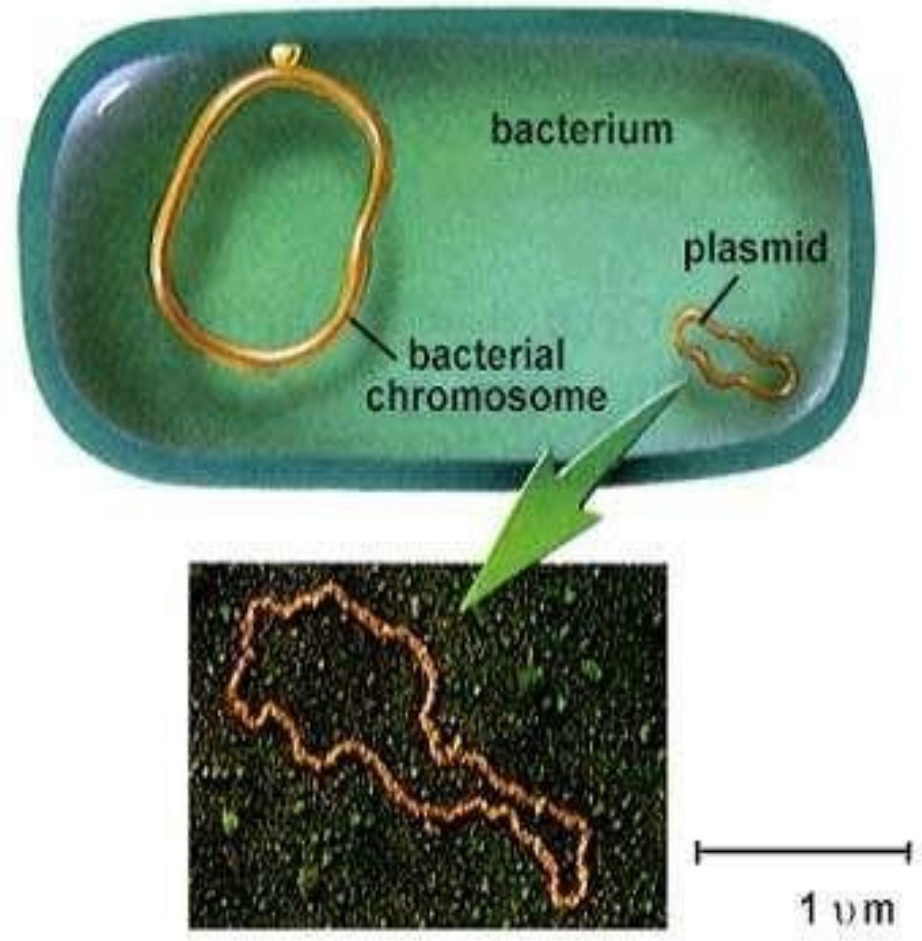
Two identical daughter cells

Chromosomes



Prokaryotic Chromosome

- ✓**The DNA of prokaryotes (bacteria) is one, circular chromosome attached to the inside of the cell membrane**



Eukaryotic Chromosomes

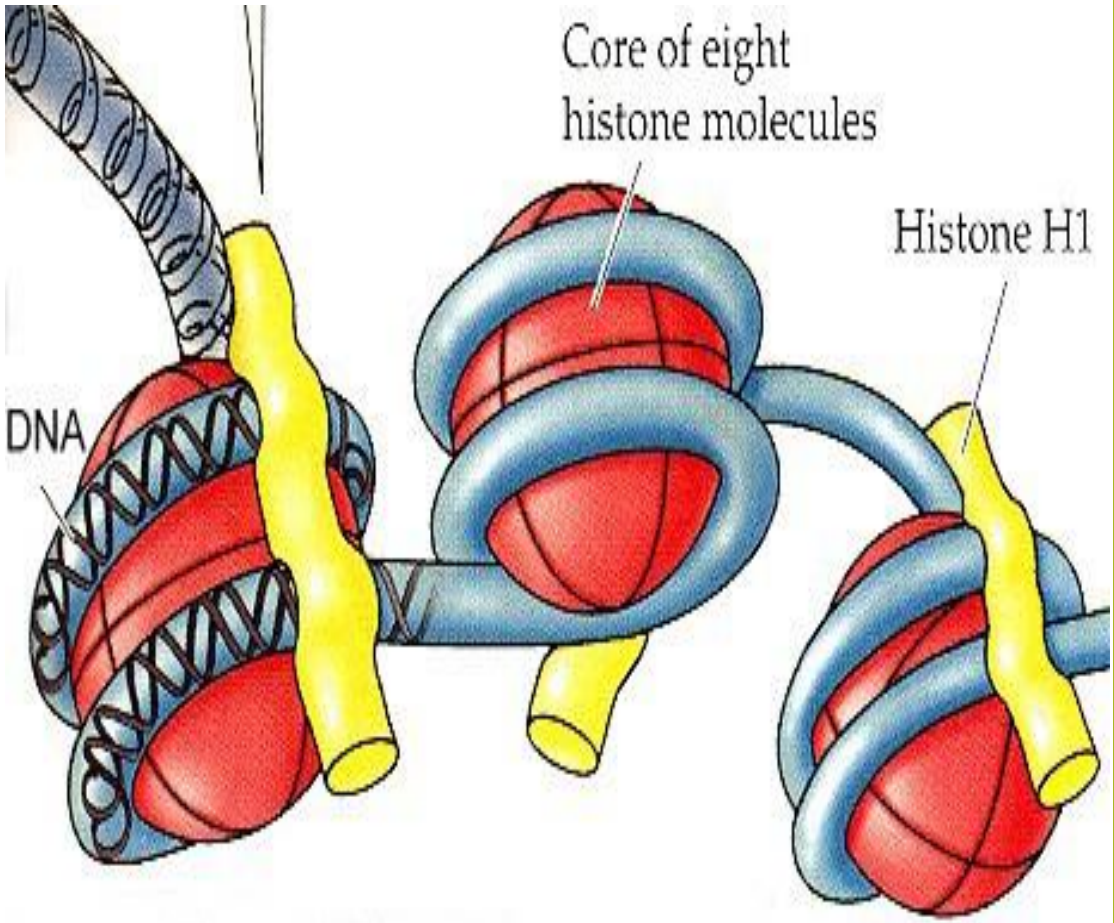
- ✓ All eukaryotic cells store genetic information in chromosomes
- ✓ Most eukaryotes have between 10 and 50 chromosomes in their body cells
- ✓ Human body cells have 46 chromosomes or 23 identical pairs

Eukaryotic Chromosomes

- ✓ Each chromosome is composed of a single, tightly coiled DNA molecule
- ✓ Chromosomes can't be seen when cells aren't dividing and are called chromatin

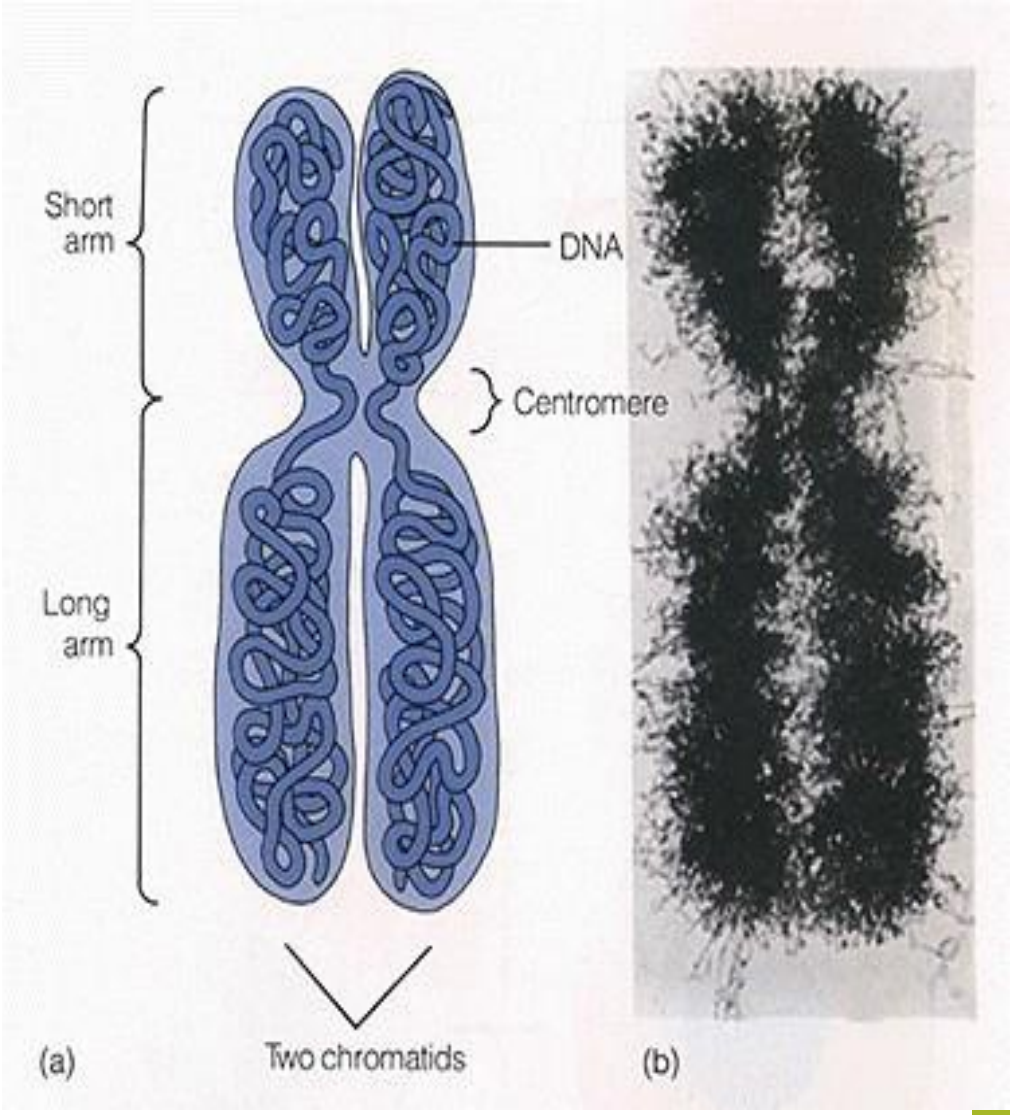
Compacting DNA into Chromosomes

- ✓ DNA is tightly coiled around proteins called histones



Chromosomes in Dividing Cells

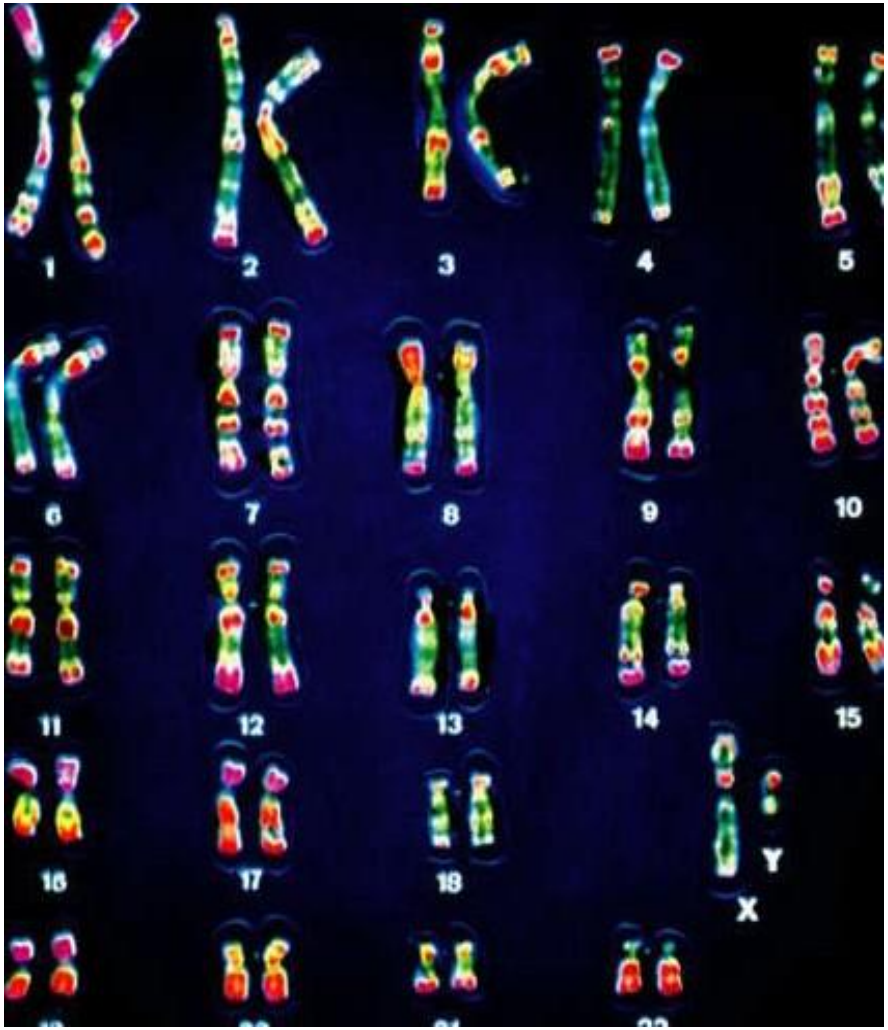
- Duplicated chromosomes are called chromatids & are held together by the centromere



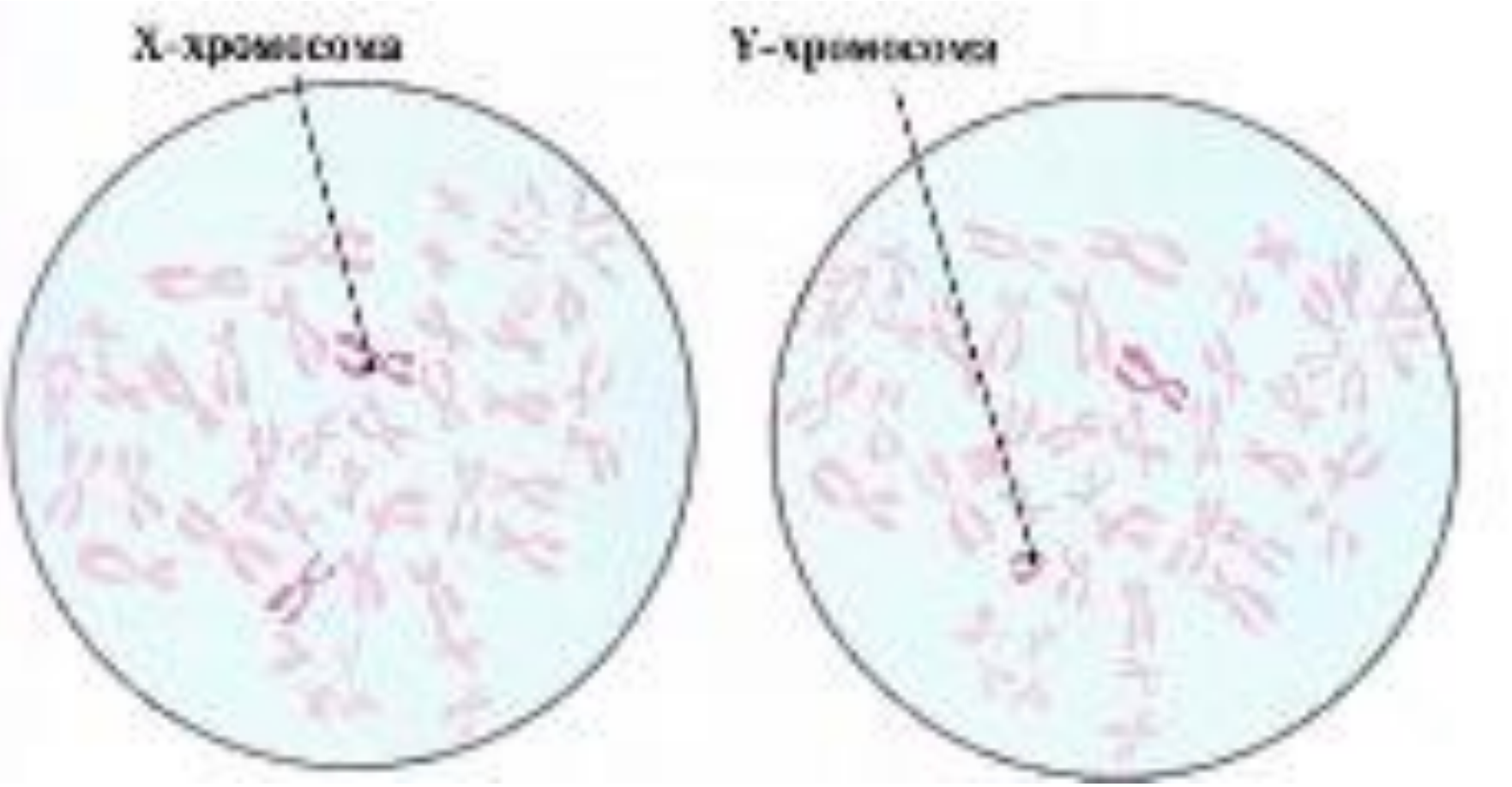
Called Sister Chromatids

Karyotype

- ✓ A picture of the chromosomes from a human cell arranged in pairs by size
- ✓ First 22 pairs are called autosomes
- ✓ Last pair are the sex chromosomes
- ✓ XX female or XY male



Boy or Girl?
The Y Chromosome Decides

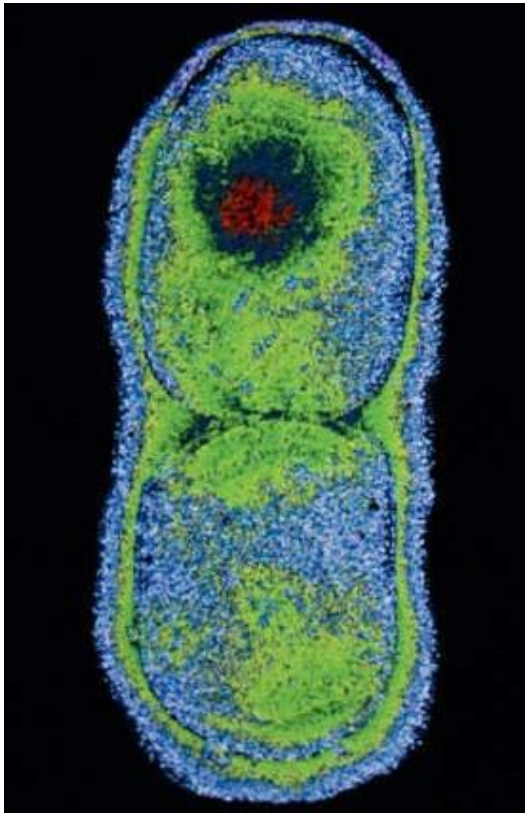


Cell Reproduction

Types of Cell Reproduction

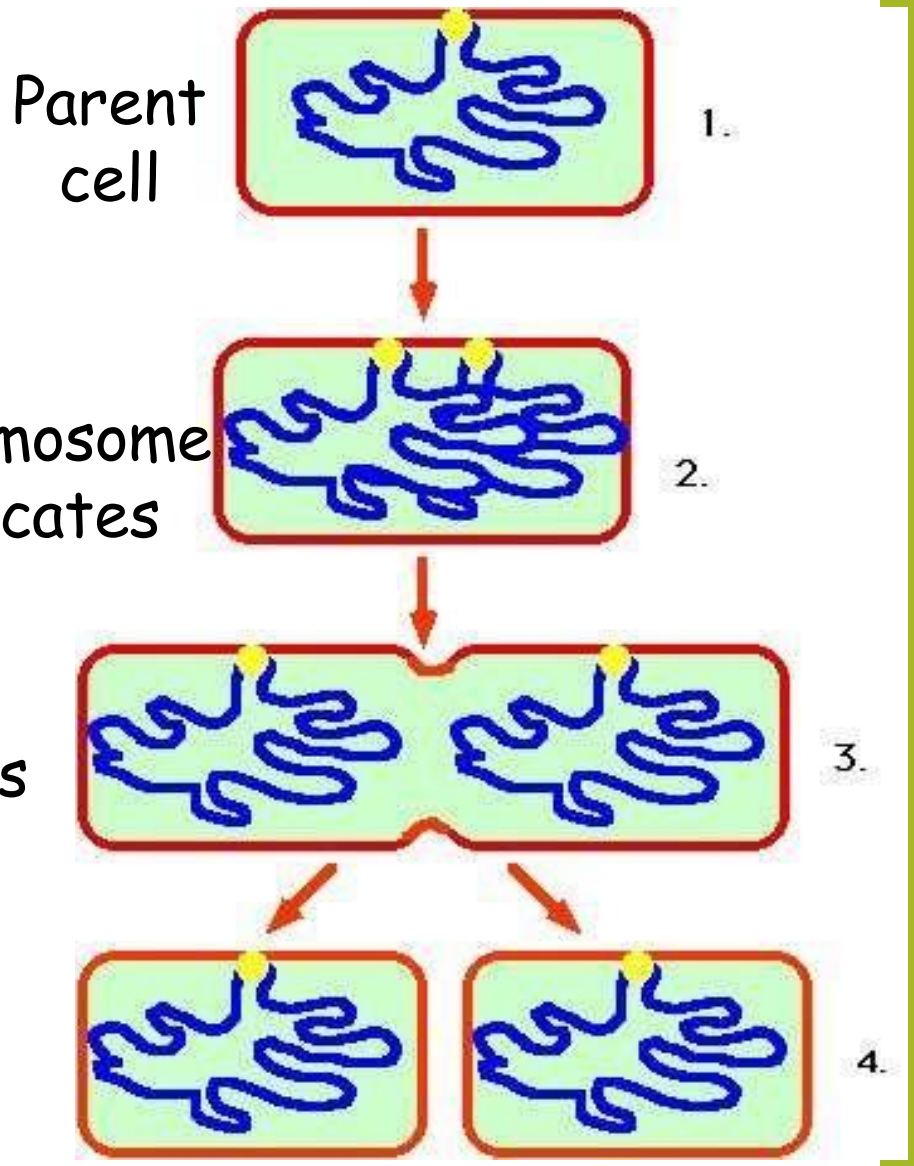
- Asexual reproduction involves a single cell dividing to make 2 new, identical daughter cells
- Mitosis & binary fission are examples of asexual reproduction
- Sexual reproduction involves two cells (egg & sperm) joining to make a new cell (zygote) that is NOT identical to the original cells
  - Meiosis is an example

Cell Division in Prokaryotes



Cell Division in Prokaryotes

- ✓ Prokaryotes such as bacteria divide into 2 identical cells by the process of binary fission
- ✓ Single chromosome makes a copy of itself
- ✓ Cell wall forms between the chromosomes dividing the cell



The Cell Cycle

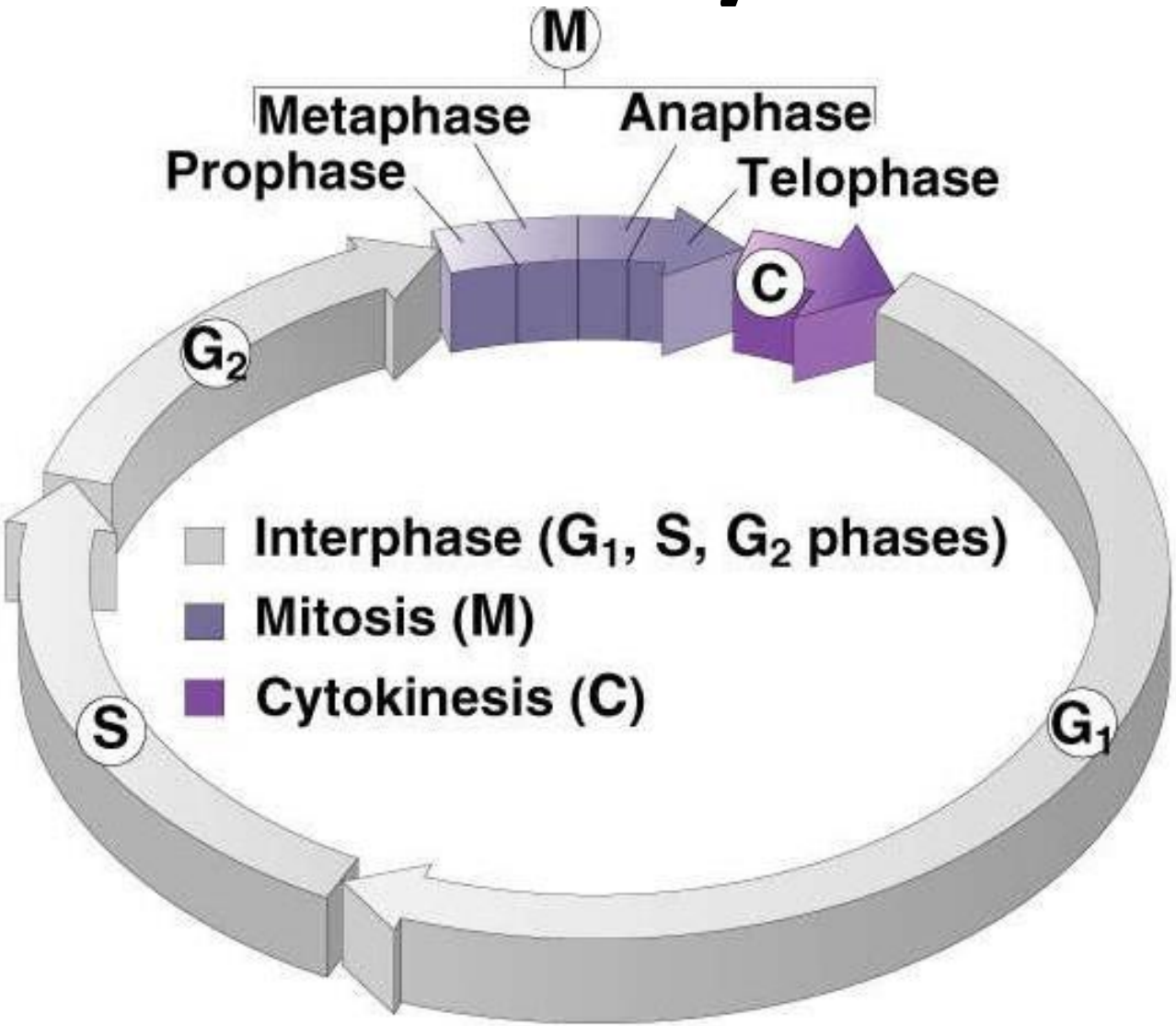
Five Phases of the Cell Cycle

- ✓G_1 - primary growth phase
- ✓S – synthesis; DNA replicated
- ✓G_2 - secondary growth phase

collectively these 3 stages are called interphase

- ✓M - mitosis
- ✓C - cytokinesis

Cell Cycle

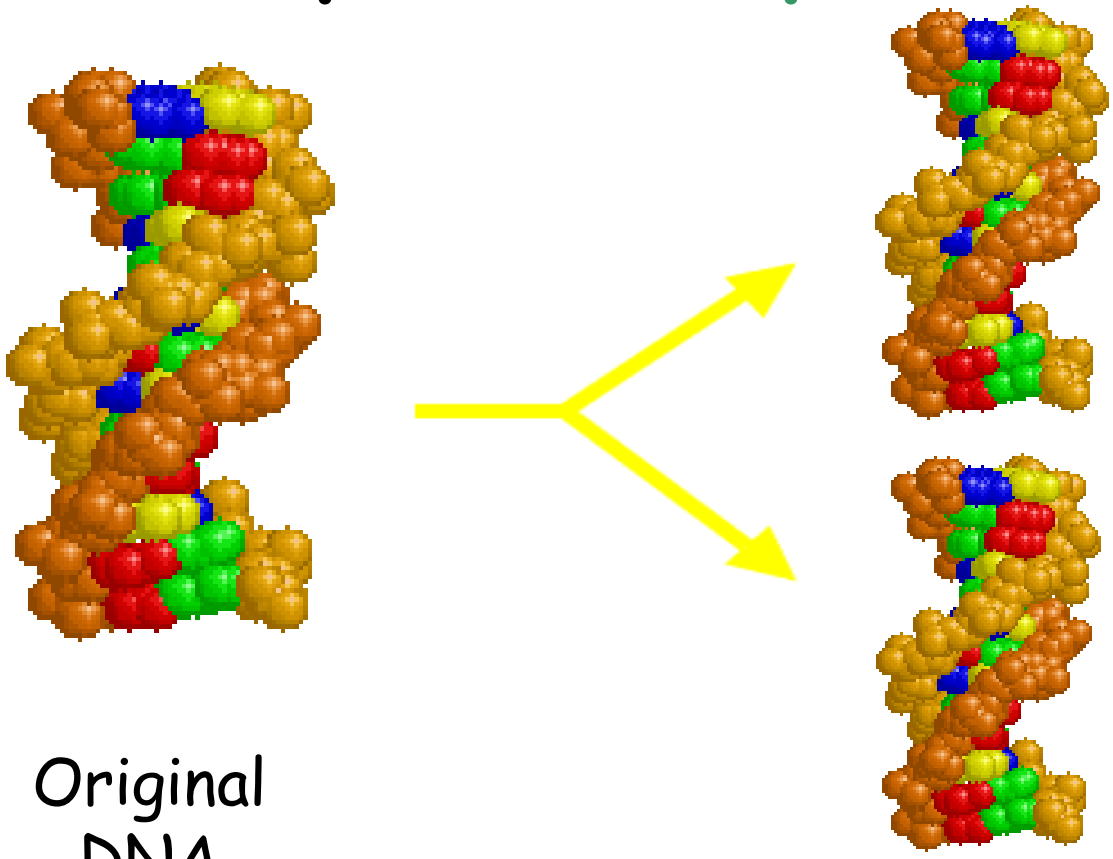

M
Metaphase
Anaphase
Prophase
Telophase
C
G2
Interphase (G1, S, G2 phases)
Mitosis (M)
Cytokinesis (C)
S
G1

Interphase - G_1 Stage

- ✓ 1st growth stage after cell division
- ✓ Cells mature by making more cytoplasm & organelles
- ✓ Cell carries on its normal metabolic activities

Interphase – S Stage

- ✓ **Synthesis stage**
- ✓ **DNA is copied or replicated**



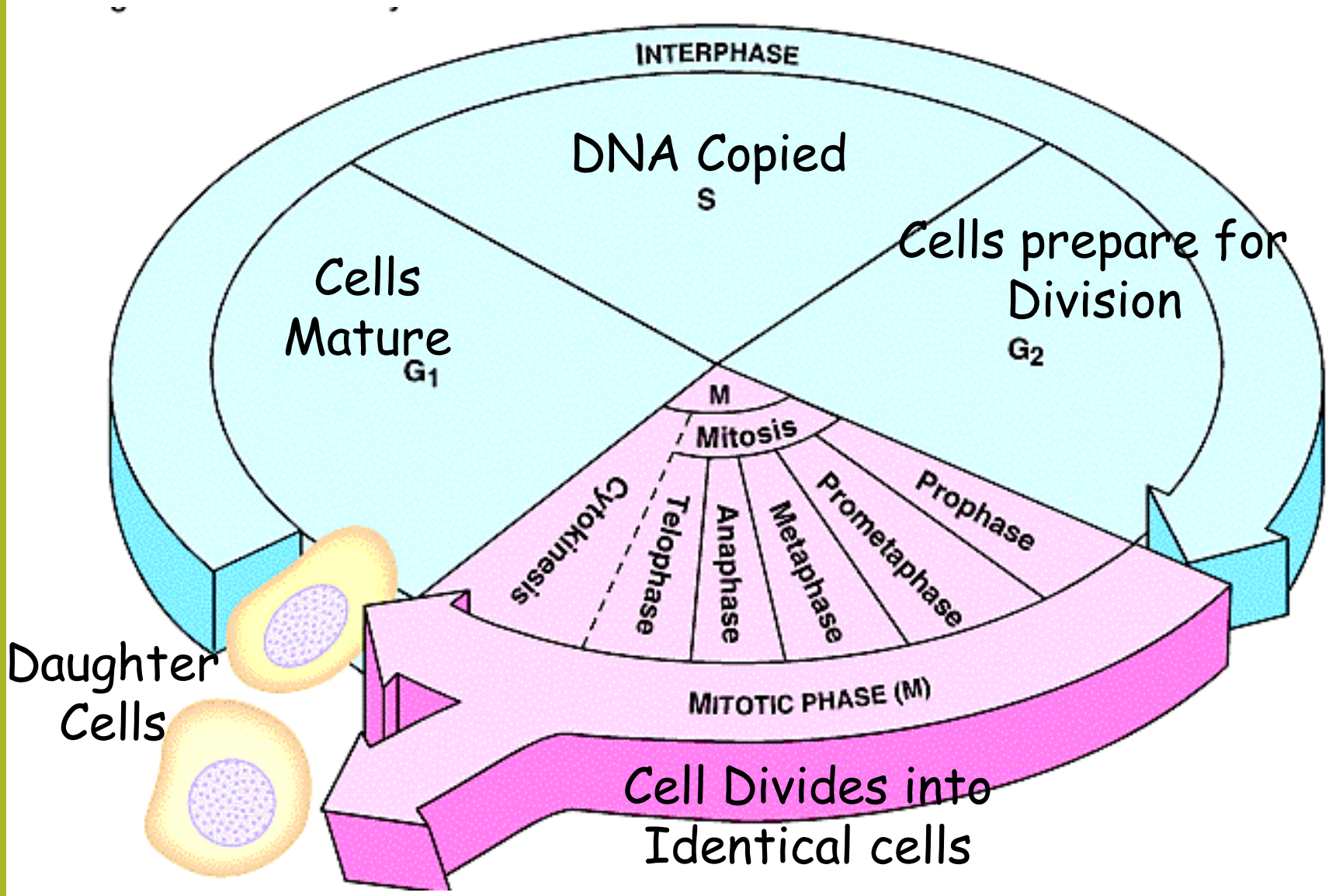
Original DNA

Two identical copies of DNA

Interphase – G_2 Stage

- ✓ 2nd Growth Stage
  - ✓ Occurs after DNA has been copied
  - ✓ All cell structures needed for division are made (e.g. centrioles)
  - ✓ Both organelles & proteins are synthesized

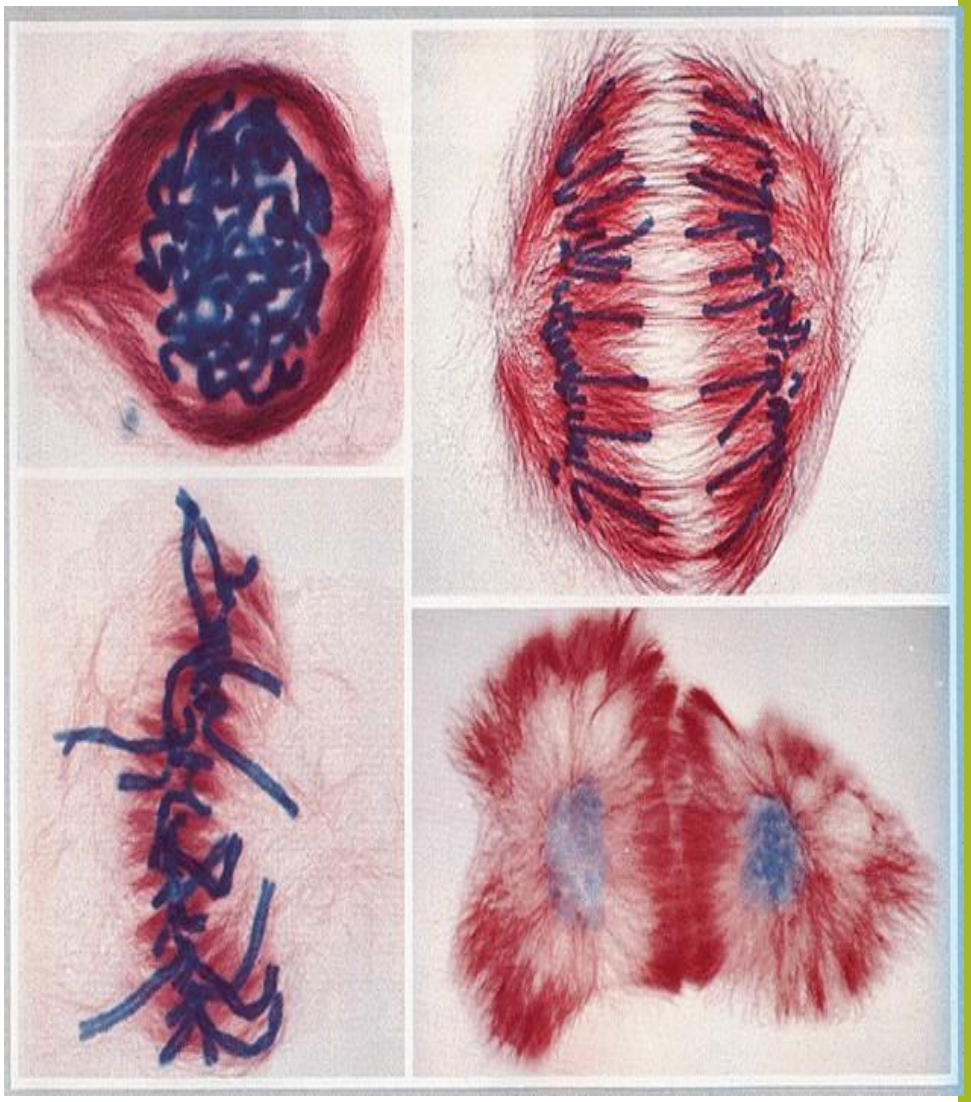
Sketch the Cell Cycle



Mitosis

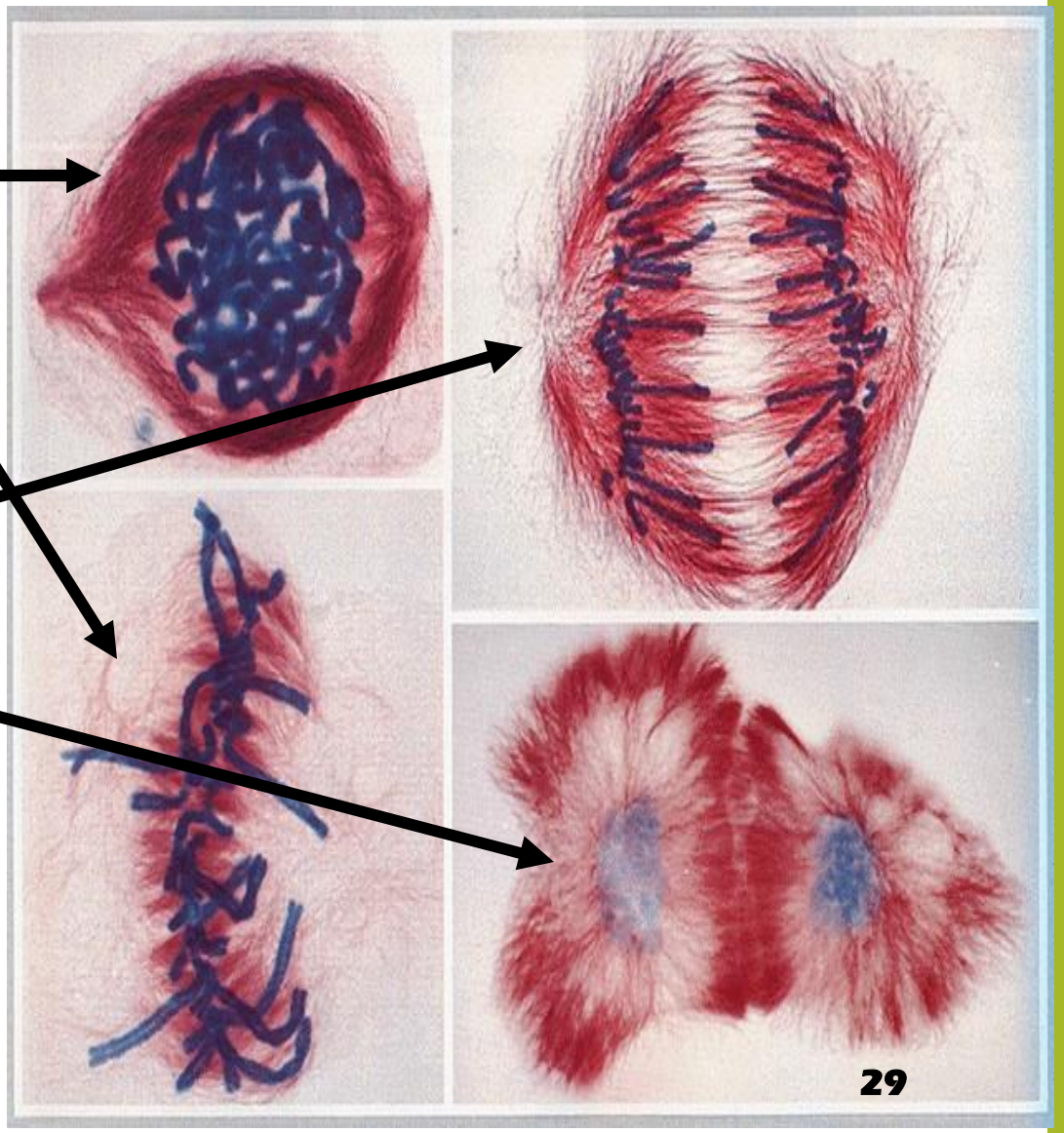
Mitosis

- ✓ Division of the nucleus
- ✓ Also called karyokinesis
- ✓ Only occurs in eukaryotes
- ✓ Has four stages
- ✓ Doesn't occur in some cells such as brain cells



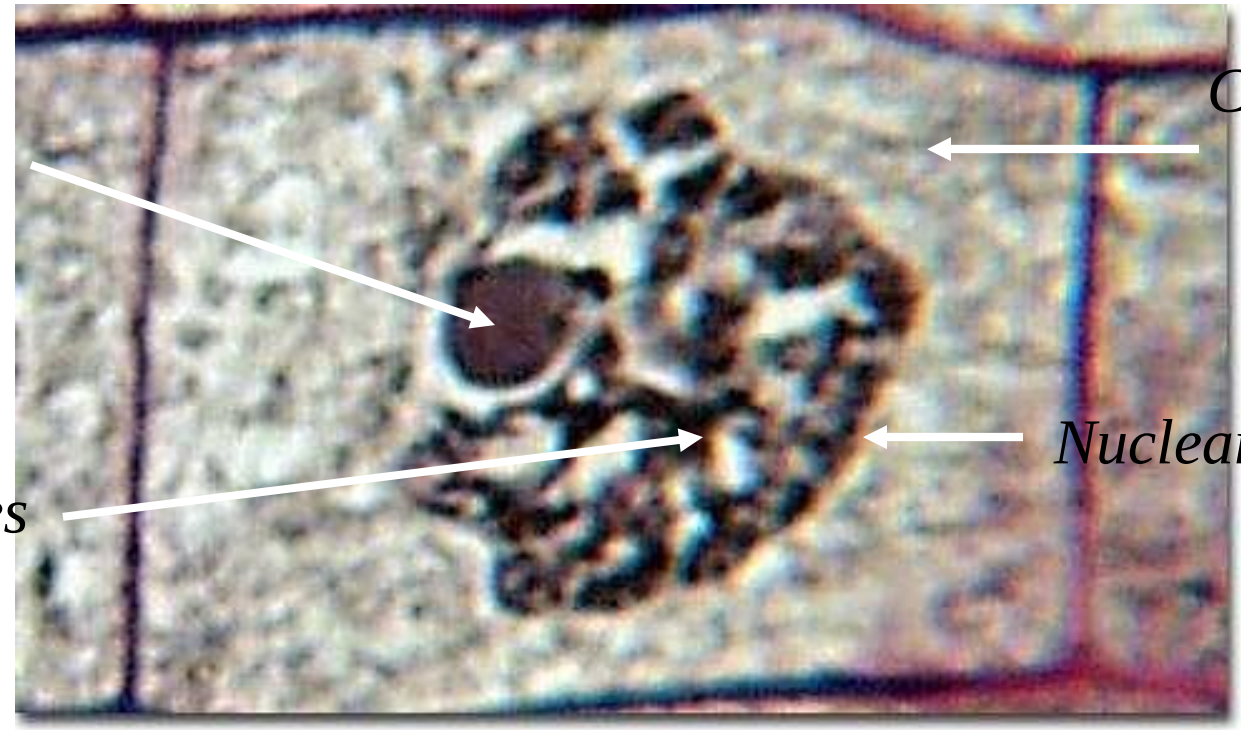
Four Mitotic Stages

- ✓Prophase
- ✓Metaphase
- ✓Anaphase
- ✓Telophase



Early Prophase

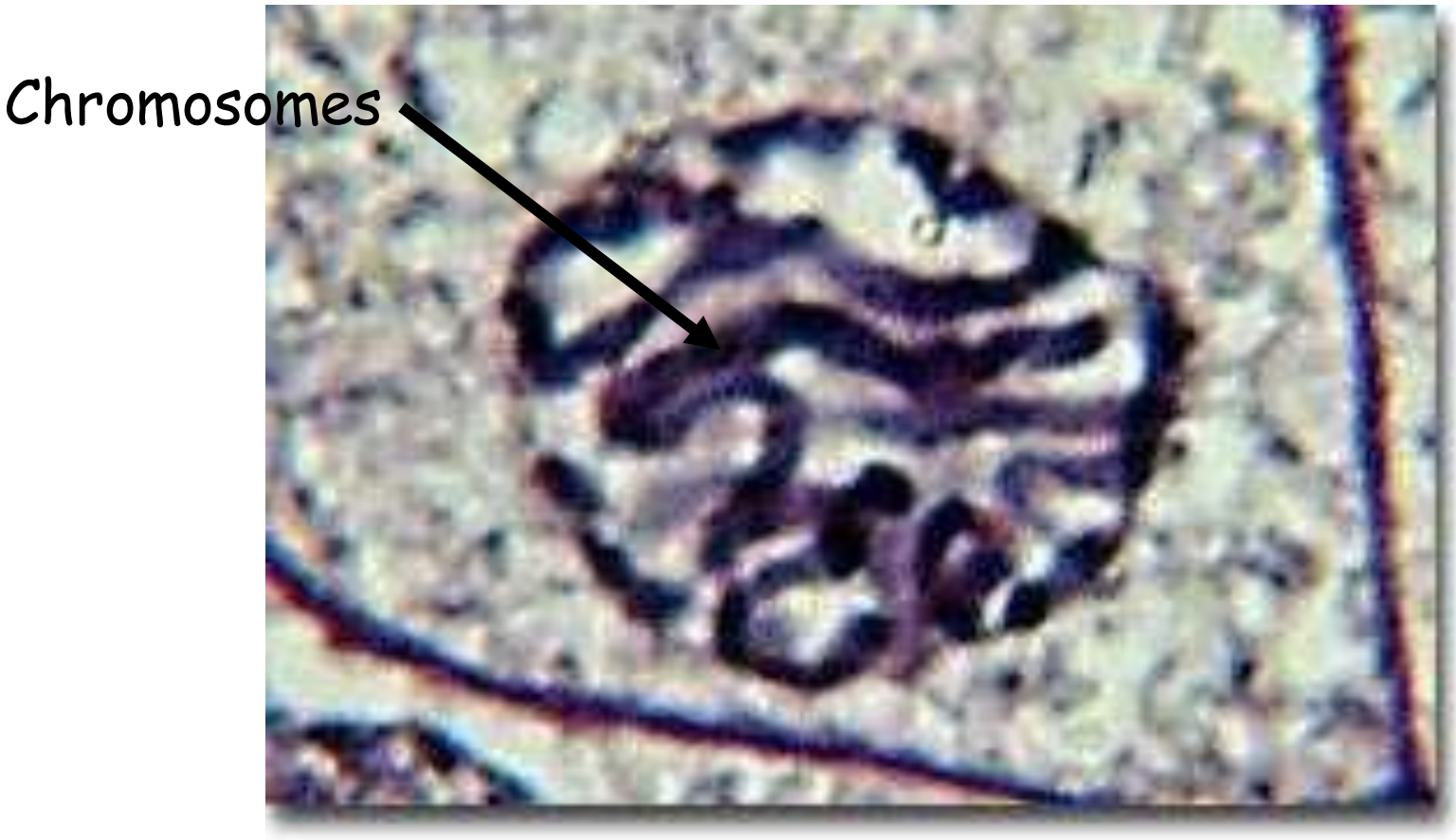
- ✓ **Chromatin** in nucleus condenses to form **visible chromosomes**
- ✓ **Mitotic spindle** forms from fibers in cytoskeleton or centrioles



Late Prophase

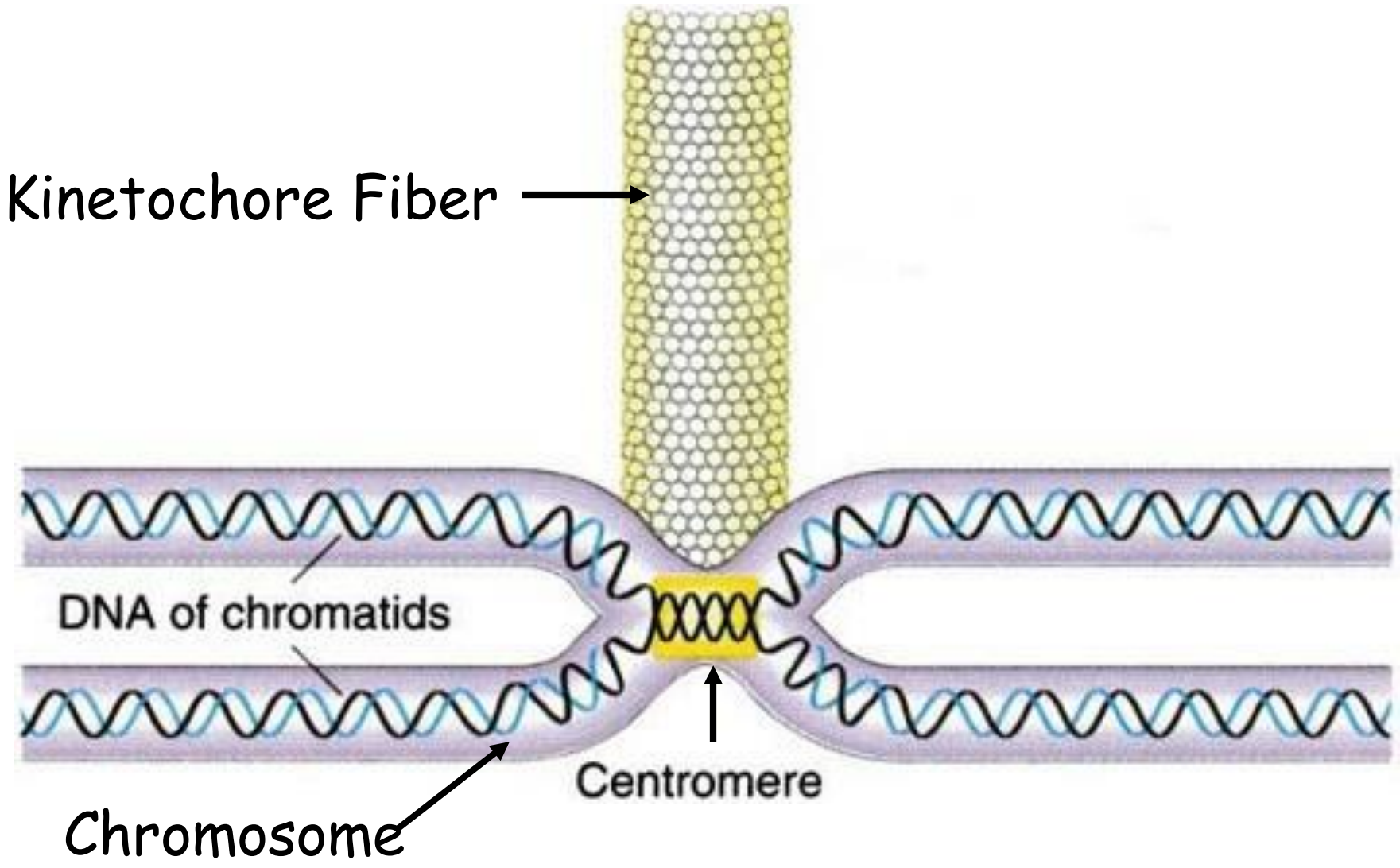
- ✓ Nuclear membrane & nucleolus are broken down
- ✓ Chromosomes continue condensing & are clearly visible
- ✓ Spindle fibers called kinetochores attach to the centromere of each chromosome
- ✓ Spindle finishes forming between the poles of the cell

Late Prophase

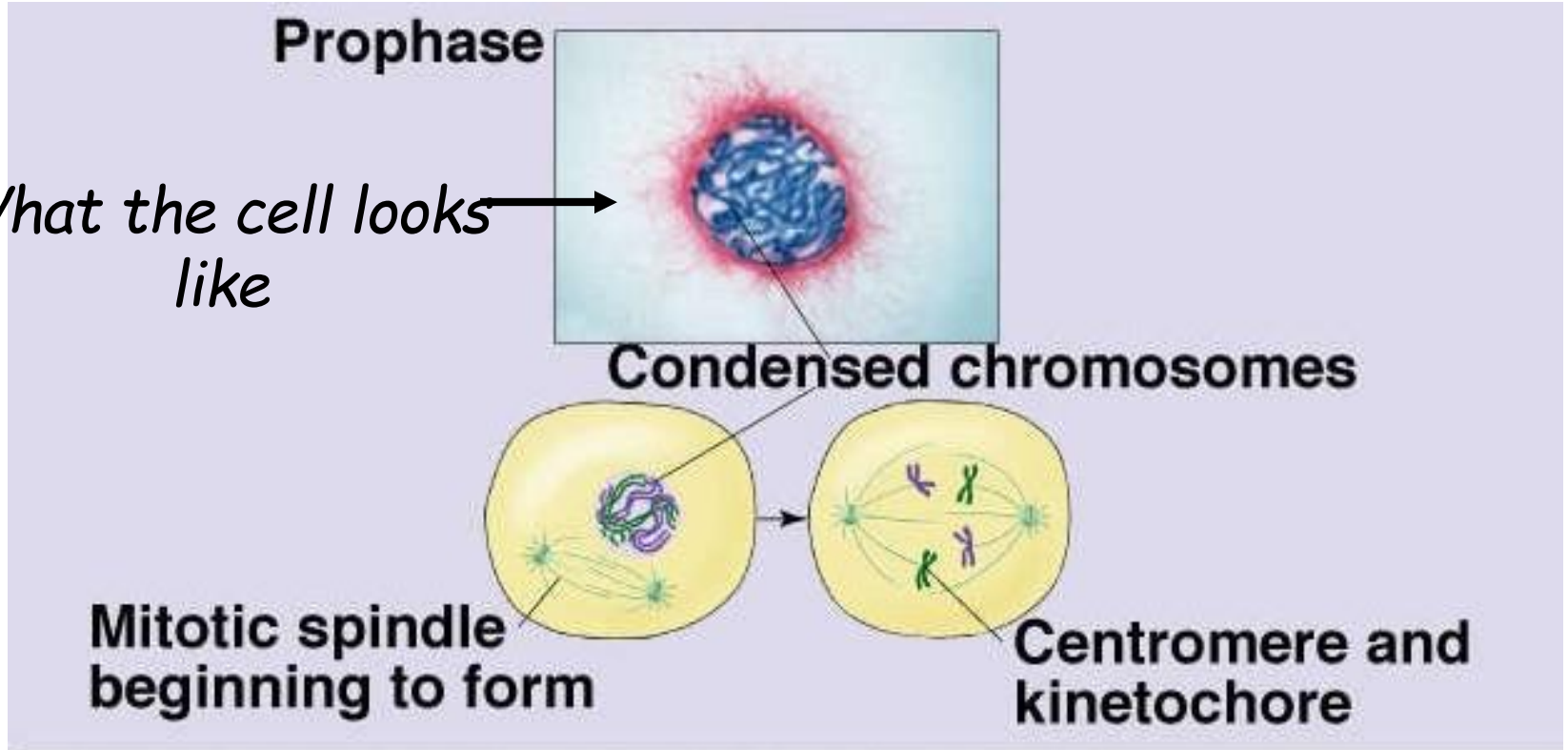


Nucleus & Nucleolus have disintegrated

Spindle Fiber attached to Chromosome



Review of Prophase



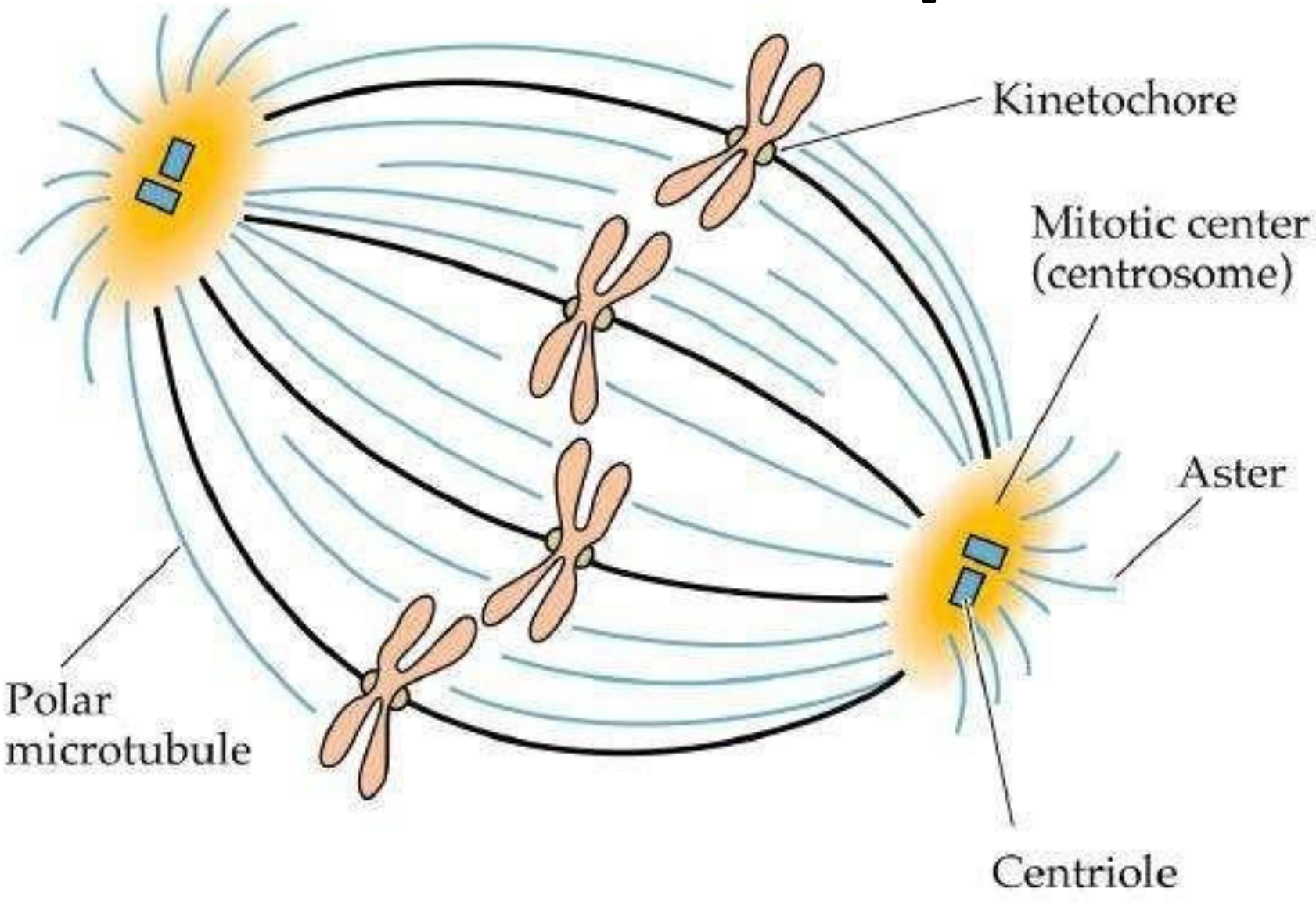
- Nuclear membrane disintegrates, and nucleolus disappears
- Chromosomes condense
- Mitotic spindle begins to form and is complete at the end of prophase
- Kinetochores begin to mature and attach to spindle

What's happening

Spindle Fibers

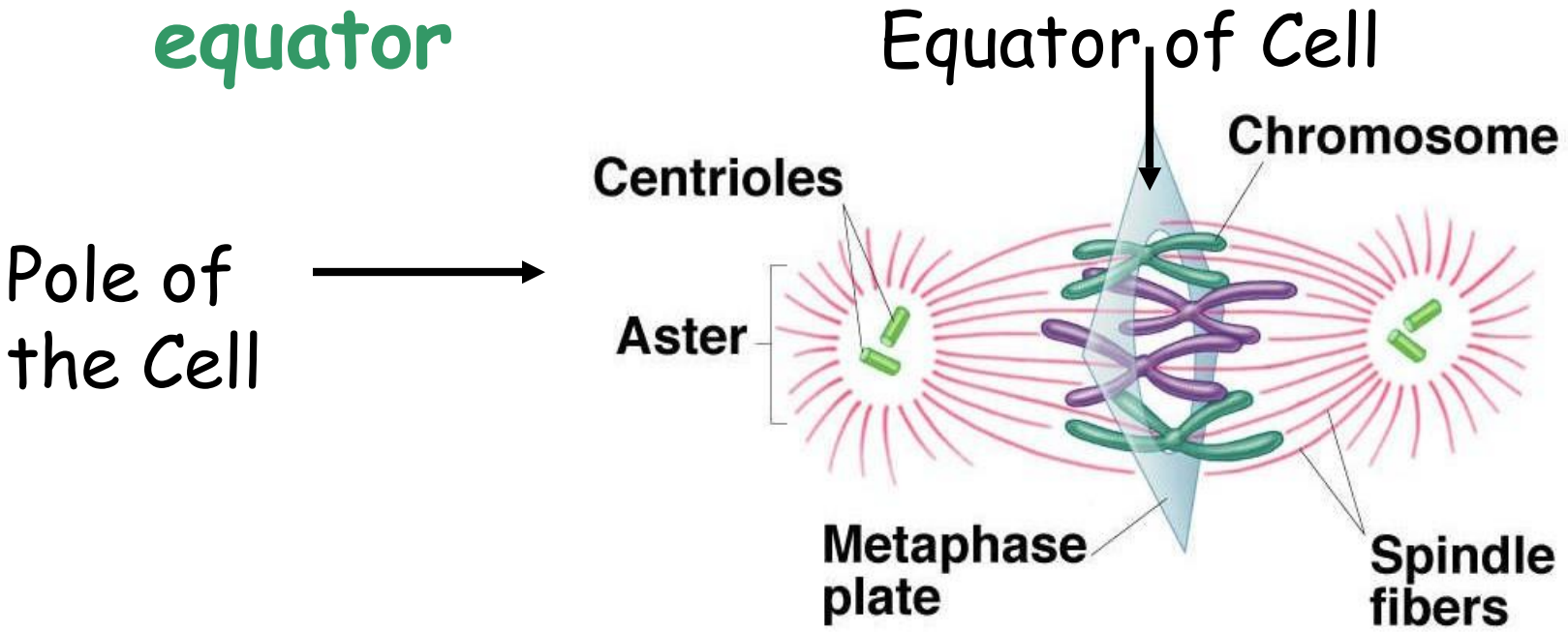
- The mitotic spindle form from the microtubules in plants and centrioles in animal cells
- Polar fibers extend from one pole of the cell to the opposite pole
- Kinetochore fibers extend from the pole to the centromere of the chromosome to which they attach
- Asters are short fibers radiating from centrioles

Sketch The Spindle

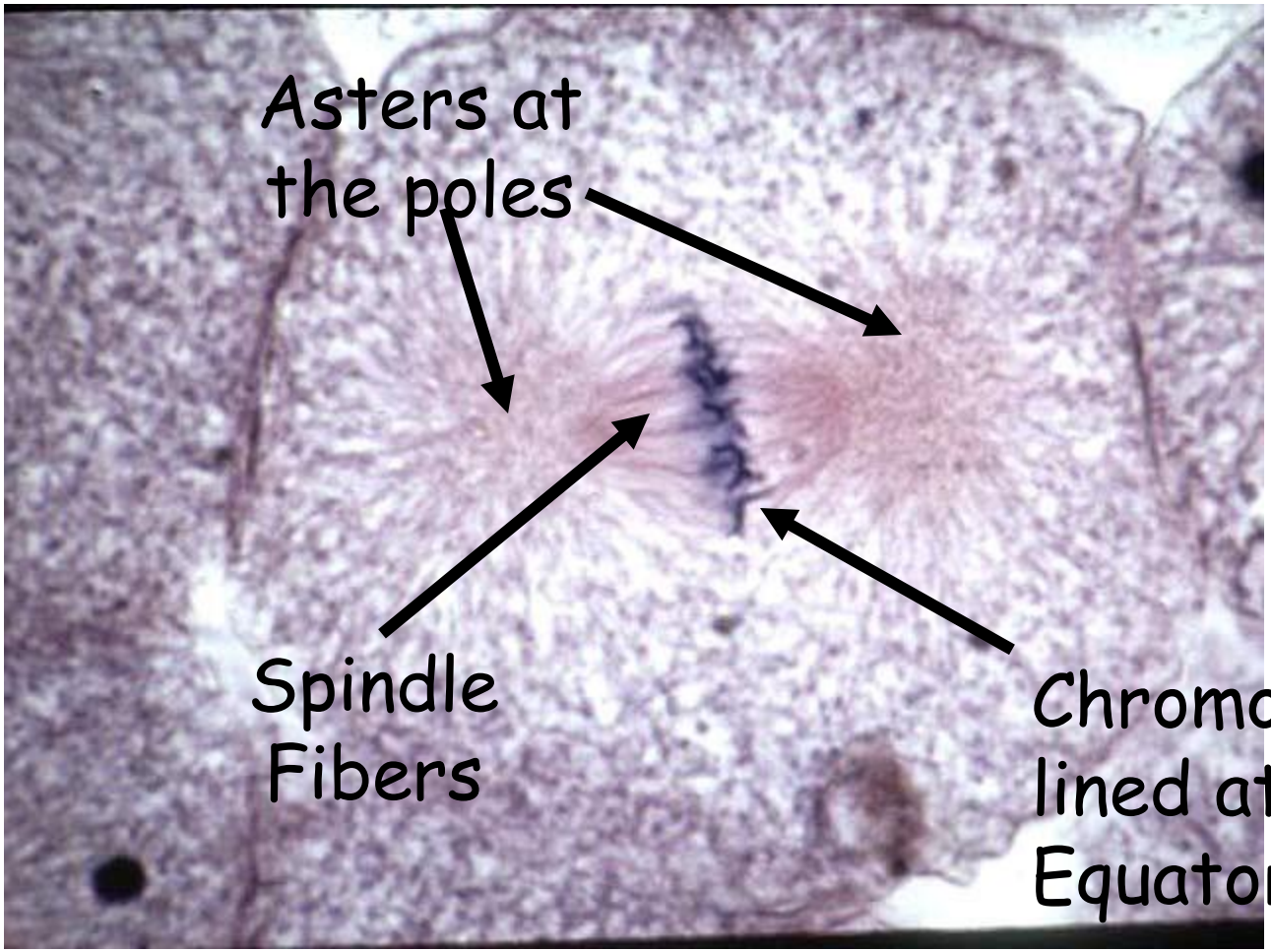


Metaphase

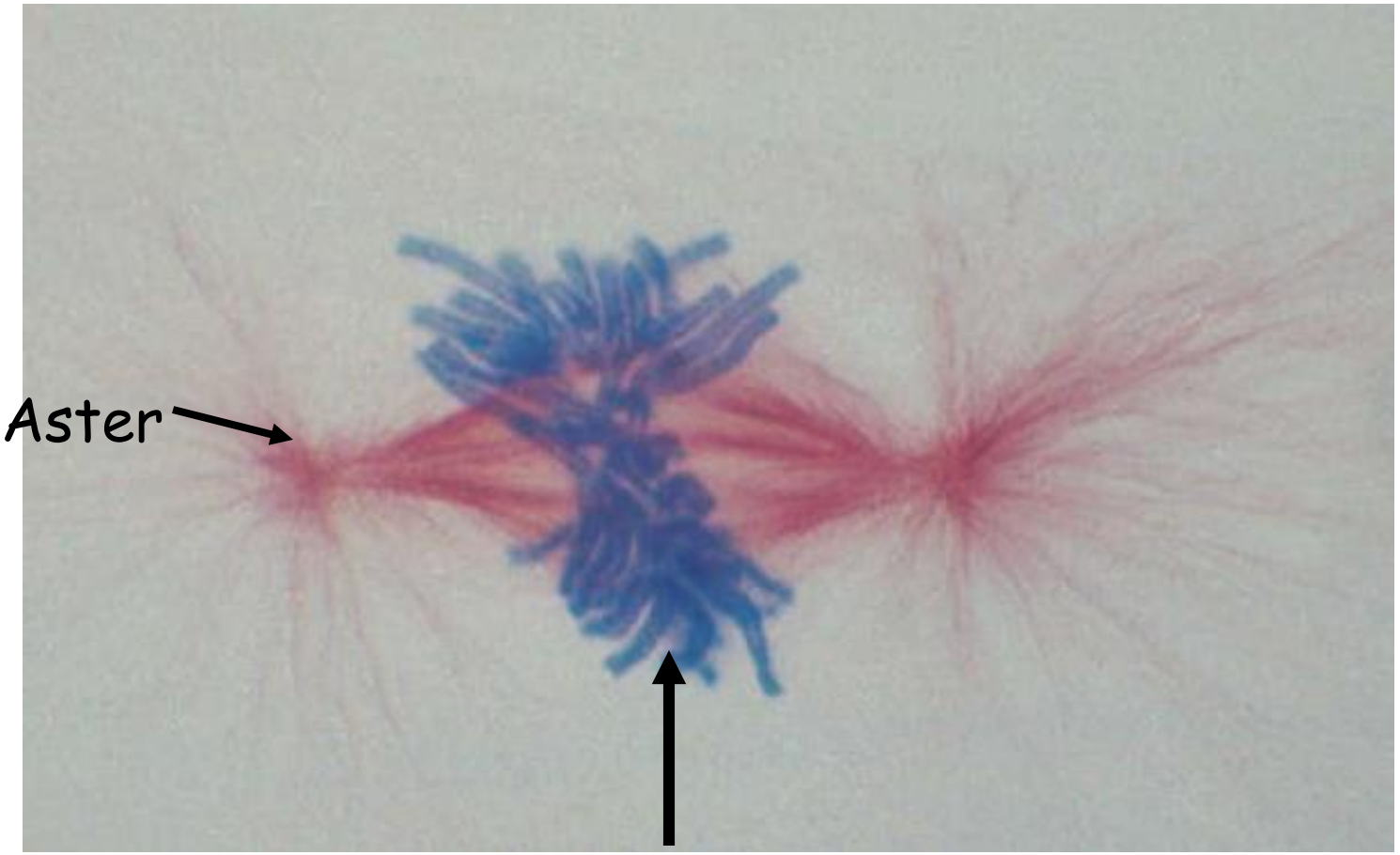
- ✓ Chromosomes, attached to the kinetochore fibers, move to the center of the cell
- ✓ Chromosomes are now lined up at the equator



Metaphase

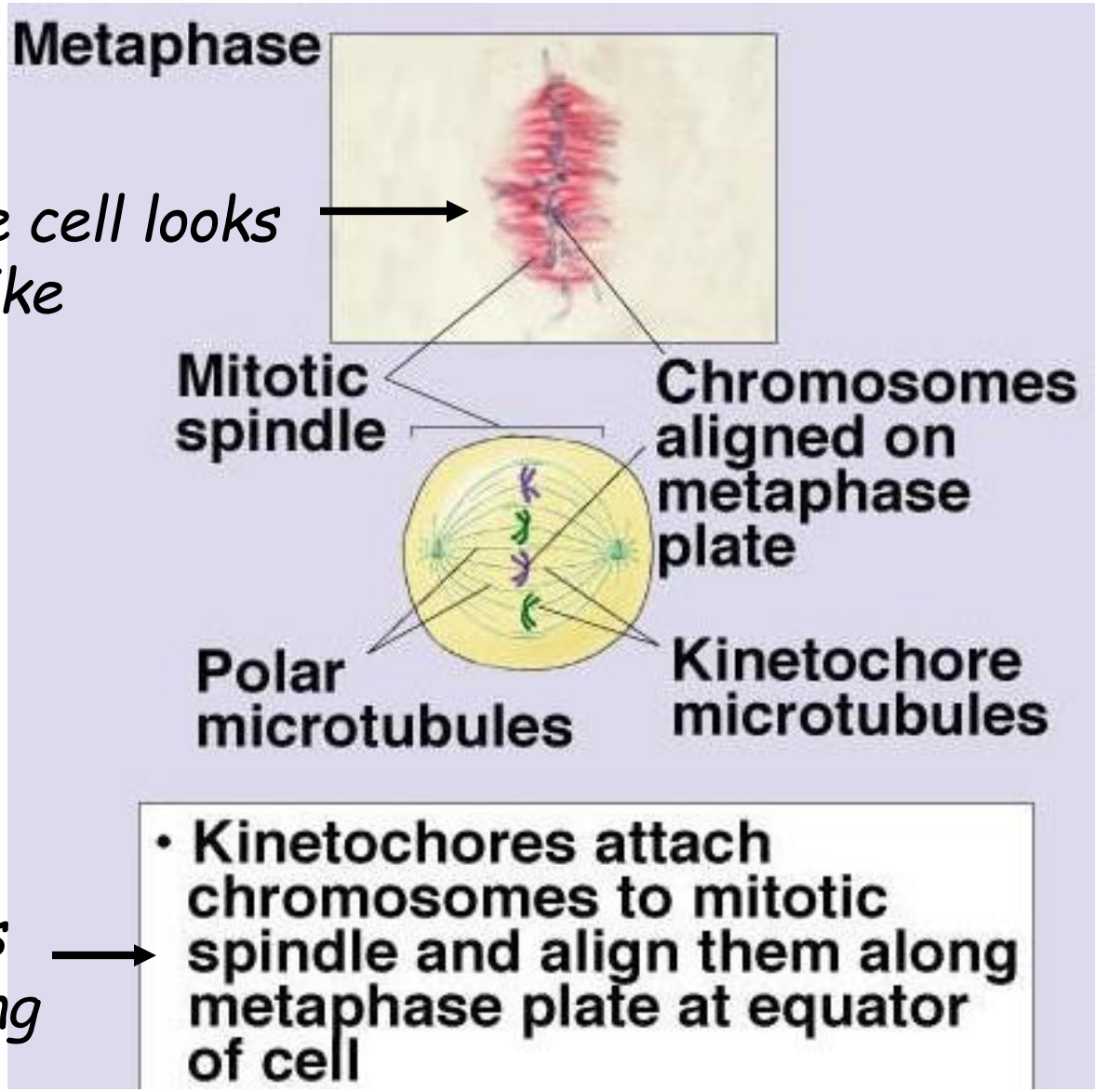

Asters at the poles
Spindle Fibers
Chromosomes lined at the Equator

Metaphase



Review of Metaphase

What the cell looks like →

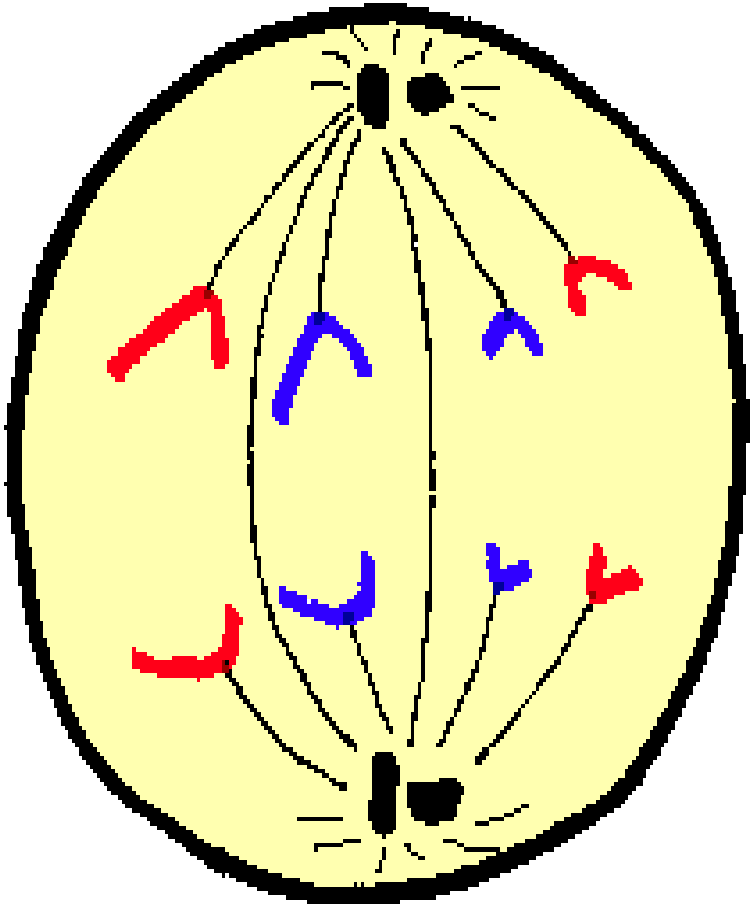


What's occurring →

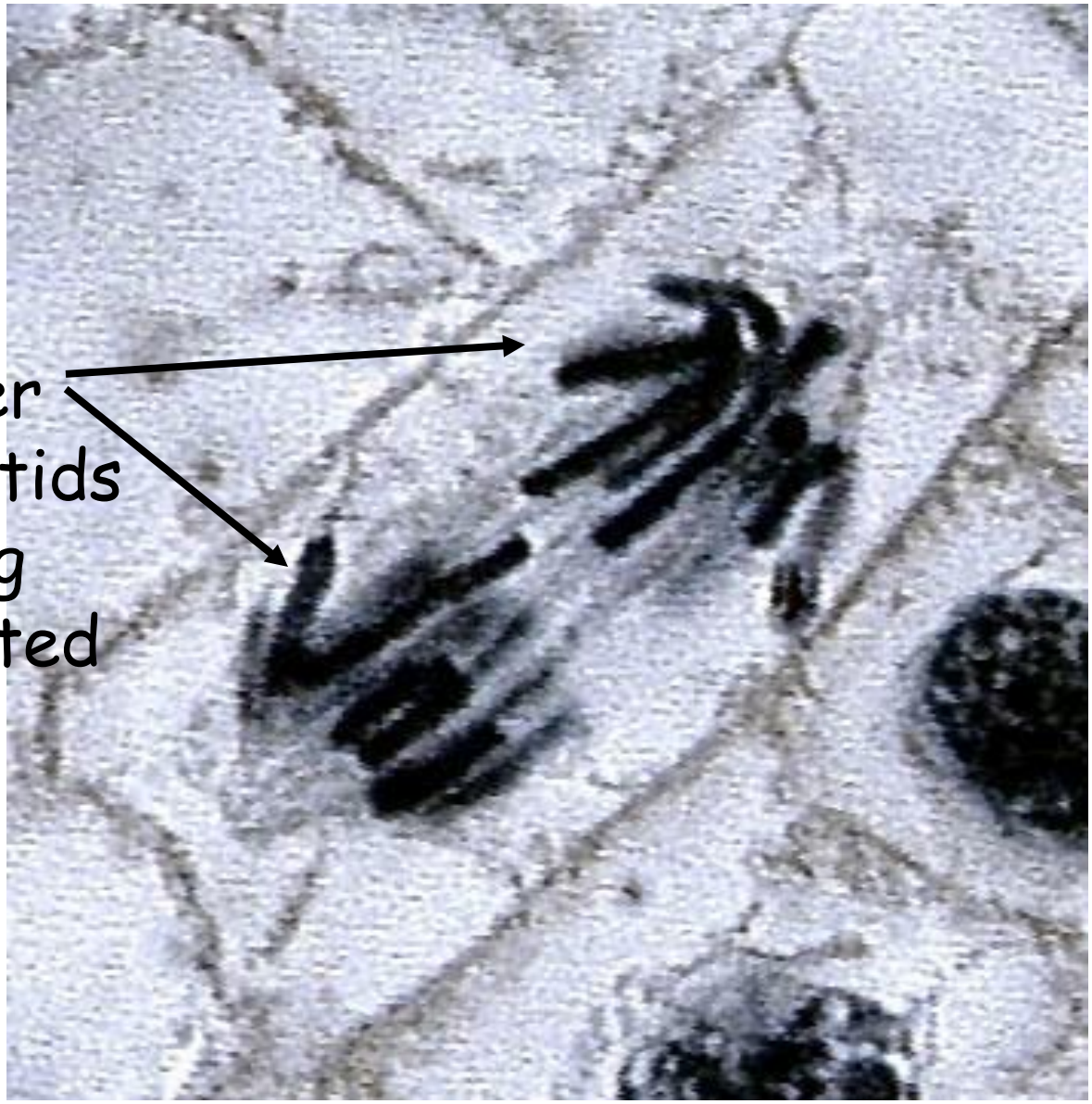
- Kinetochores attach chromosomes to mitotic spindle and align them along metaphase plate at equator of cell

Anaphase

- ✓ Occurs rapidly
- ✓ Sister chromatids are pulled apart to opposite poles of the cell by kinetochore fibers

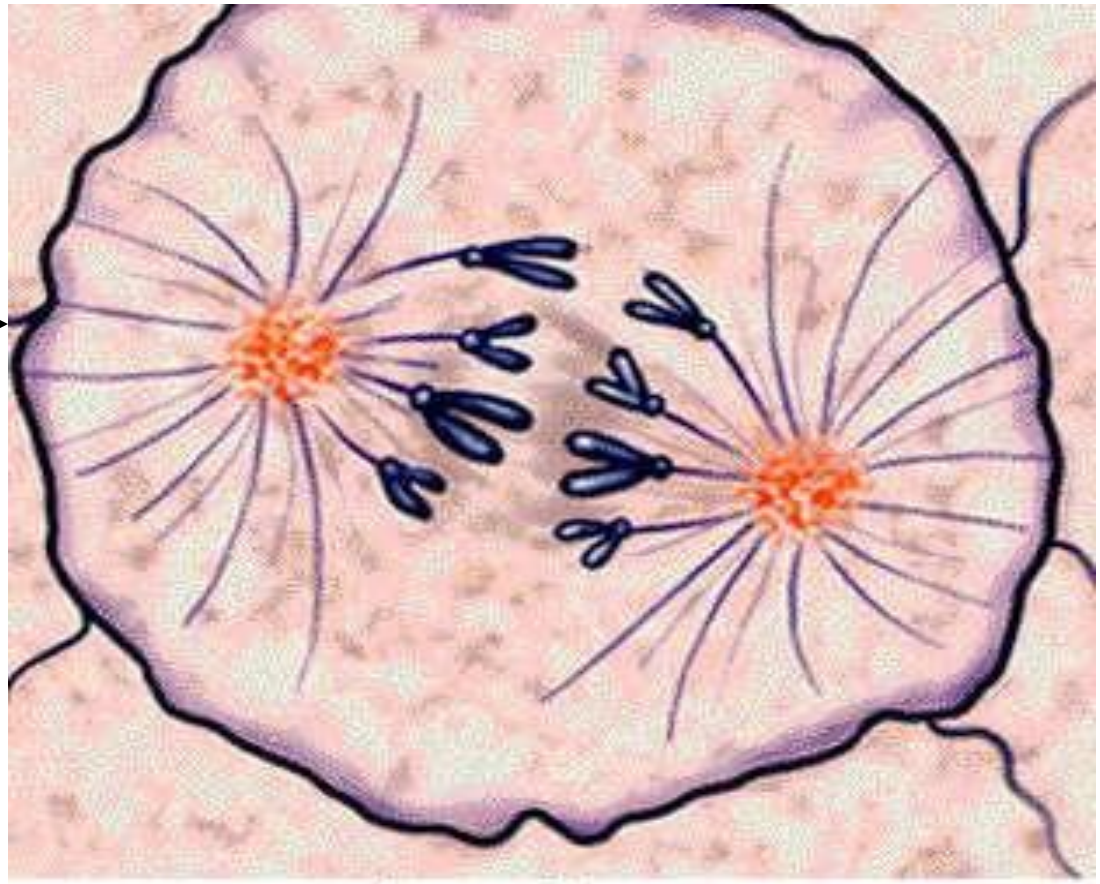


Anaphase



Anaphase Review

What the cell looks like →



What's occurring →

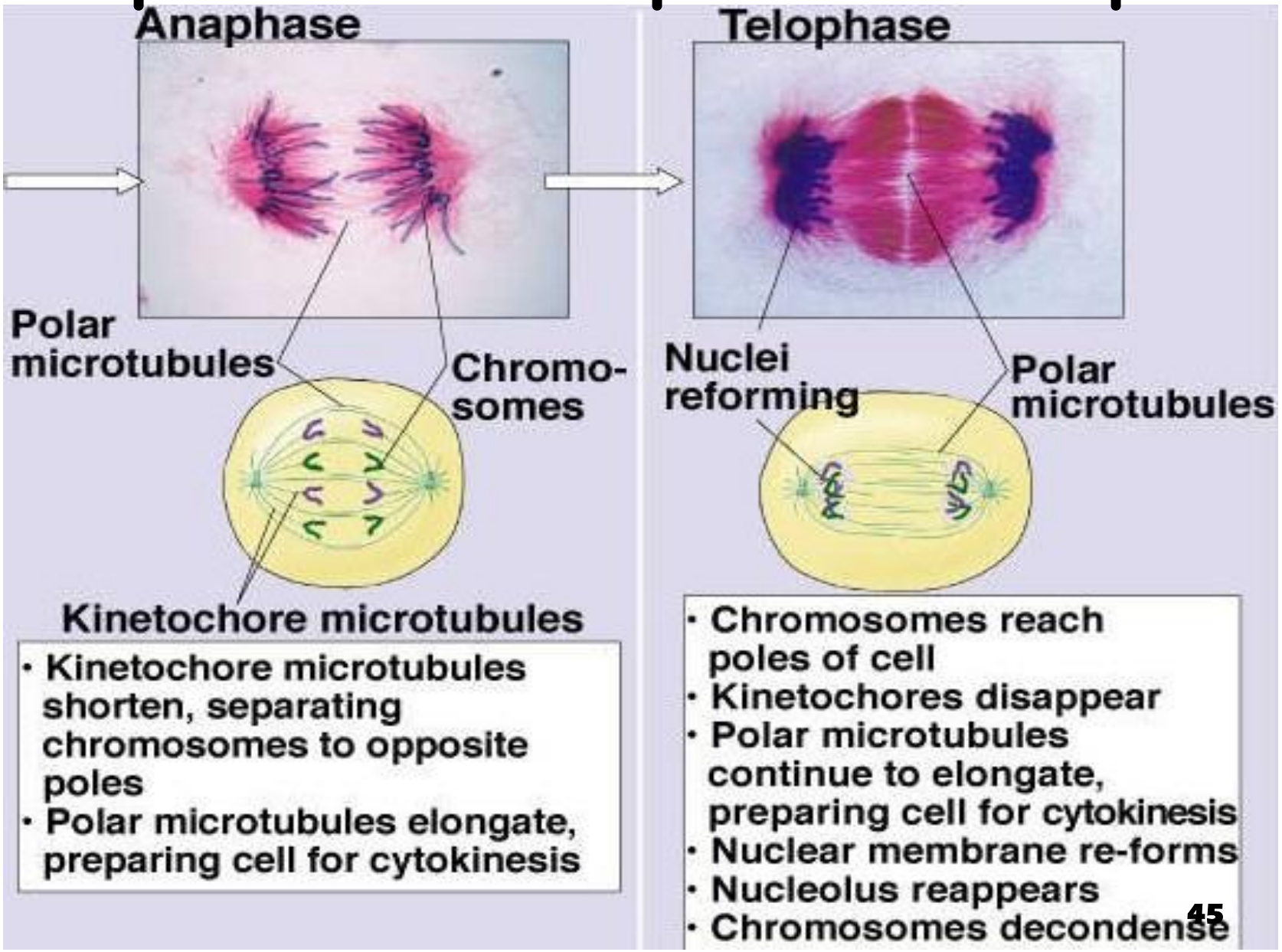
Anaphase

Centromeres divide in two.
Spindle fibers pull sister chromatids to opposite poles of cell.
Each pole (future daughter cell) now has an identical set of genes.

Telophase

- ✓Sister chromatids at opposite poles
- ✓Spindle disassembles
- ✓Nuclear envelope forms around each set of sister chromatids
- ✓Nucleolus reappears
- ✓CYTOKINESIS occurs
- ✓Chromosomes reappear as chromatin

Comparison of Anaphase & Telophase



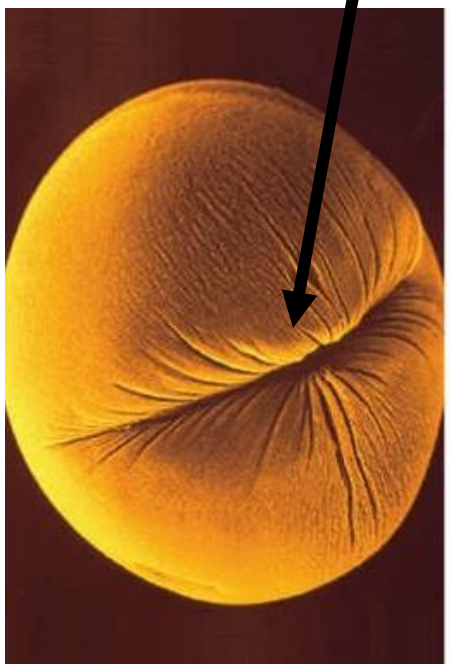
Cytokinesis

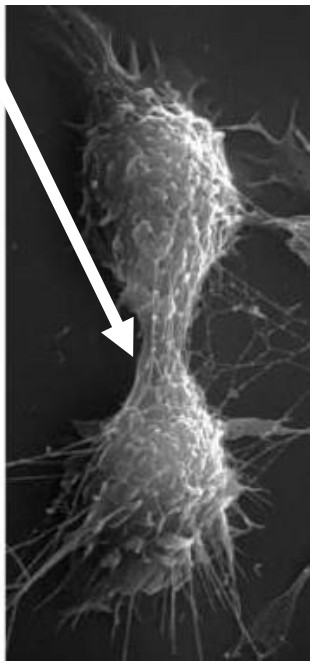
- ✓ Means division of the cytoplasm
- ✓ Division of cell into two, identical halves called daughter cells
- ✓ In plant cells, cell plate forms at the equator to divide cell
- ✓ In animal cells, cleavage furrow forms to split cell

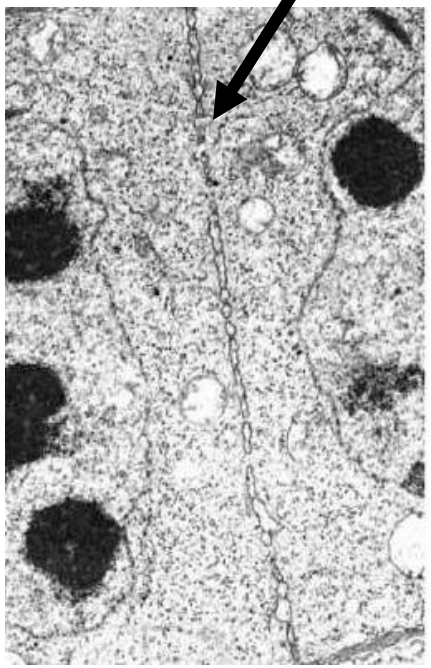
Cytokinesis

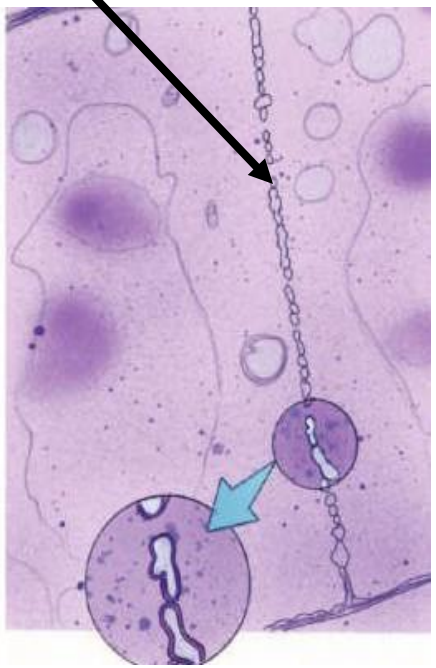
Cleavage furrow in animal cell

Cell plate in plant cell

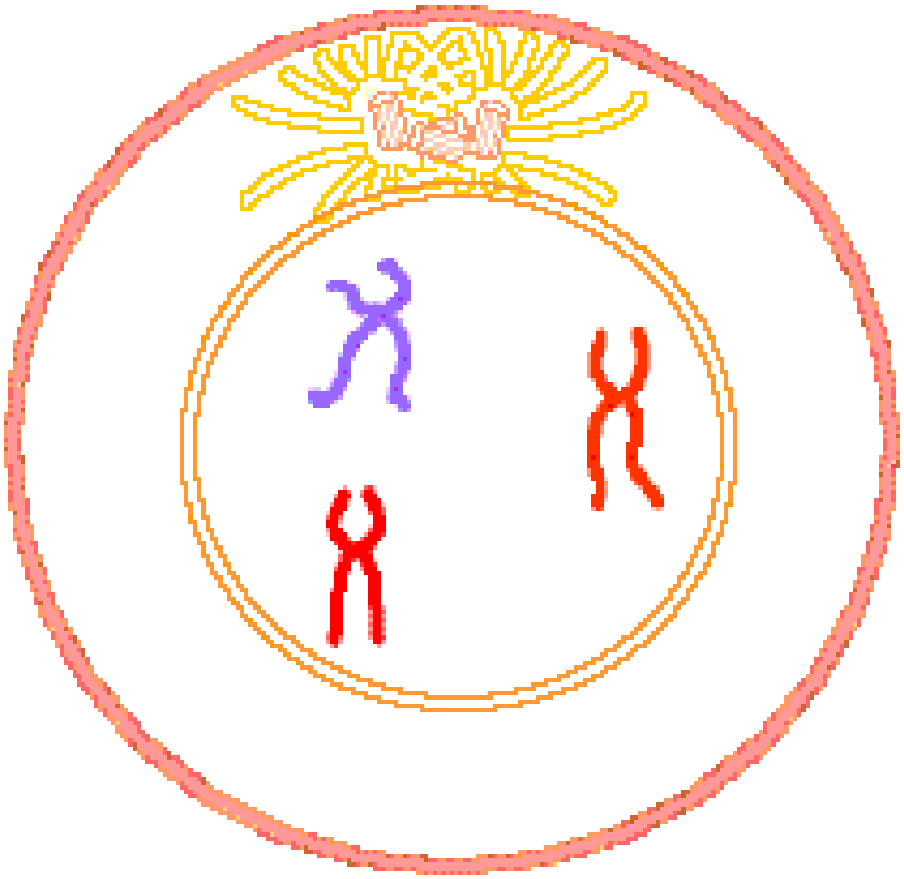








Mitotic Stages



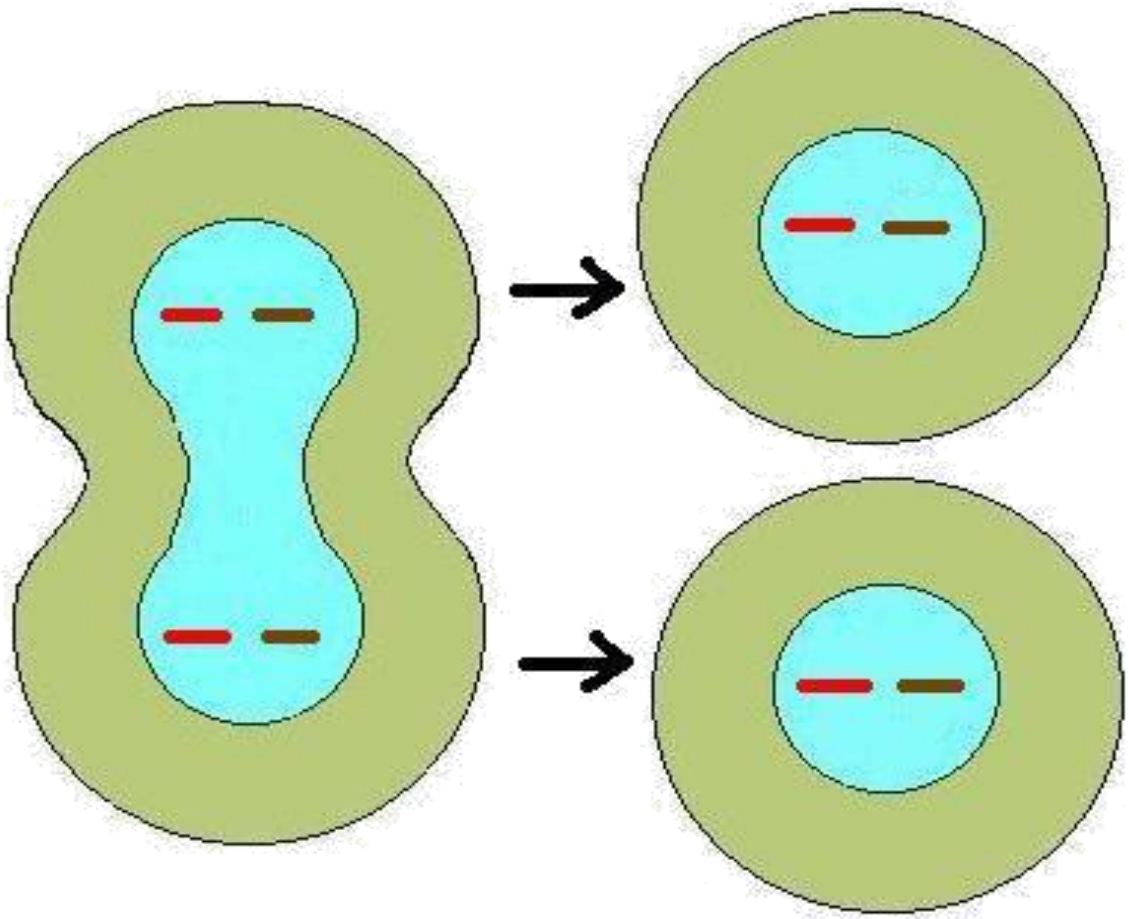
Prophase:

- condensation of chromosomes
- disappearance of nucleoli and nuclear envelope

Daughter Cells of Mitosis

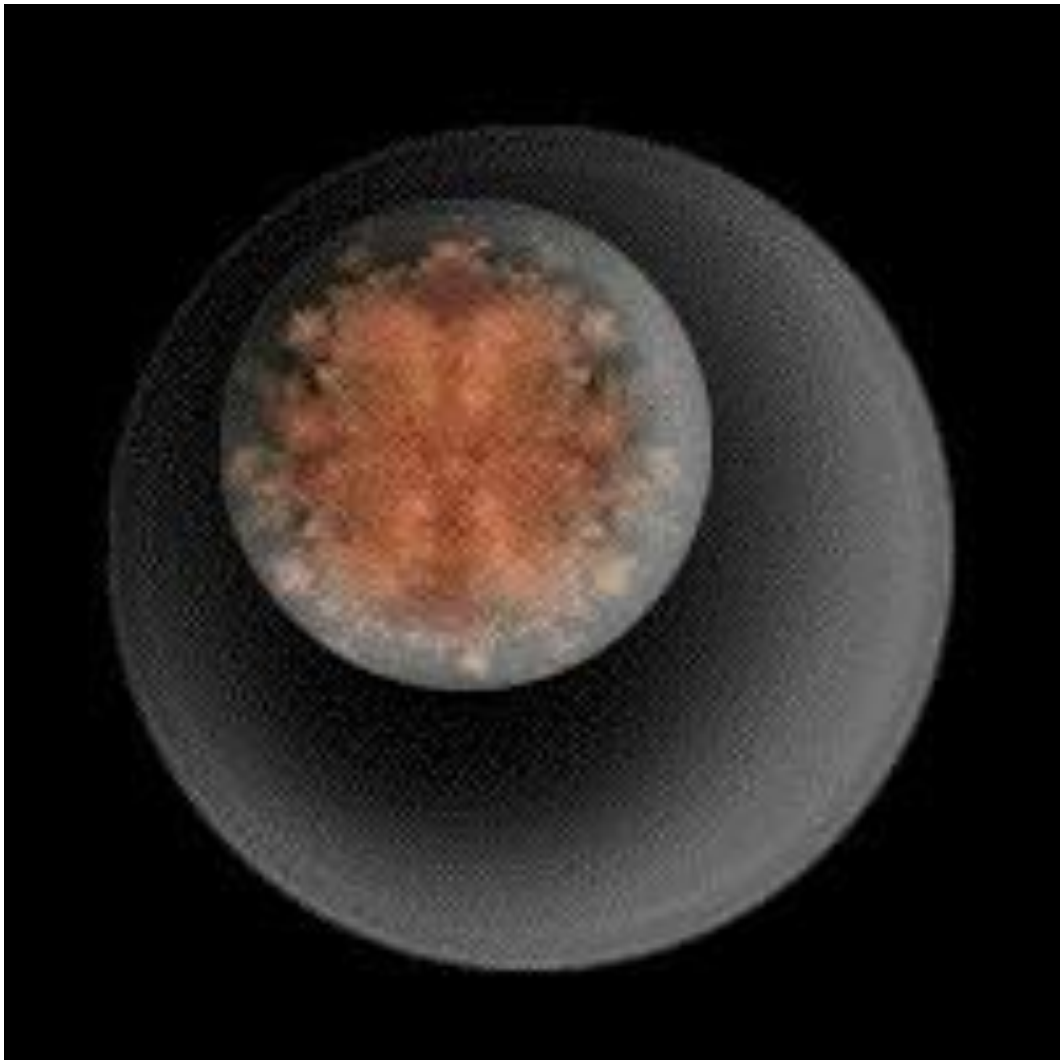
- ✓ Have the same number of chromosomes as each other and as the parent cell from which they were formed
- ✓ Identical to each other, but smaller than parent cell
- ✓ Must grow in size to become mature cells (G_1 of Interphase)

Identical Daughter Cells

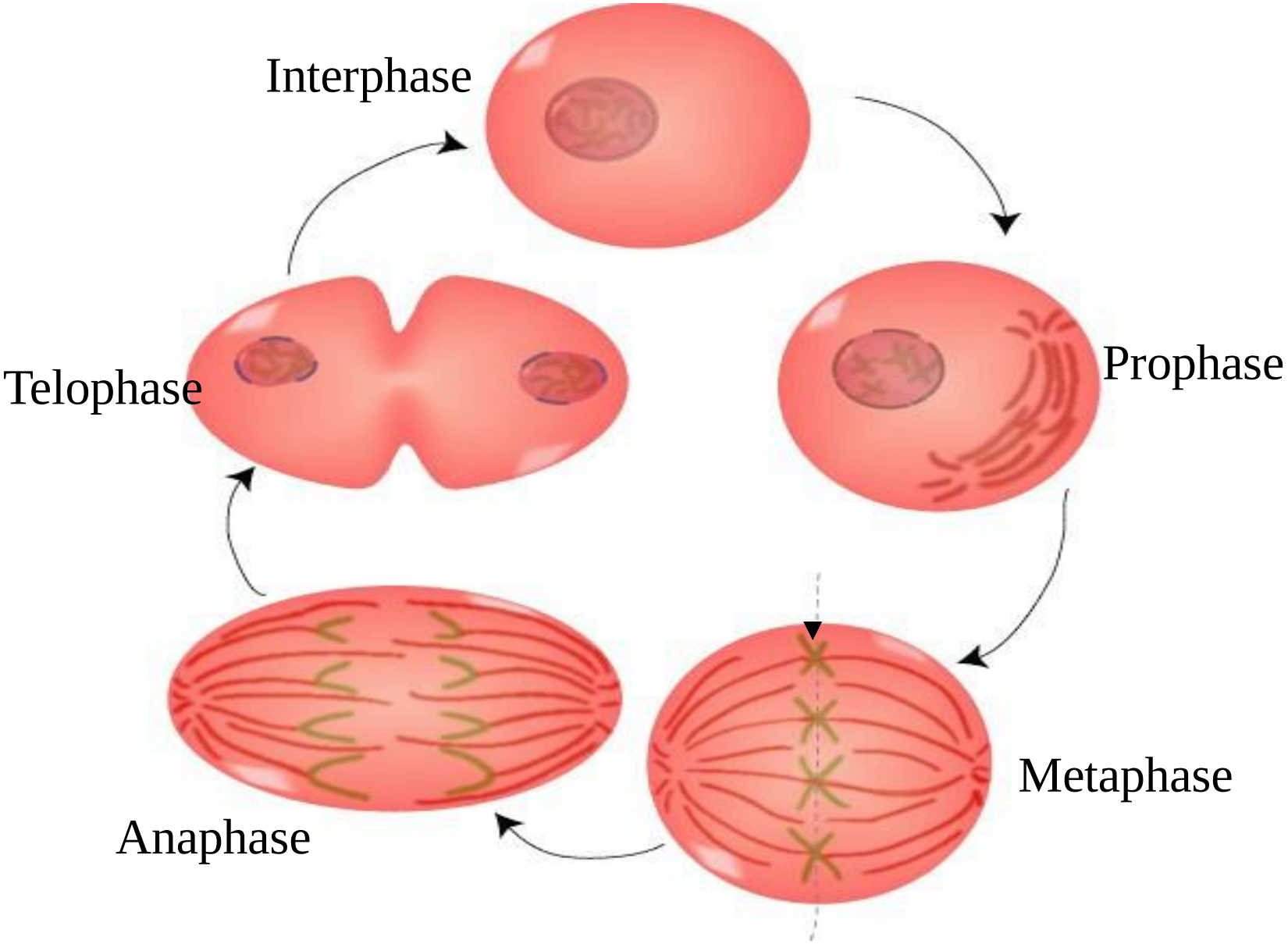


Chromosome number the same, but cells smaller than parent cell

Review of Mitosis

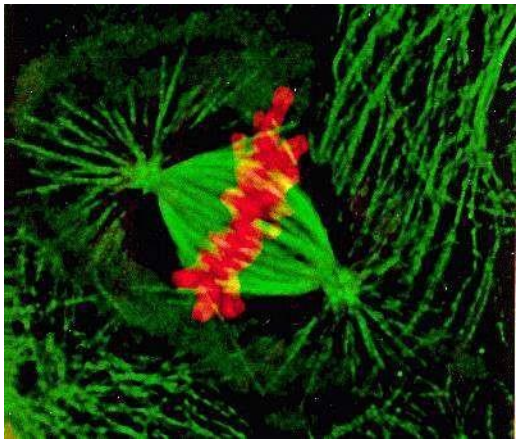


Name the Mitotic Stages:

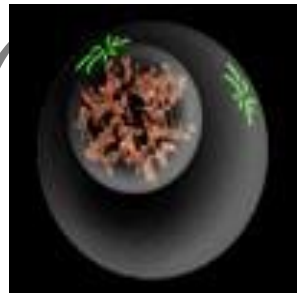


Eukaryotic Cell Division

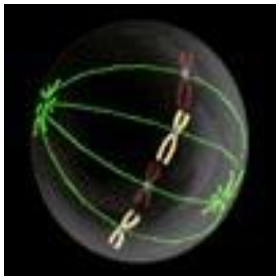
- ✓ Used for growth and repair
- ✓ Produce two new cells identical to the original cell
- ✓ Cells are diploid (2n)



Chromosomes during Metaphase of mitosis

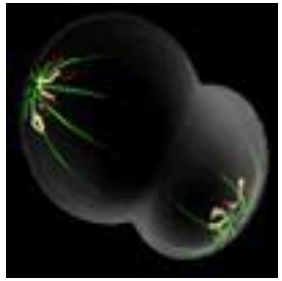


Prophase

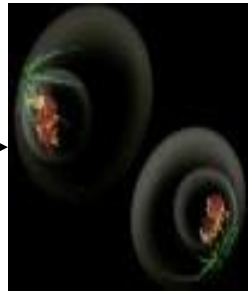


Metaphase

Anaphase



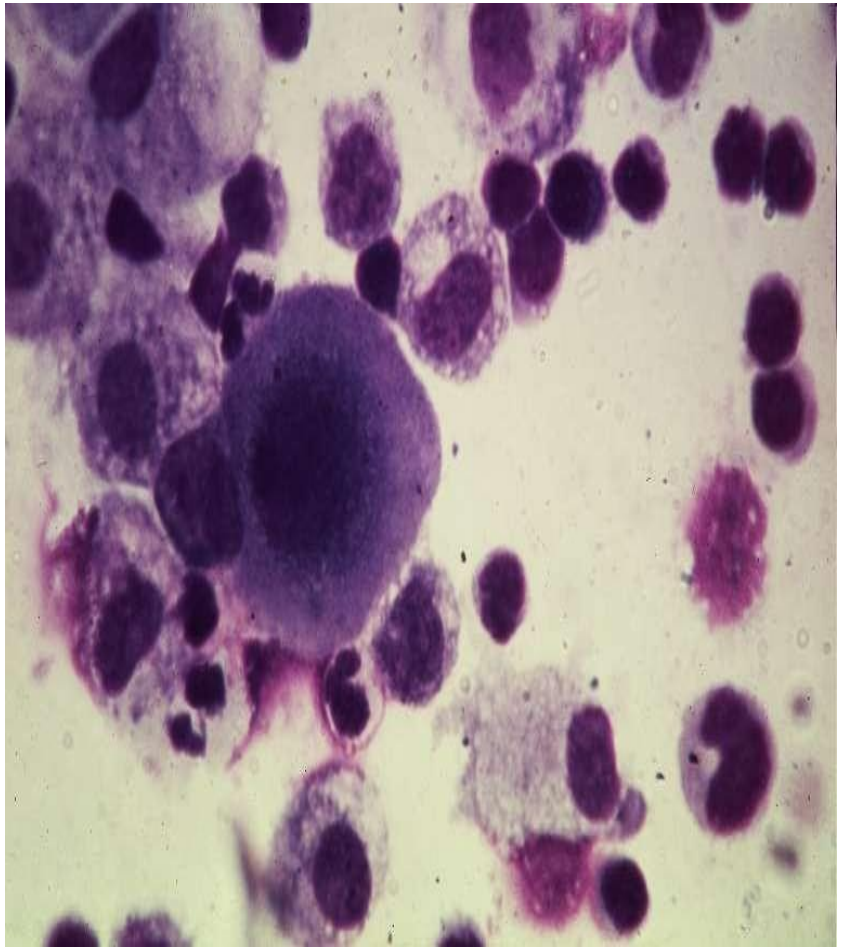
Telophase



Cytokinesis

Uncontrolled Mitosis

- If mitosis is not controlled, unlimited cell division occurs causing cancerous tumors
- Oncogenes are special proteins that increase the chance that a normal cell develops into a tumor cell



Meiosis

- Formation of Gametes
- (Eggs & Sperm)

Facts About Meiosis

- ✓ Preceded by interphase which includes chromosome replication
- ✓ Two meiotic divisions --- Meiosis I and Meiosis II
- ✓ Called Reduction- division
- ✓ Original cell is diploid (2n)
- ✓ Four daughter cells produced that are monoploid (1n)

Facts About Meiosis

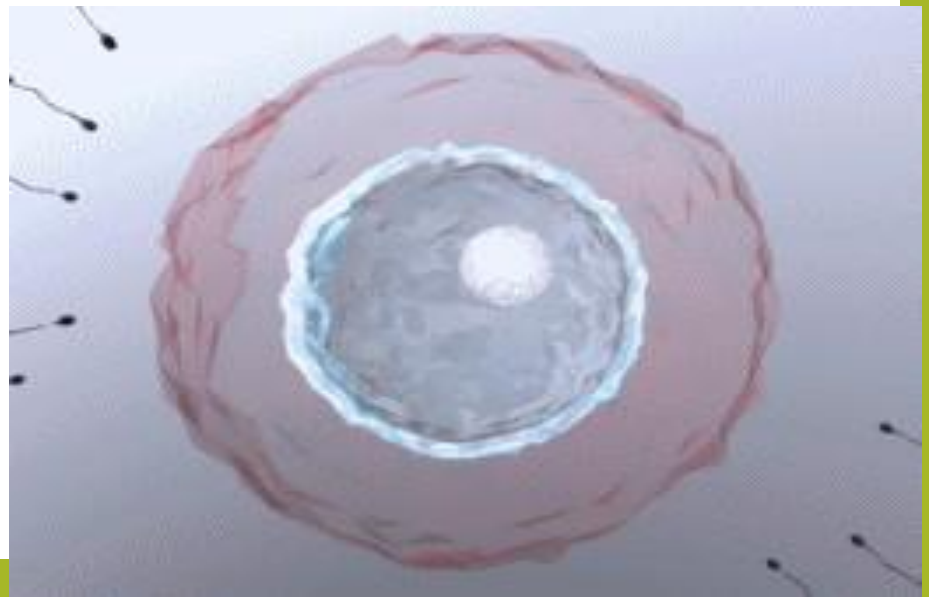
- ✓ Daughter cells contain half the number of chromosomes as the original cell
- ✓ Produces gametes (eggs & sperm)
- ✓ Occurs in the testes in males (Spermatogenesis)
- ✓ Occurs in the ovaries in females (Oogenesis)

More Meiosis Facts

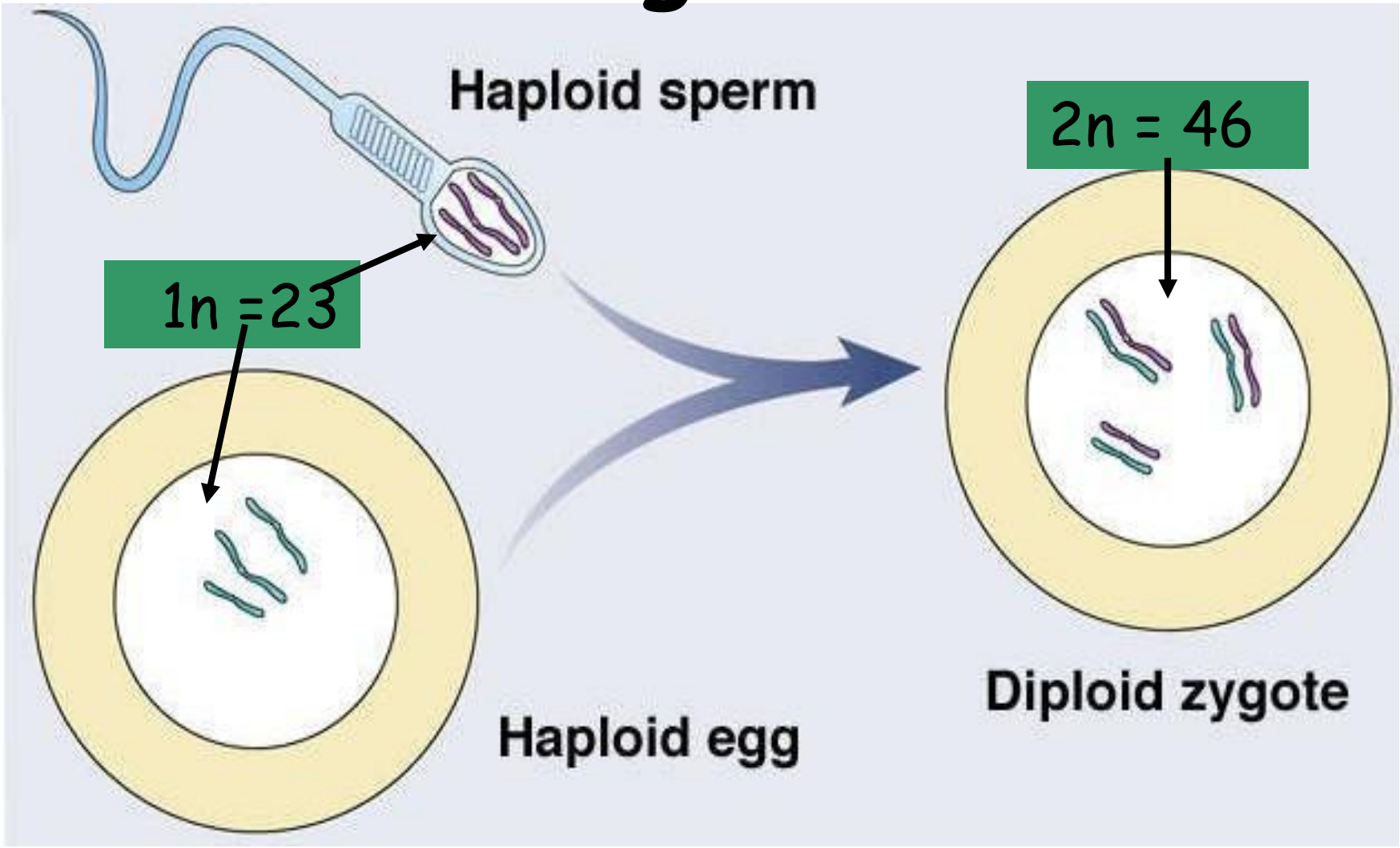
- ✓Start with 46 double stranded chromosomes (2n)
- ✓After 1 division - 23 double stranded chromosomes (n)
- ✓After 2nd division - 23 single stranded chromosomes (n)
- ✓Occurs in our germ cells that produce gametes

Why Do we Need Meiosis?

- ✓ It is the fundamental basis of sexual reproduction
- ✓ Two haploid (1n) gametes are brought together through fertilization to form a diploid (2n) zygote

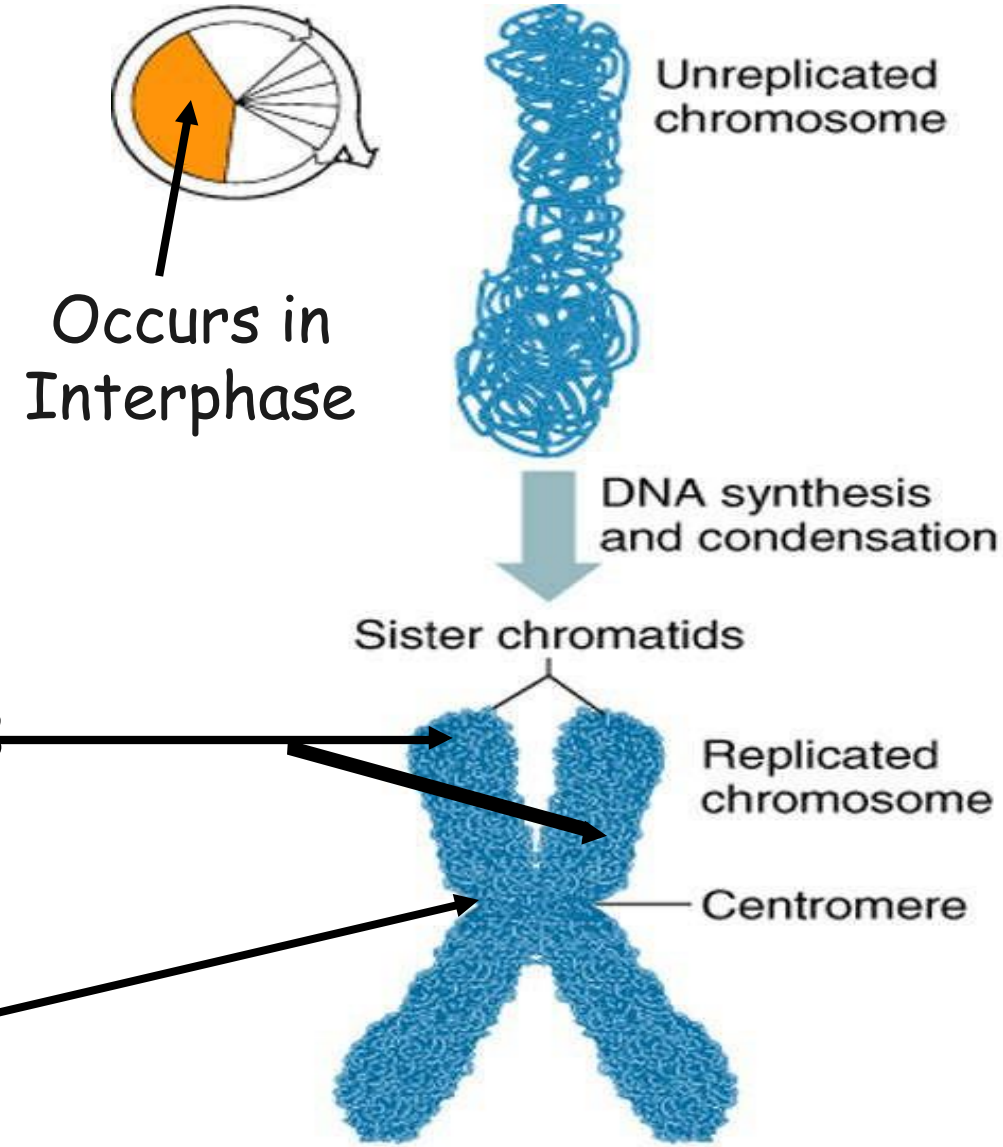


Fertilization – "Putting it all together"

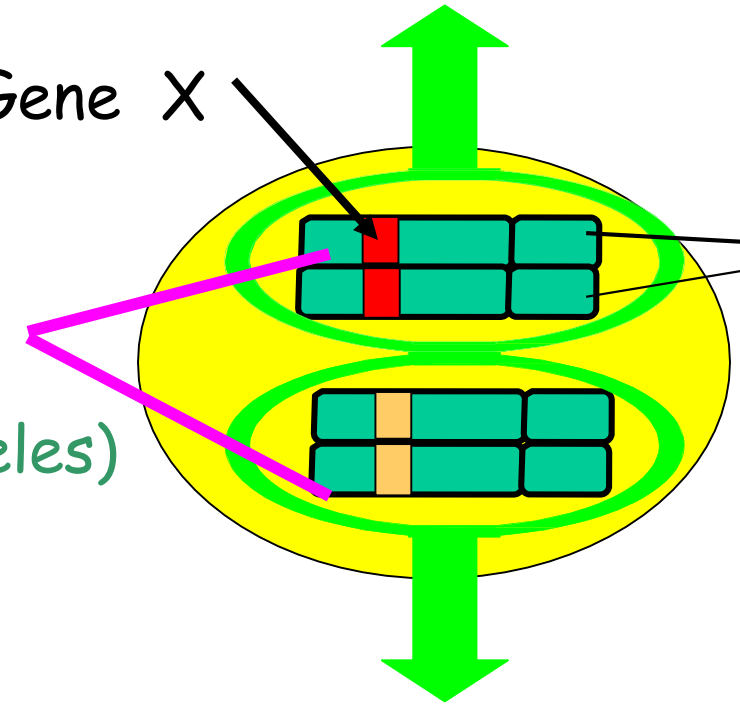


Replication of Chromosomes

- ✓Replication is the process of duplicating a chromosome
- ✓Occurs prior to division
- ✓Replicated copies are called sister chromatids
- ✓Held together at centromere



A Replicated Chromosome



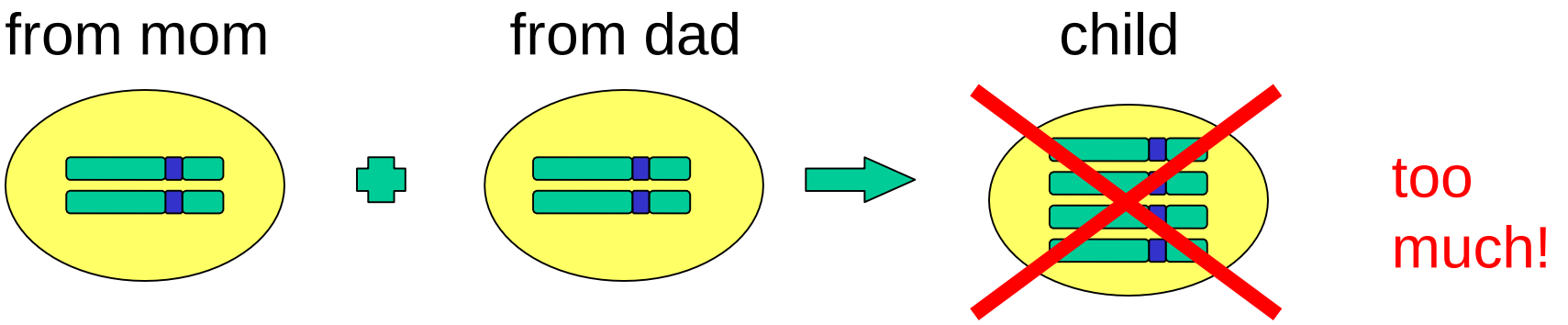
Homologs
(same genes, different alleles)

Sister Chromatids
(same genes, same alleles)

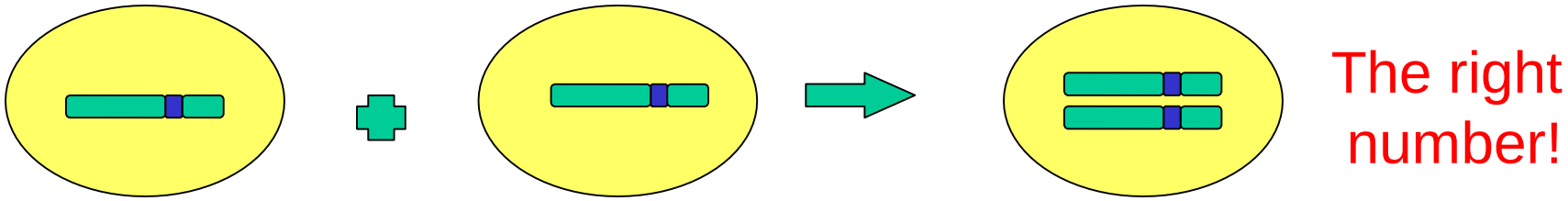
Homologs separate in meiosis I and therefore different alleles separate.

Meiosis Forms Haploid Gametes

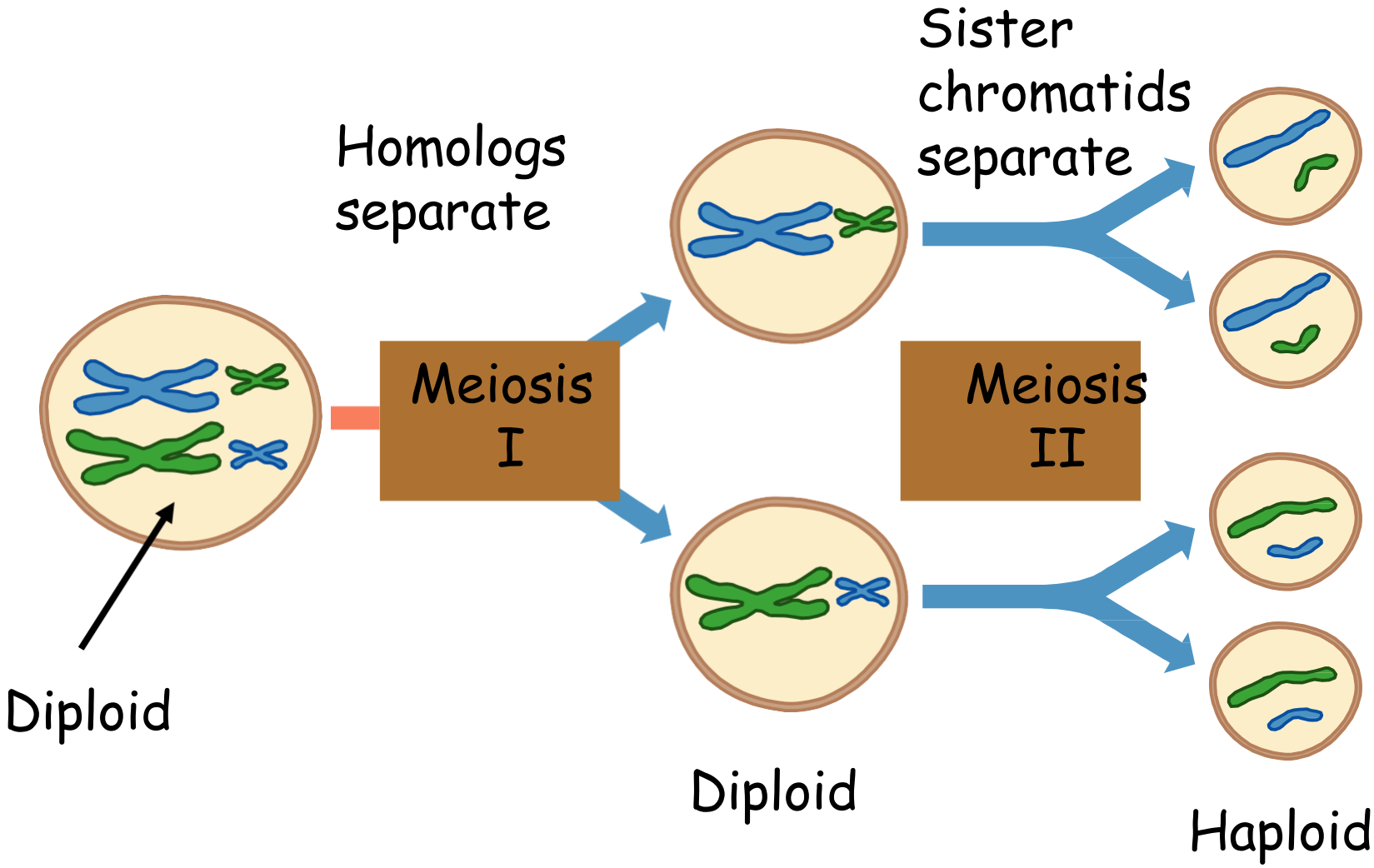
- ✓ **Meiosis must reduce the chromosome number by half**
- ✓ **Fertilization then restores the 2n number**



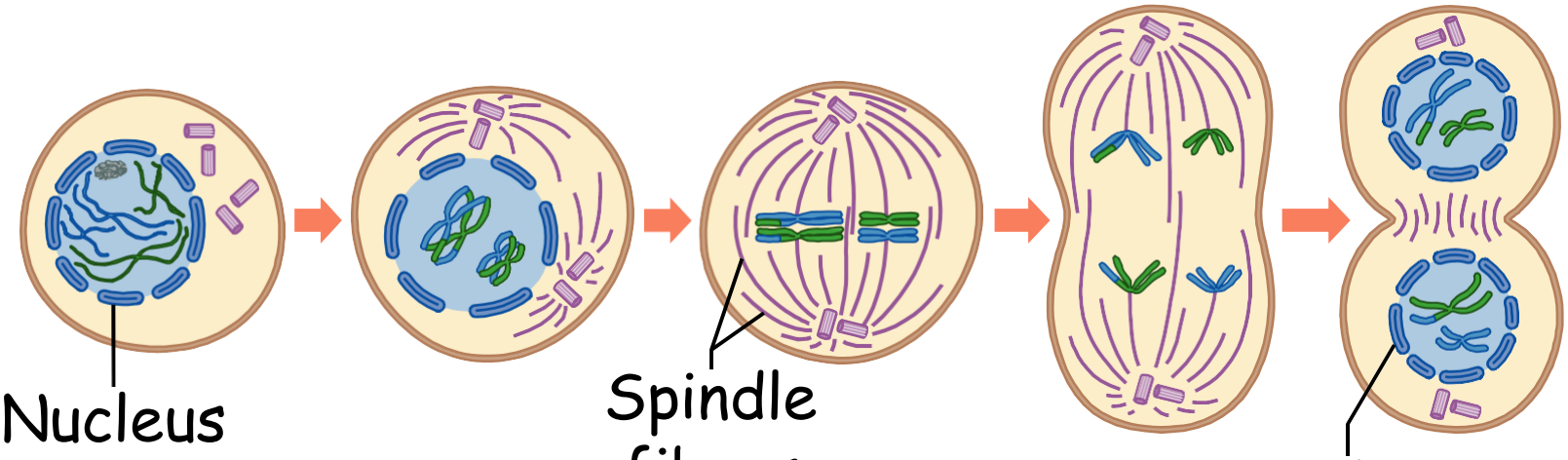
meiosis reduces genetic content



Meiosis: Two Part Cell Division



Meiosis I: Reduction Division



Early Prophase I (Chromosome number doubled)

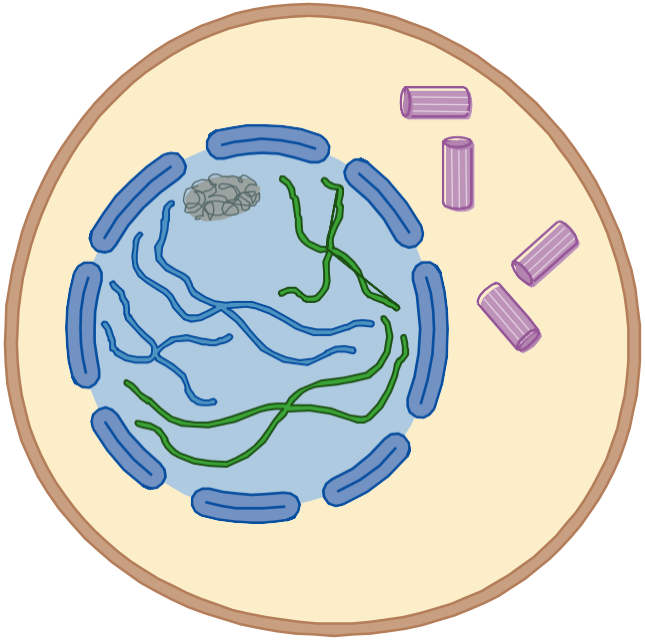
Late Prophase I

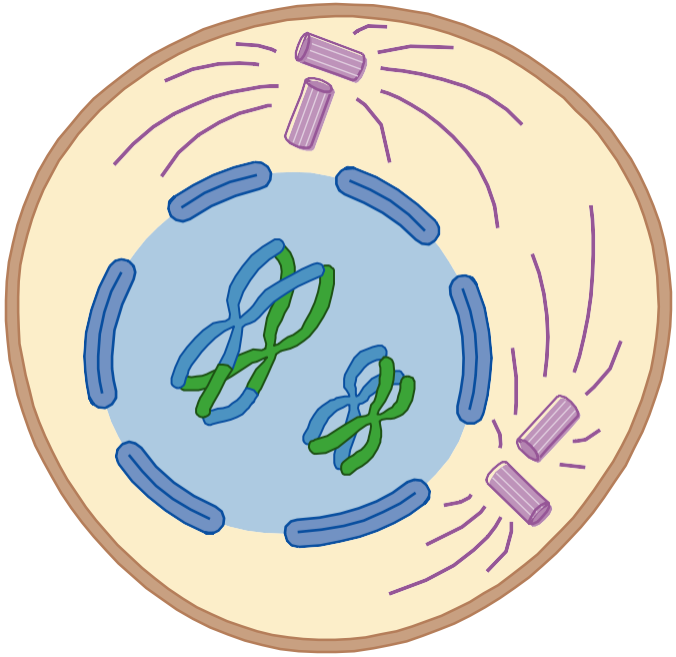
Metaphase I

Anaphase I

Telophase I (diploid)

Prophase I





Early prophase

- ✓Homologs pair.
- ✓Crossing over occurs.

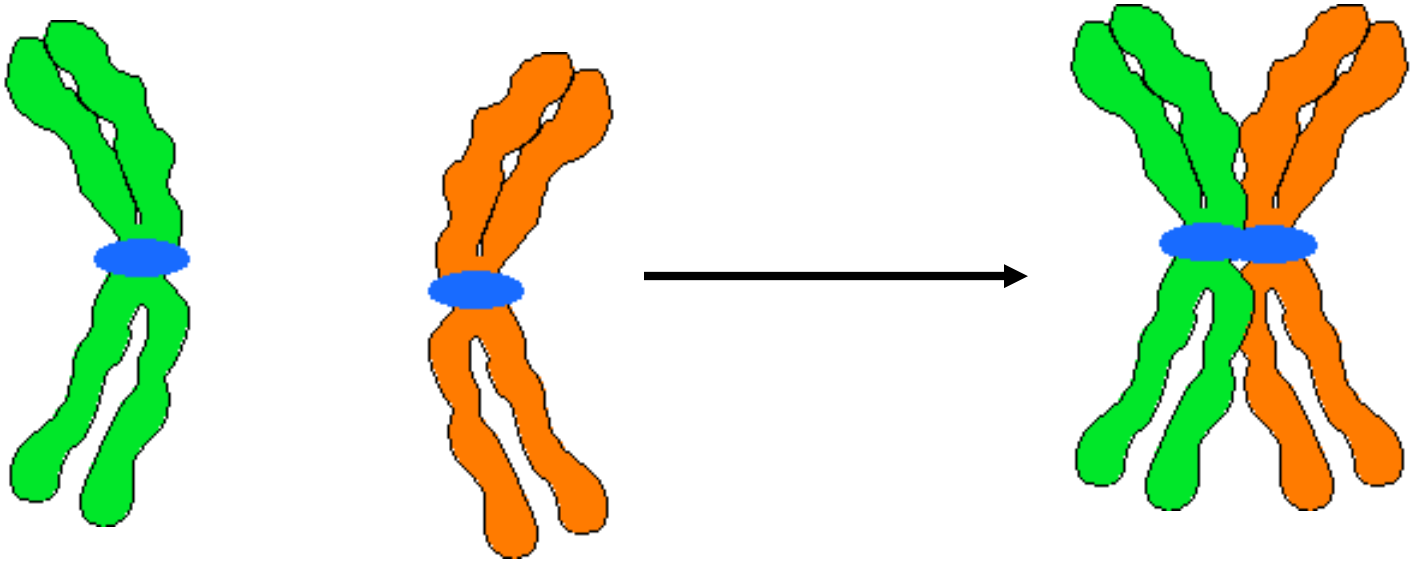
Late prophase

- ✓Chromosomes condense.
- ✓Spindle forms.
- ✓Nuclear envelope fragments.

Tetrads Form in Prophase I

Homologous chromosomes
(each with sister chromatids)

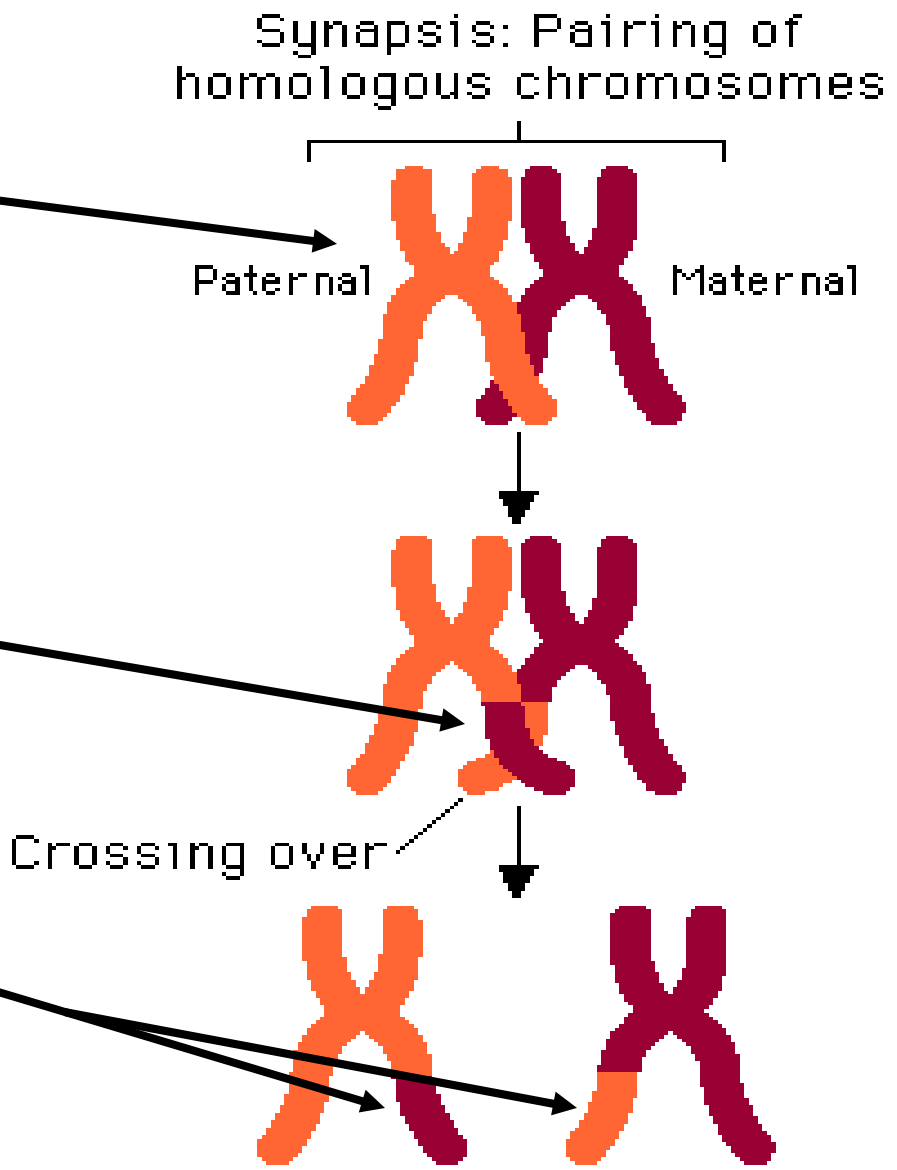
Join to form a
TETRAD



Called Synapsis

Crossing-Over

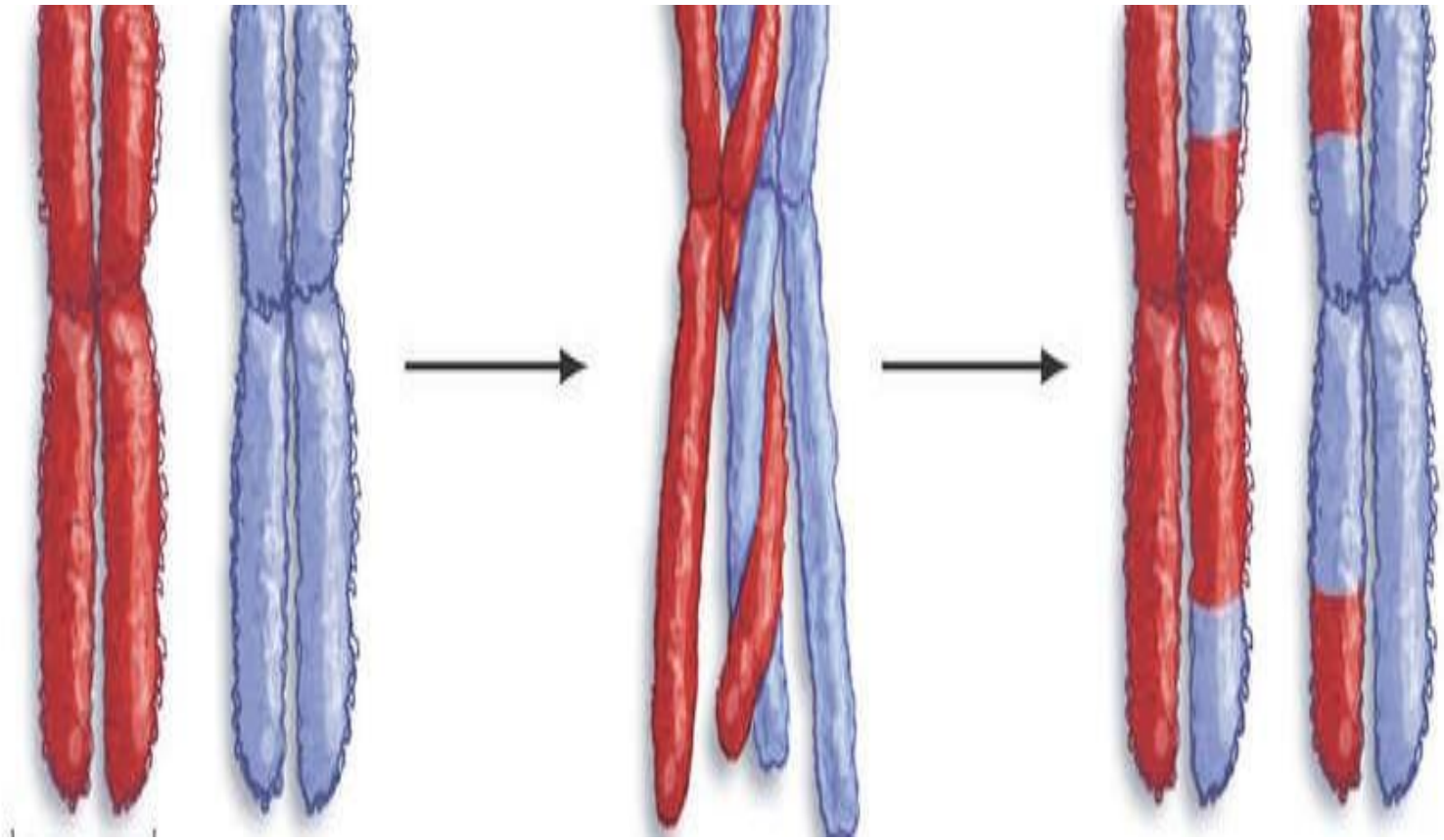
- ✓ Homologous chromosomes in a tetrad cross over each other
- ✓ Pieces of chromosomes or genes are exchanged
- ✓ Produces Genetic recombination in the offspring



During Crossing-Over

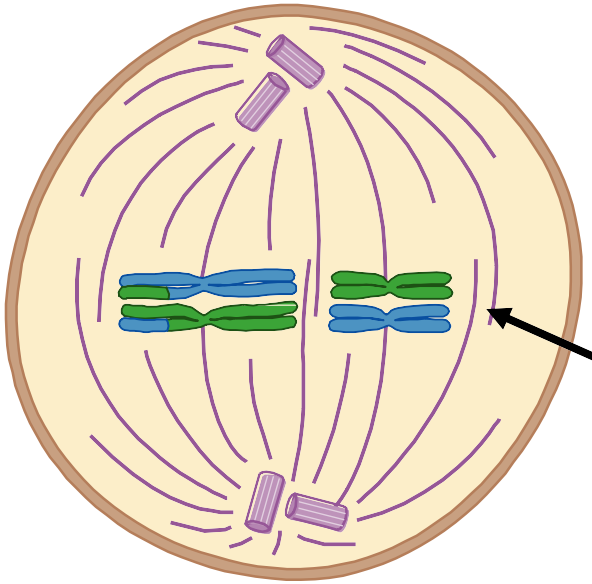
Homologous Chromosomes

Crossing-Over



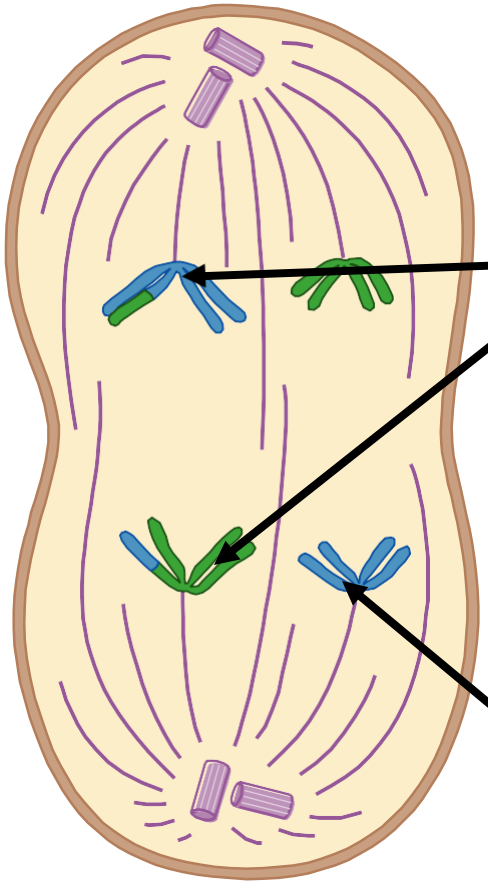
Crossing-over multiplies the already huge number of different gamete types produced by independent assortment

Metaphase I



Homologous pairs of chromosomes align along the equator of the cell

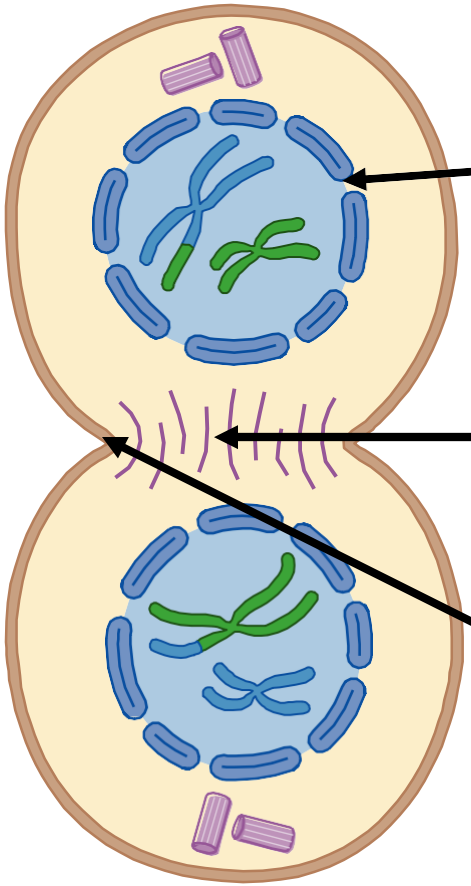
Anaphase I



Homologs separate and move to opposite poles.

Sister chromatids remain attached at their centromeres.

Telophase I

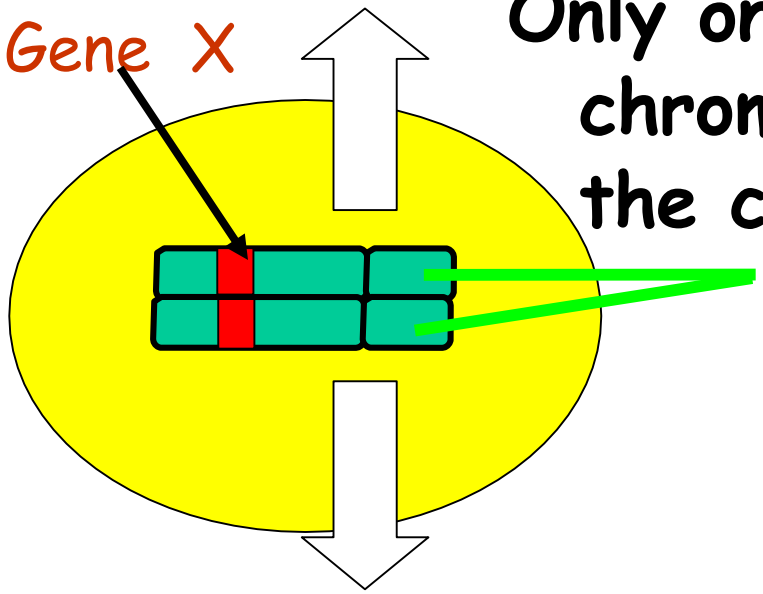


Nuclear envelopes reassemble.

Spindle disappears.

Cytokinesis divides cell into two.

Meiosis II

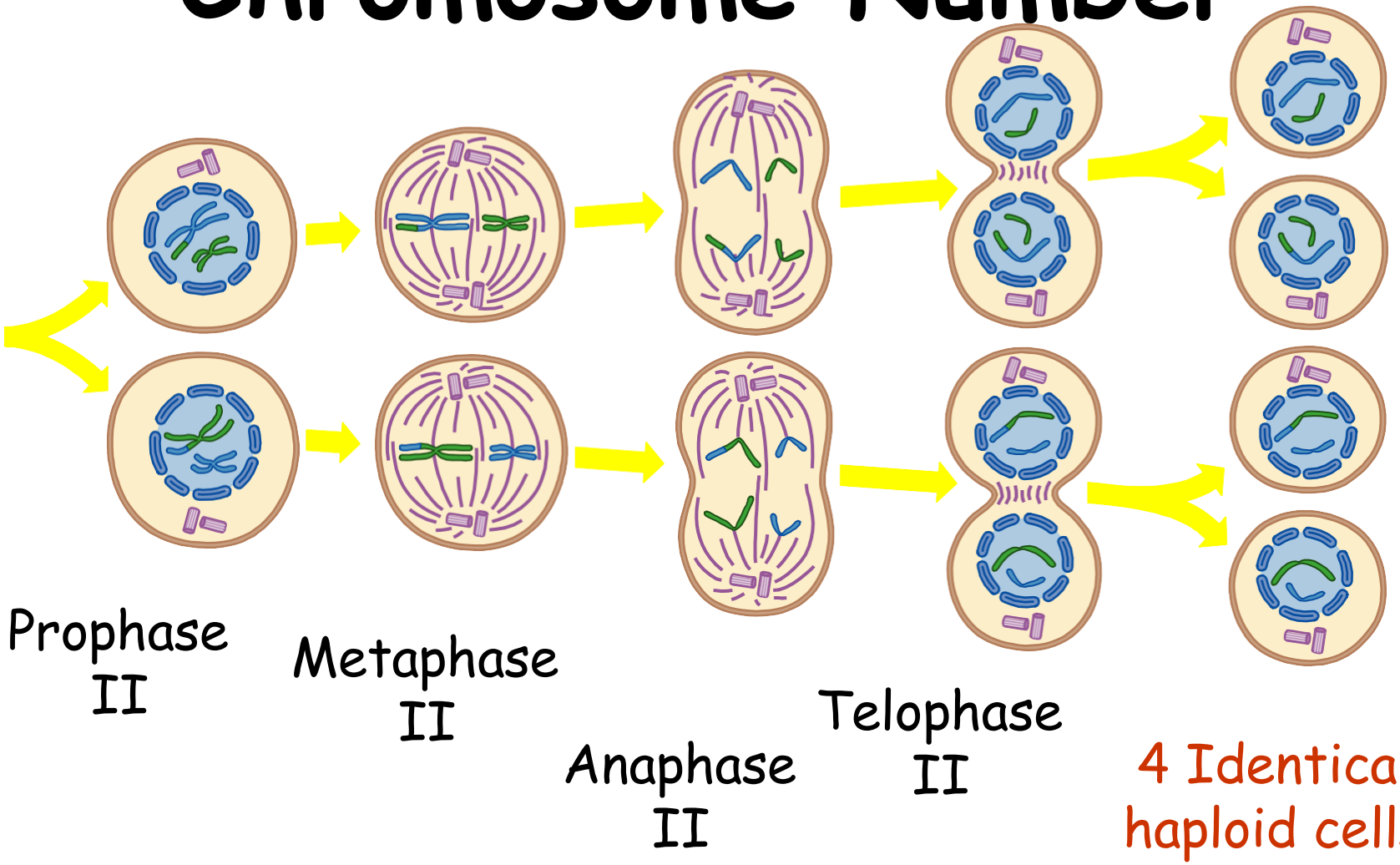


Only one homolog of each chromosome is present in the cell.

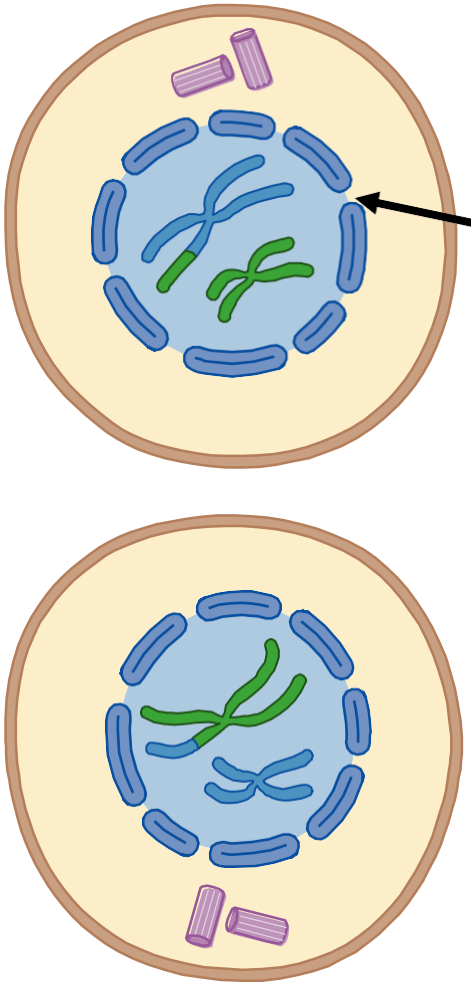
Sister chromatids carry identical genetic information.

Meiosis II produces gametes with one copy of each chromosome and thus one copy of each gene.

Meiosis II: Reducing Chromosome Number



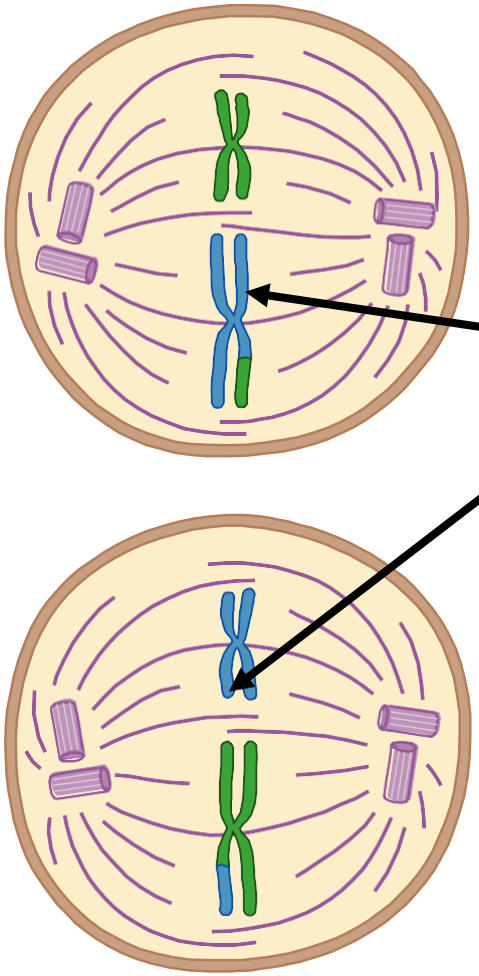
Prophase II



Nuclear envelope fragments.

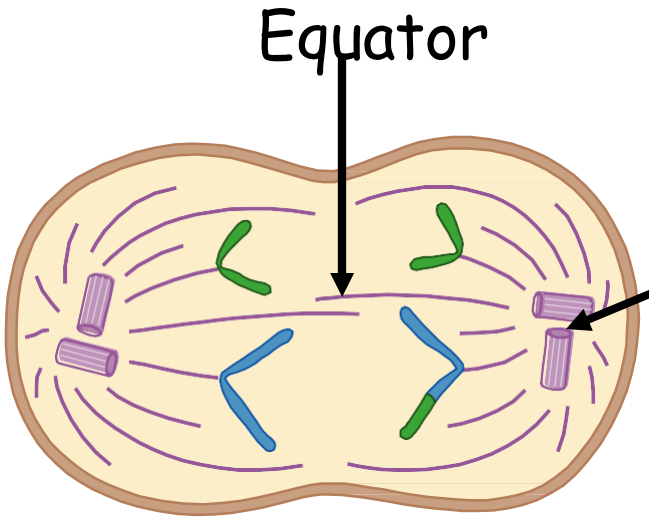
Spindle forms.

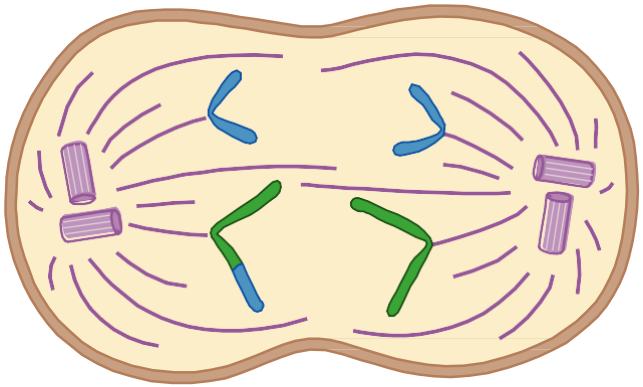
Metaphase II



Chromosomes align along equator of cell.

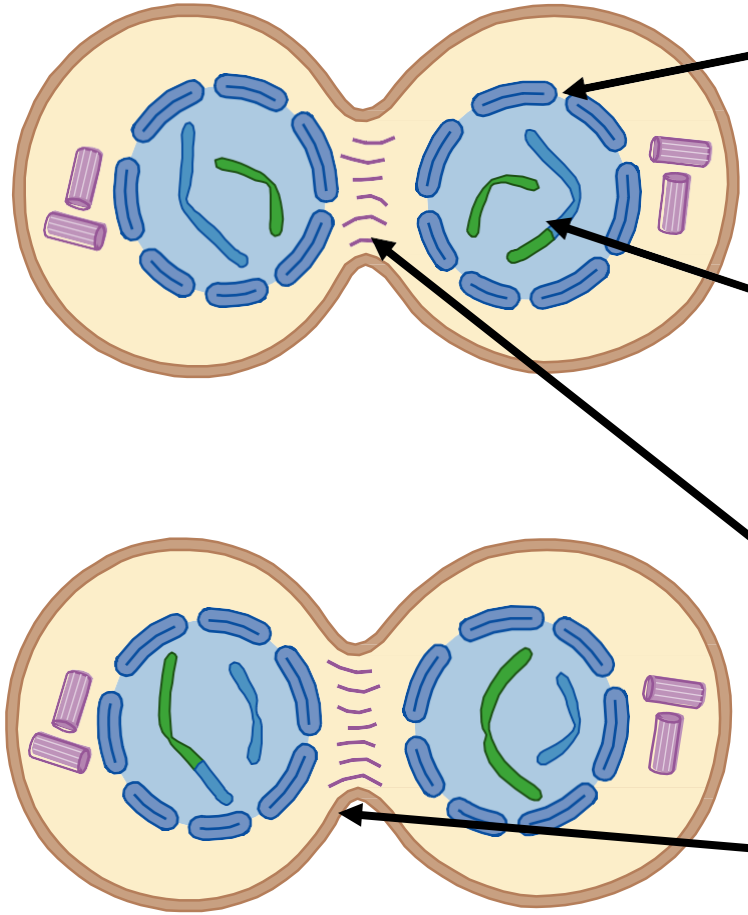
Anaphase II





Sister chromatids separate and move to opposite poles.

Telophase II



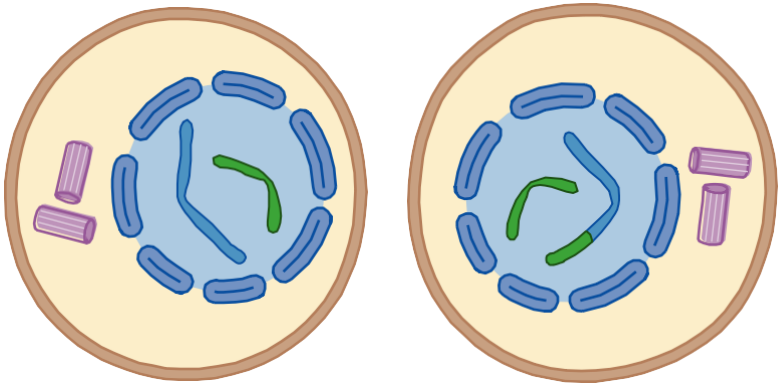
Nuclear envelope assembles.

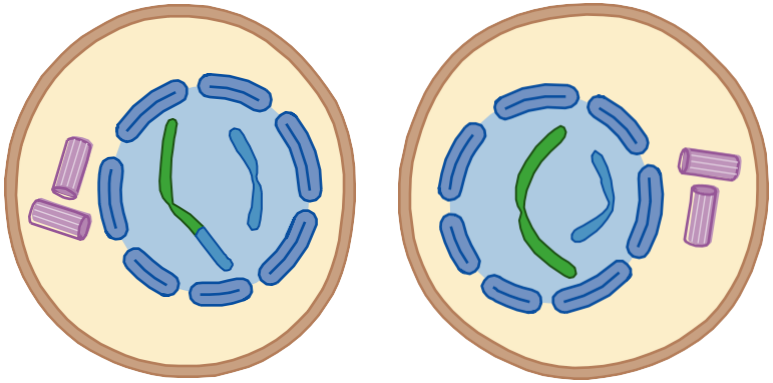
Chromosomes decondense.

Spindle disappears.

Cytokinesis divides cell into two.

Results of Meiosis





Gametes (egg & sperm) form

Four haploid cells with one copy of each chromosome

One allele of each gene

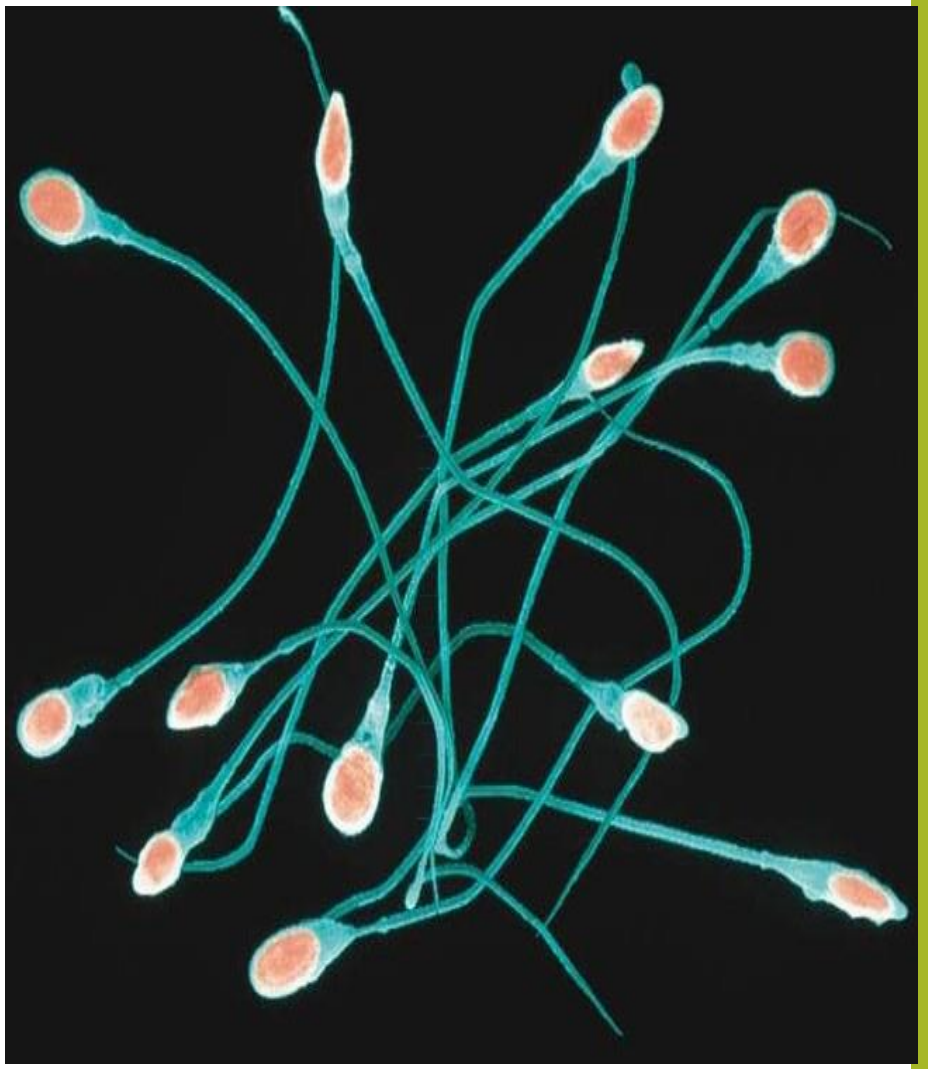
Different combinations of alleles for different genes along the chromosome

Gametogenesis

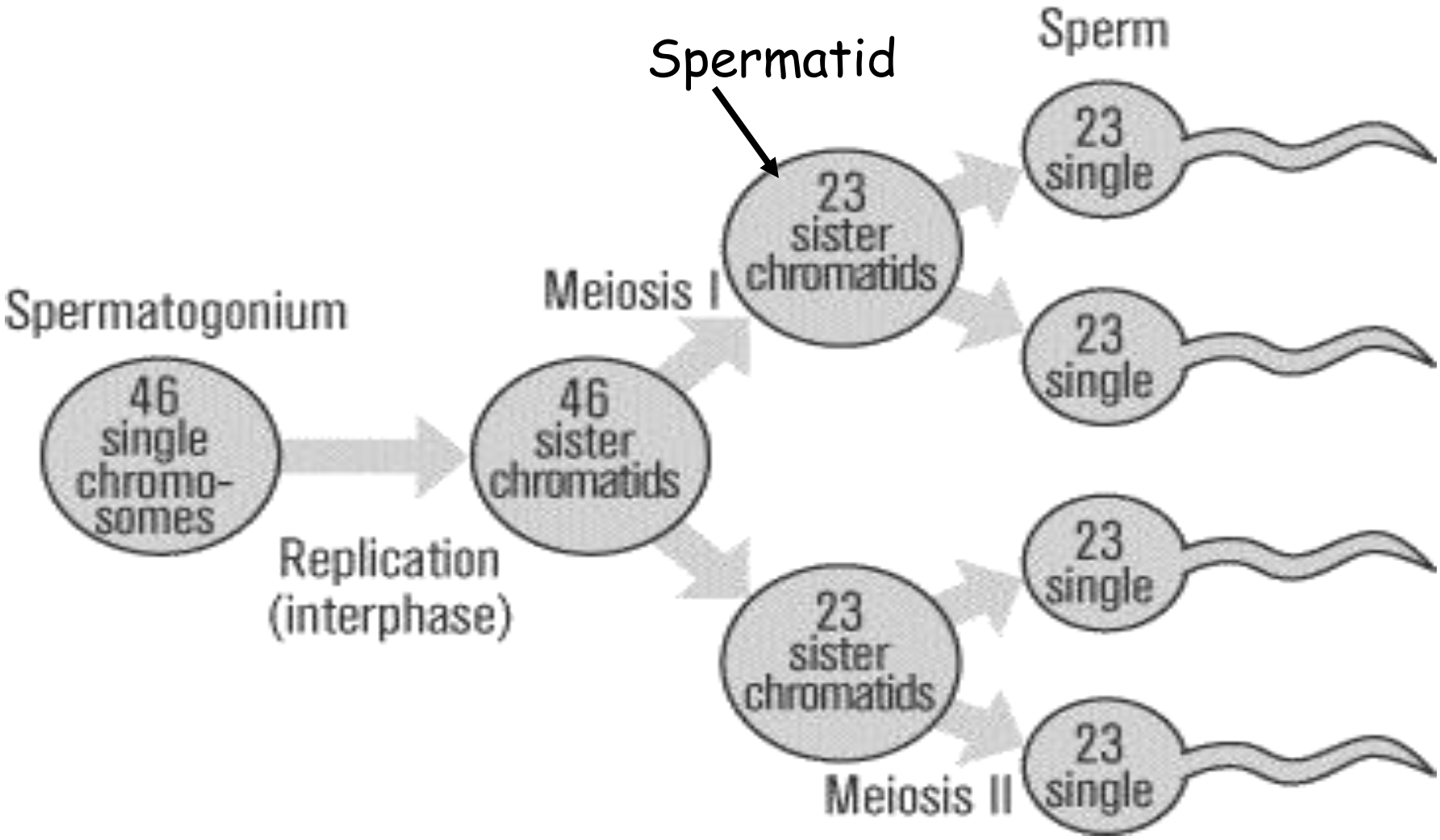
Oogenesis
or
Spermatogenesis

Spermatogenesis

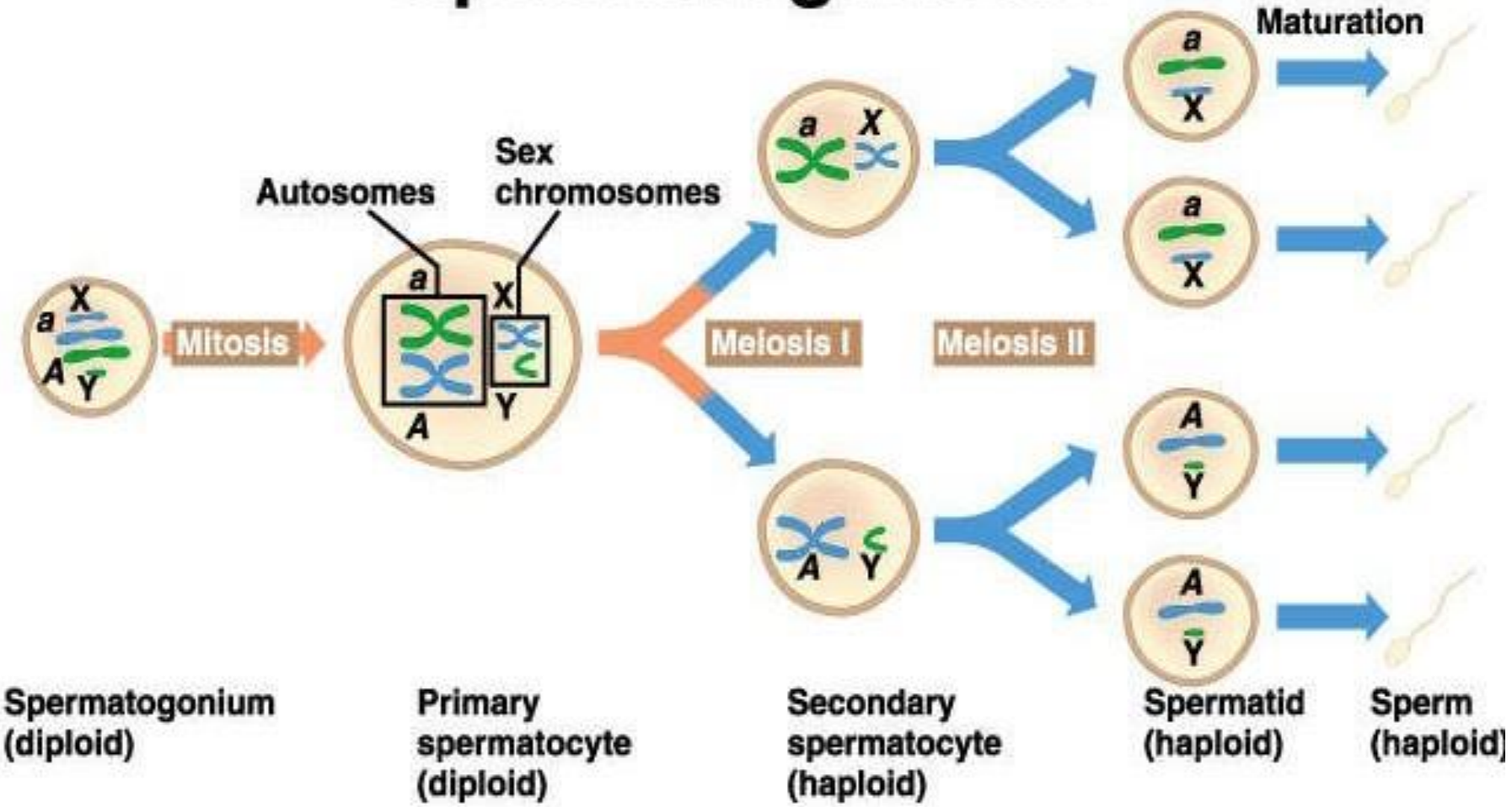
- ✓ Occurs in the testes
- ✓ Two divisions produce 4 spermatids
- ✓ Spermatids mature into sperm
- ✓ Men produce about 250,000,000 sperm per day



Spermatogenesis in the Testes



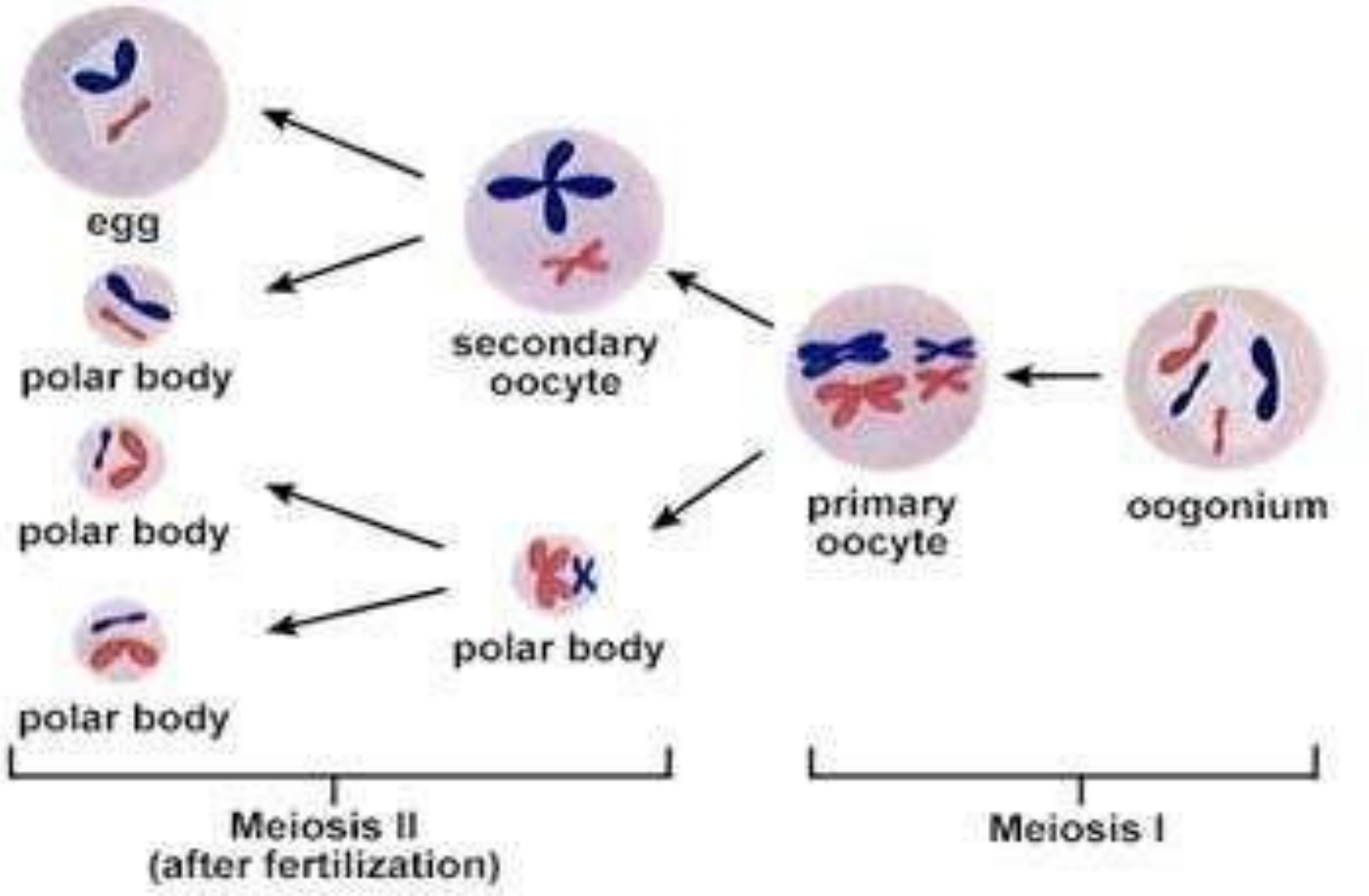
Spermatogenesis



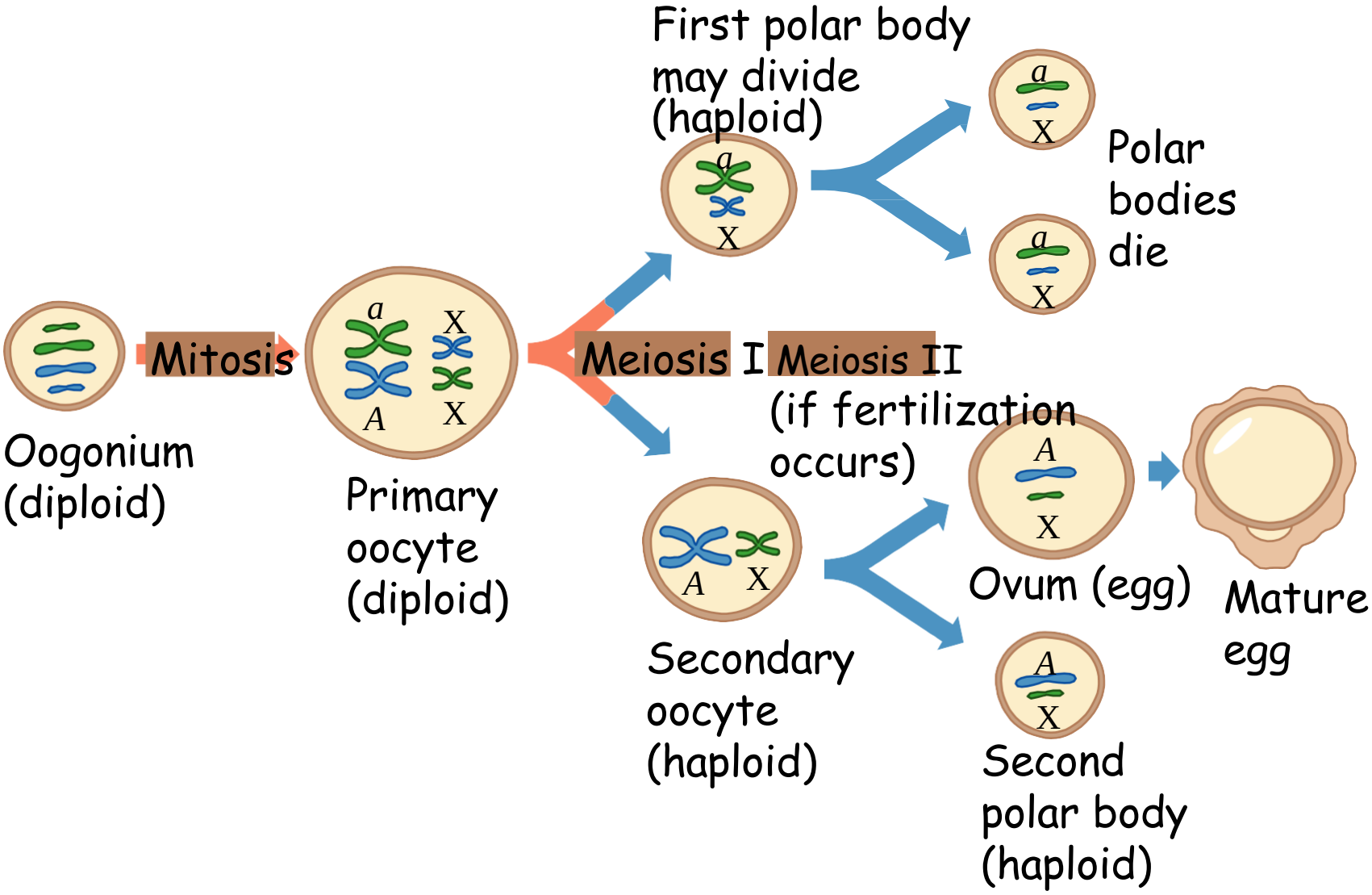
Oogenesis

- ✓ Occurs in the ovaries
- ✓ Two divisions produce 3 polar bodies that die and 1 egg
- ✓ Polar bodies die because of unequal division of cytoplasm
- ✓ Immature egg called oocyte
- ✓ Starting at puberty, one oocyte matures into an ovum (egg) every 28 days

Oogenesis in the Ovaries

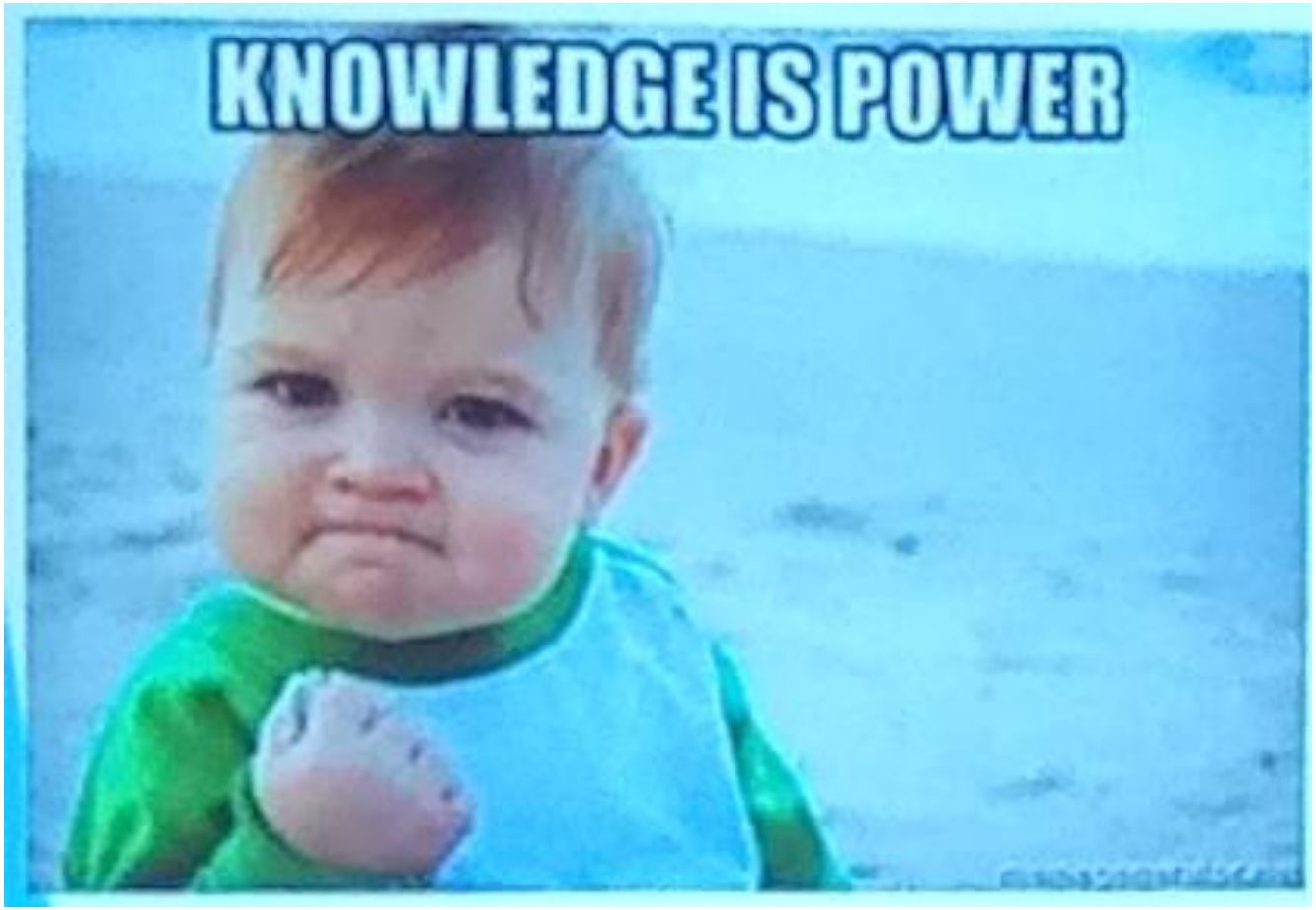


Oogenesis


First polar body may divide (haploid)
a
X
Polar bodies die
a
X
a
X
Mitosis
a
X
A
X
Meiosis I
Meiosis II
(if fertilization occurs)
Oogonium (diploid)
Primary oocyte (diploid)
A
X
A
X
Ovum (egg)
Mature egg
Secondary oocyte (haploid)
A
X
Second polar body (haploid)

Comparing Mitosis and Meiosis

Comparison of Divisions

	Mitosis	Meiosis
Number of divisions	1	2
Number of daughter cells	2	4
Genetically identical?	Yes	No
Chromosome #	Same as parent	Half of parent
Where	Somatic cells	Germ cells
When	Throughout life	At sexual maturity
Role	Growth and repair	Sexual reproduction

Thank you for attention