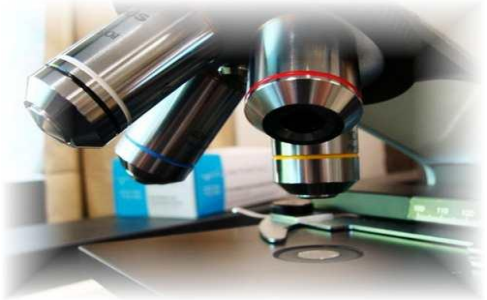


College of Science
Biology Dept.
Zoology

•Cell Cycle and cell Division

•Prof. Dr. Mohammed Qais

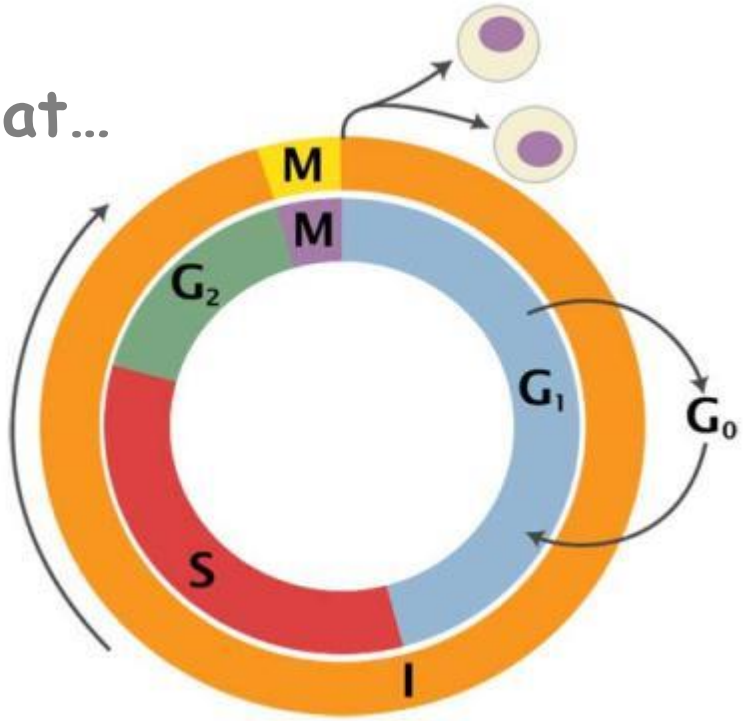
Eukaryotic Cell Cycle

Like prokaryotic cell cycle, in that…

- Cell grows.

- DNA is replicated.

- Mitotic cell division produces daughter cell identical to the parent.

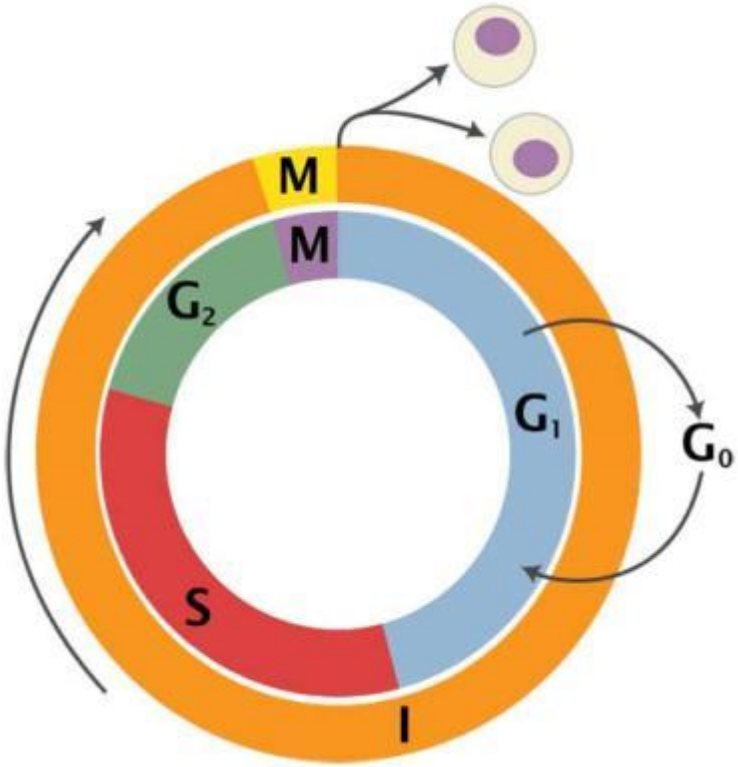


Different from prokaryotic cell cycle, in that…

- Eukaryotic cells have more DNA on many linear chromosomes.
(Q: How many do humans have?).

- The timing of replication and cell division is highly regulated.

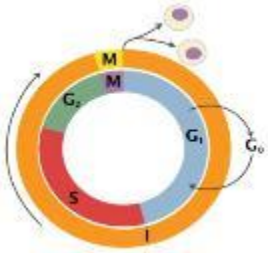
Eukaryotic Cell Cycle



2 major phases:

- (3 stages)
  - DNA uncondensed

- (4 phases + cytokinesis)
  - Nuclear division & division of cytoplasm
  - DNA condensed



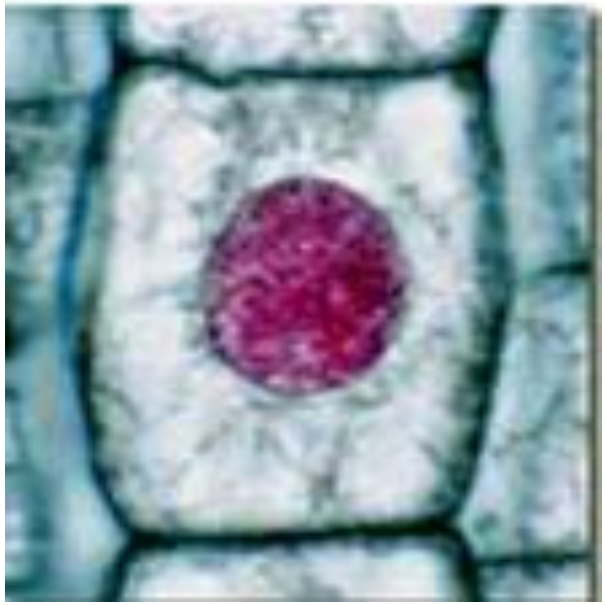
Interphase

Non-dividing state With 3 sub-stages:

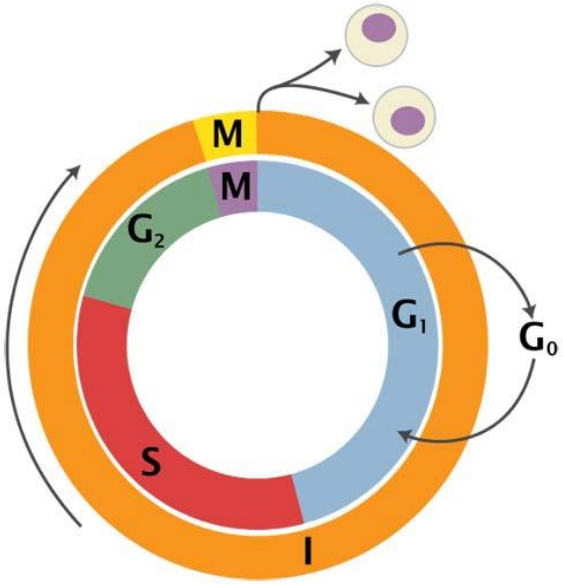
___ – cell grows in size

___ – replication of DNA
And organelles

___ – synthesis of proteins



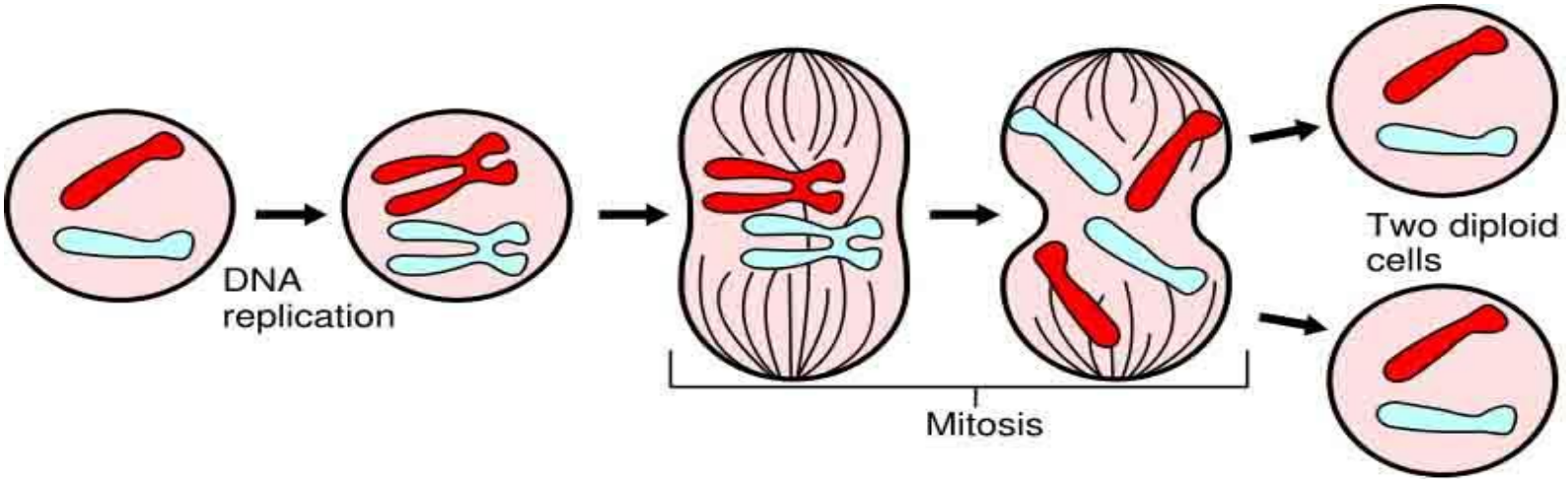
Mitosis



Division of **somatic** cells (non-reproductive cells) in eukaryotic organisms.

A single cell divides into two identical daughter cells.

Daughter cells have same # of chromosomes as does parent cell.



Packing for the move…

When cell is not dividing…

- DNA molecules in extended, uncondensed form = **chromatin**

- Cell can only replicate and transcribe DNA when in extended state.

When cell is preparing for division…

- DNA molecules condense to form **chromosomes** prior to division.

– each chromosome is a single molecule of DNA

– easier to sort and organize the replicated DNA into daughter cells

Mitosis

4 sub-phases:

1st – Prophase

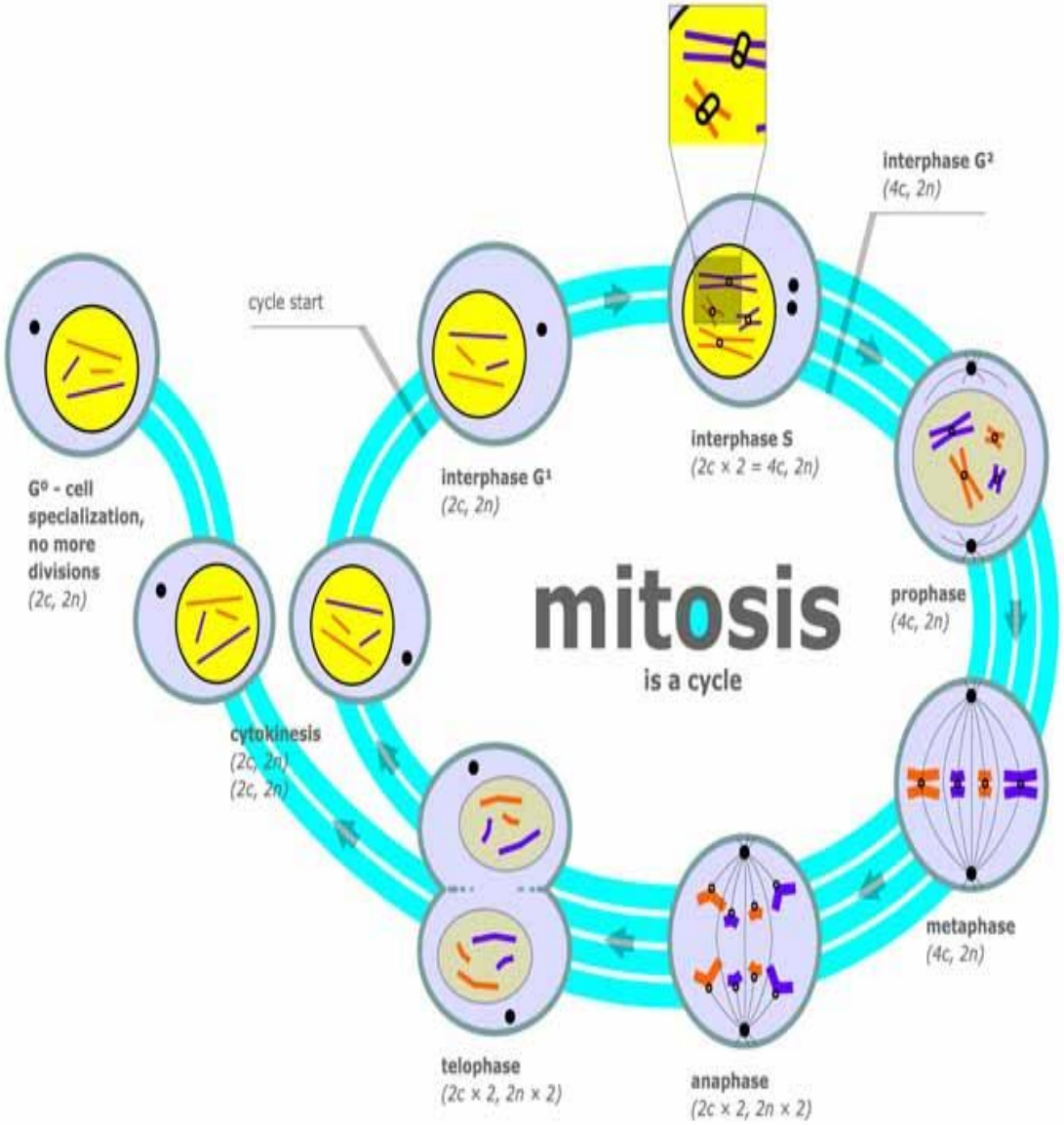
2nd – Metaphase

3rd – Anaphase

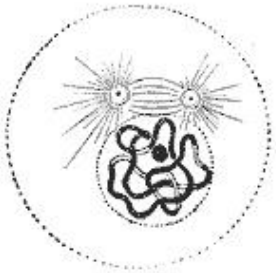
4th – Telophase

followed by

Cytokinesis



Secret to remembering phases in order…



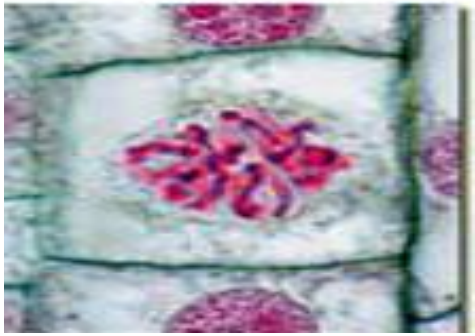
1. Prophase

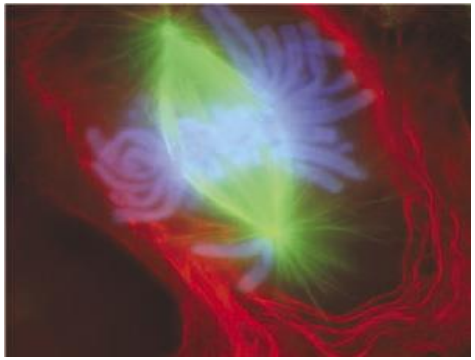
3 Major Events

- chromosomes condense

- spindle fibers form
  (spindle fibers are specialized microtubules radiating out from centrioles)

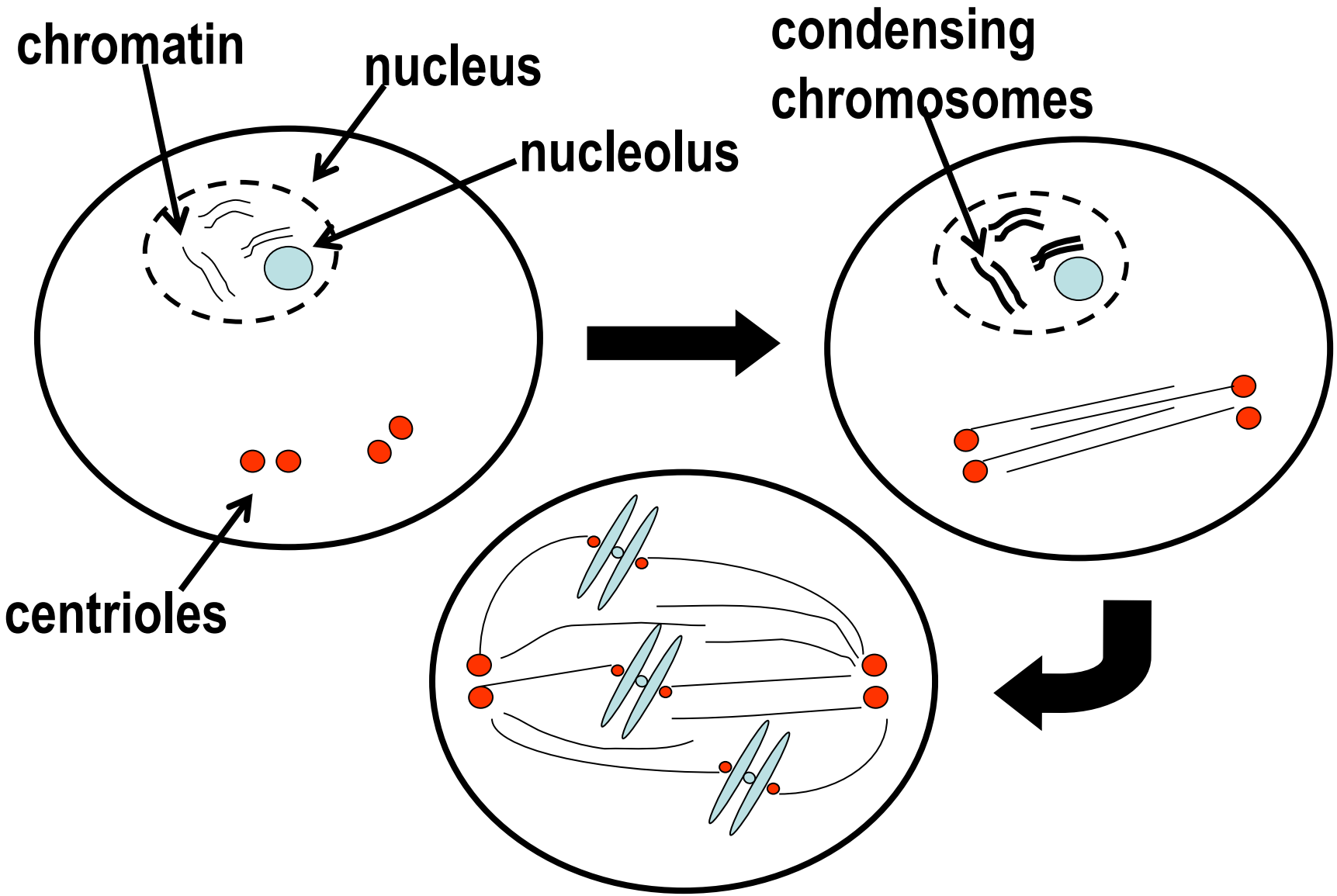
- chromosomes are captured by spindle

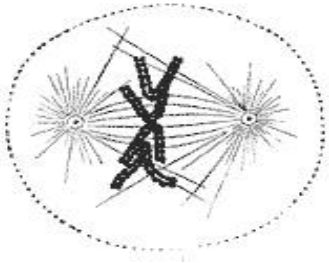




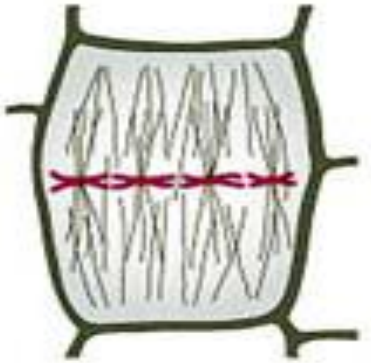
Fluoresced eukaryotic cell. Chromosomes in blue. Mitotic spindle apparatus in green.

Prophase

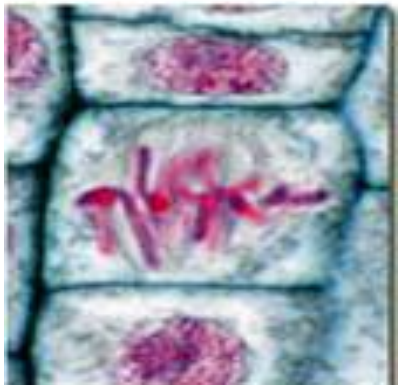

chromatin
nucleus
nucleolus
condensing
chromosomes
centrioles

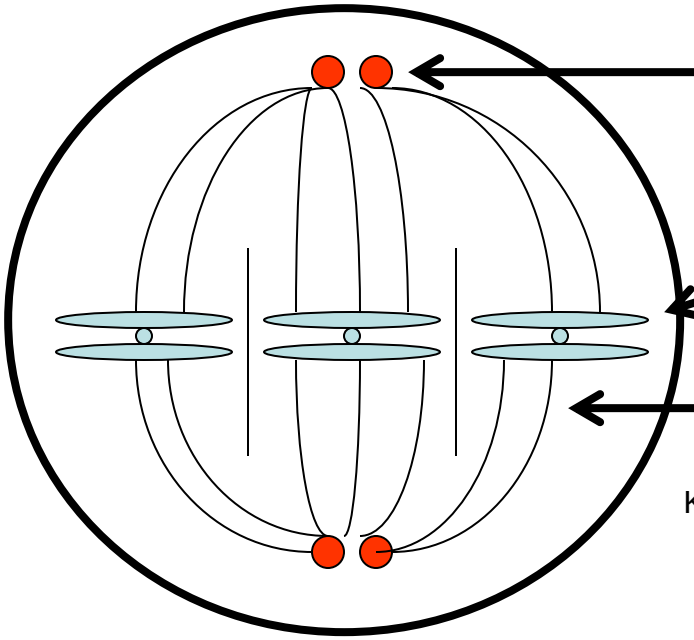


2. Metaphase

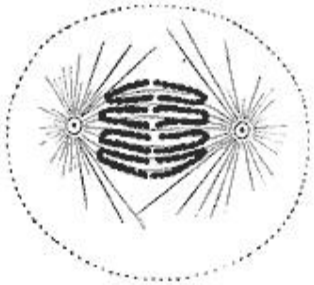


- chromosomes align along equator of the cell, with one kinetochore facing each pole

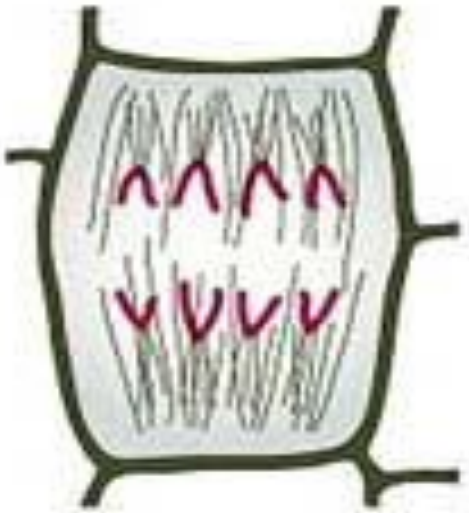




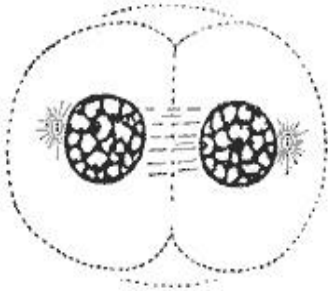
Kinetocores not pictured in this illustration.



3. Anaphase



- sister chromatids separate
- spindle fibers attached to kinetochores **shorten** and **pull** chromatids towards the poles.
- free spindle fibers **lengthen** and **push** poles of cell apart



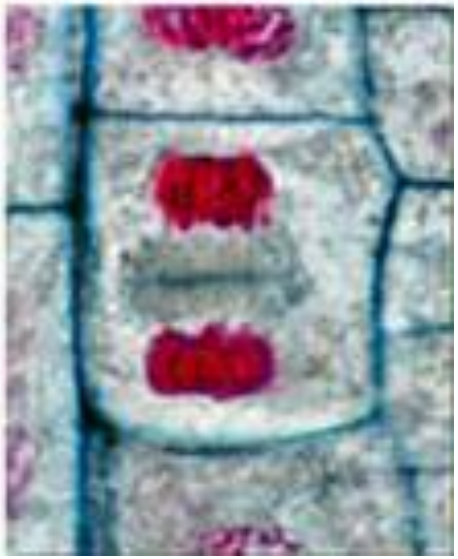
4. Telophase

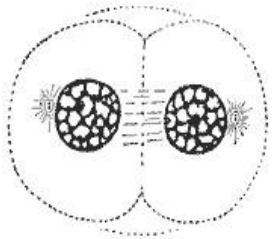
- spindle fibers disintegrate

- nuclear envelopes form around both groups of chromosomes

- chromosomes revert to their extended state

- cytokinesis occurs, enclosing each daughter nucleus into a separate cell



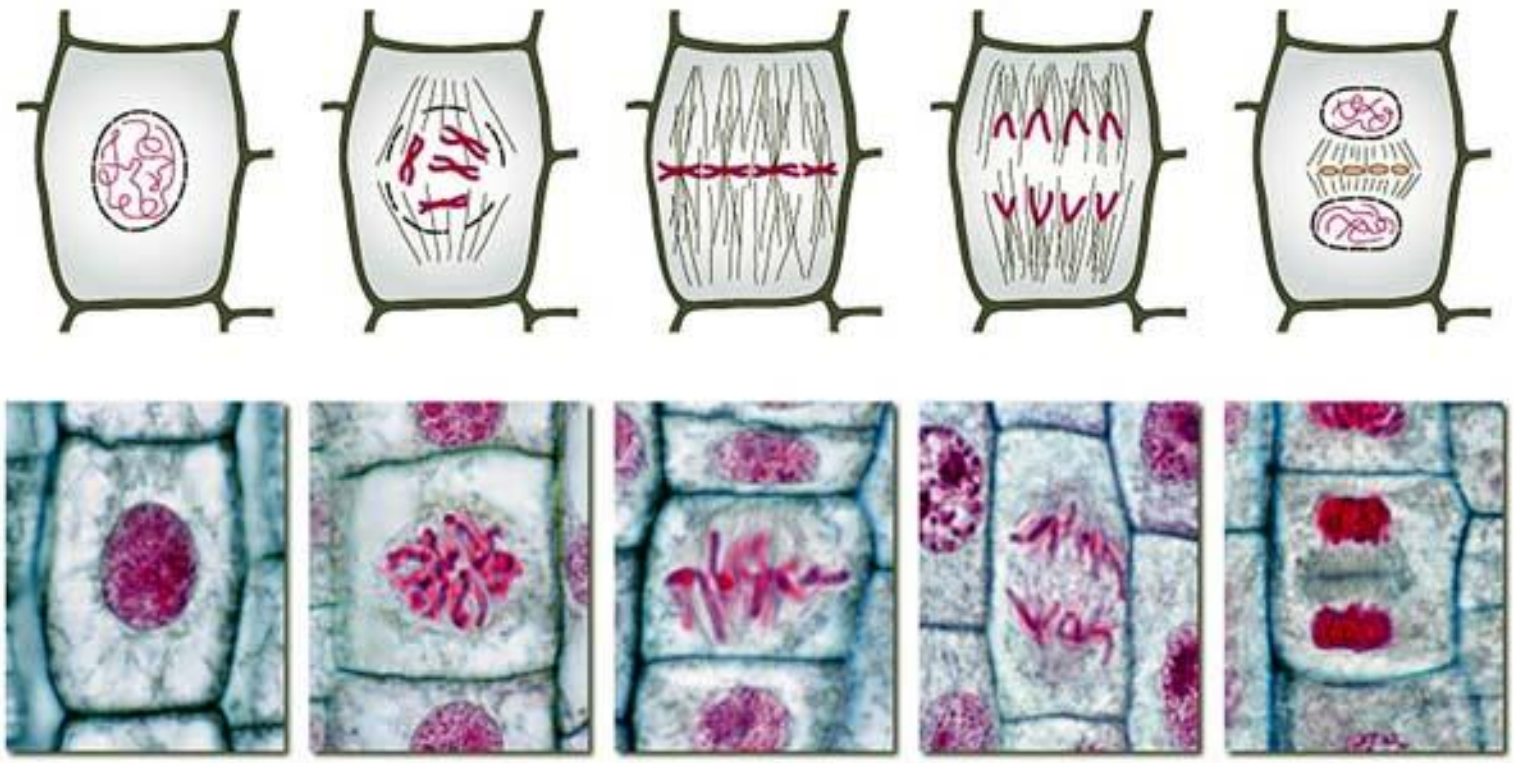


Cytokinesis – Plant vs. Animal Cell

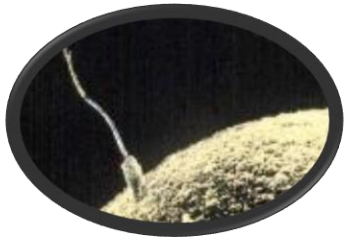
- **Plant cells** undergo cytokinesis by forming a cell plate between the two daughter nuclei.

- **Animal cells** undergo cytokinesis through the formation of a cleavage furrow. A ring of microtubules contract, pinching the cell in half.

Stages of Mitosis



Genetics Terminology



Sexually reproducing eukaryotes, have 2 types of body cells…

1. **somatic cells**

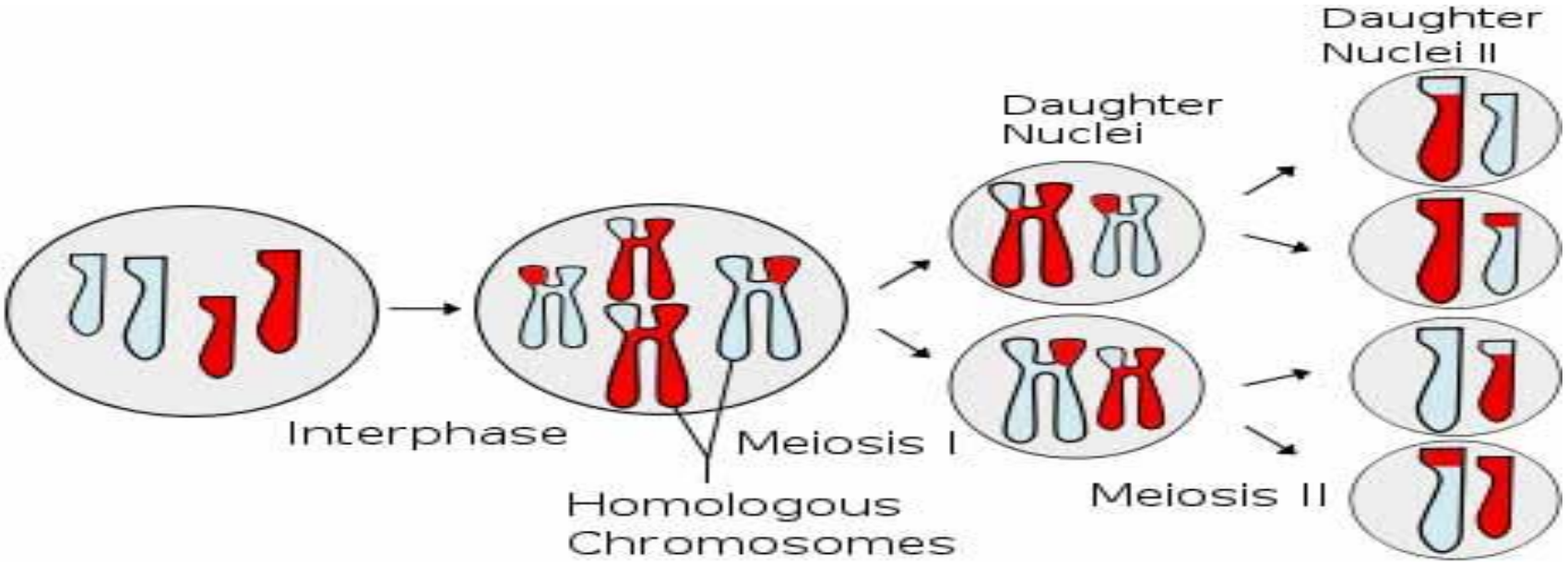
2. **sex cells**
   (. gametes)

What is cell division of gametes called?

Meiosis

- A single germ cell divides into four unique daughter cells.

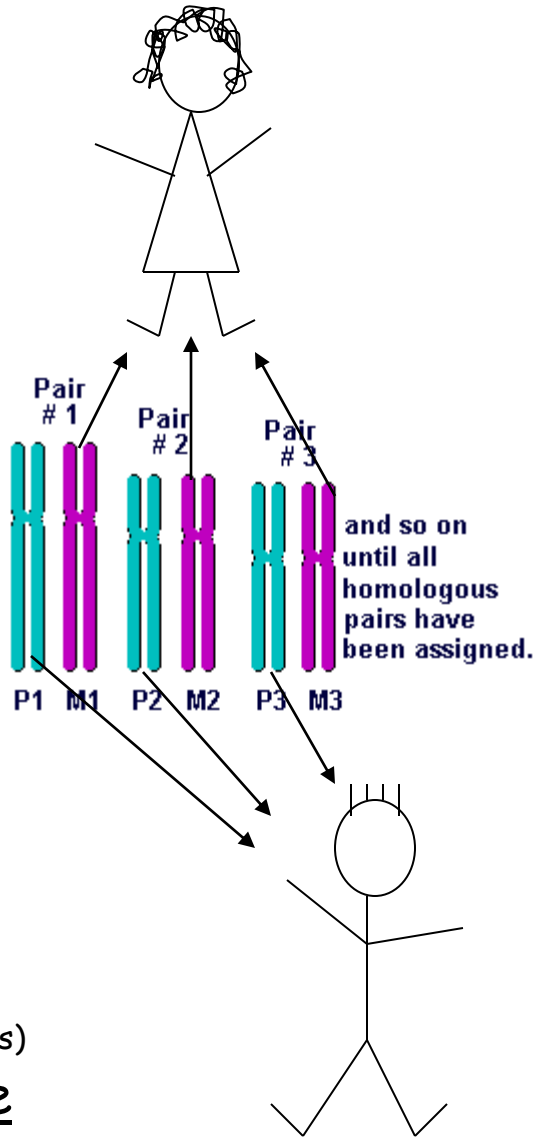
- Daughter cells have half the # of chromosomes as parent cell, so they considered **haploid**.



Genetics Terminology: Ploidy

Refers to the number of sets of chromosomes in cells.

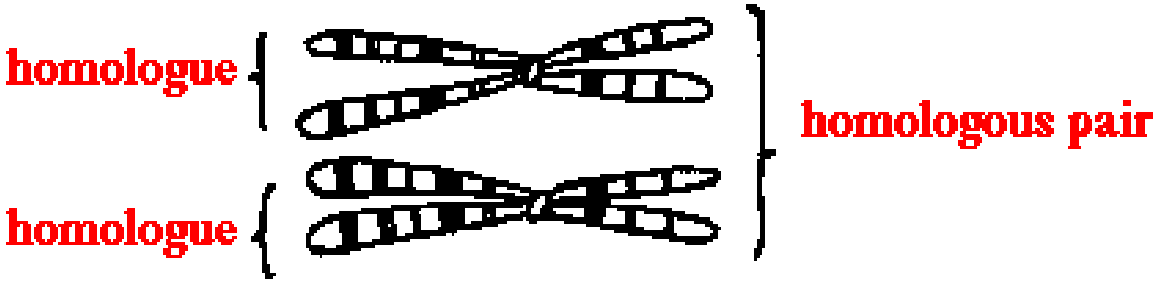
- **Haploid** – one copy of each chromosome
  - designated as "n", the number of chromosomes in one "set"
  - gametes
- **Diploid** – two sets of chromosomes
  - two of each chromosome
  - designated as "2n"
  - somatic cells



Diploid organisms receive one of each type of chromosome from female parent (maternal chromosomes) and one of each type of chromosome from male parent (paternal chromosomes)

Genetics Terminology: Homologues

Chromosomes exist in homologous pairs in diploid (2n) cells.

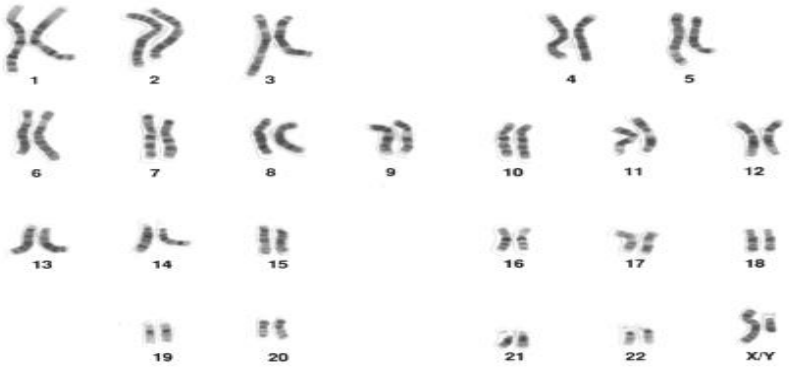


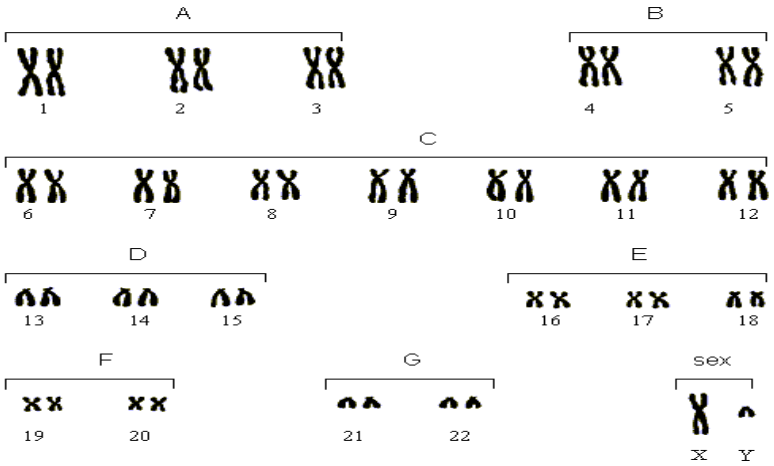
Exception: **Sex chromosomes** (X, Y).

Other chromosomes, known as **autosomes**, they have homologues.

Karyotype

- Q: Which, of the top two karyotypes is replicated?
- Q: How many homologous pair in each karyotype?
- Q: How is the bottom karyotype different from the top two?

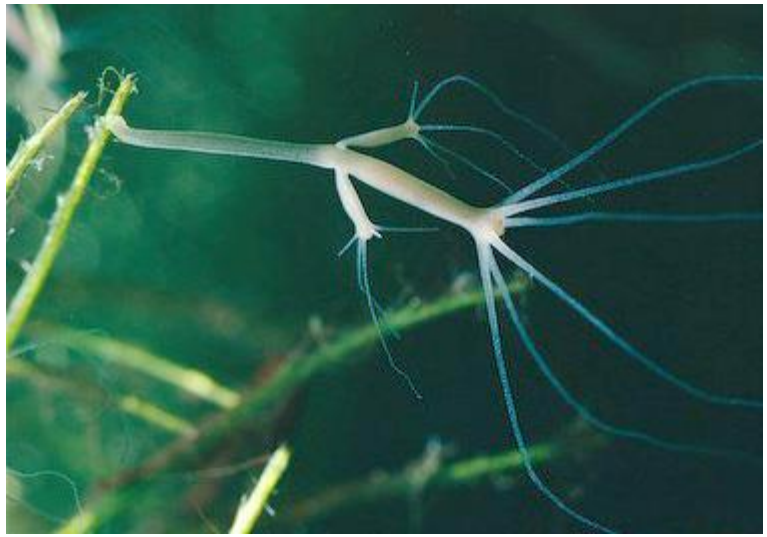




Asexual Reproduction

- Many single-celled organisms reproduce by splitting, budding.

- Some multicellular organisms can reproduce asexually, produce **clones** (*offspring genetically identical to parent*).



Sexual Reproduction

- Fusion of two **gametes** to produce a single zygote.
- Introduces greater genetic variation, allows genetic recombination.
- With exception of self-fertilizing organisms, zygote has gametes from two different parents.

Sexual reproduction in humans …

- At fertilization, 23 chromosomes are donated by each parent.
  (total = 46 or 23 pairs).

- **Gametes** (sperm/ova):
  - Contain 22 autosomes and 1 sex chromosome.
  - Are haploid (haploid number *"n" = 23 in humans*).

- Fertilization results in diploid zygote.
  - Diploid cell; *2n = 46.* (*n = 23 in humans*)

- **Q**: Most cells in the body are produced through what type of cell division?

- Only gametes are produced through **meiosis**.

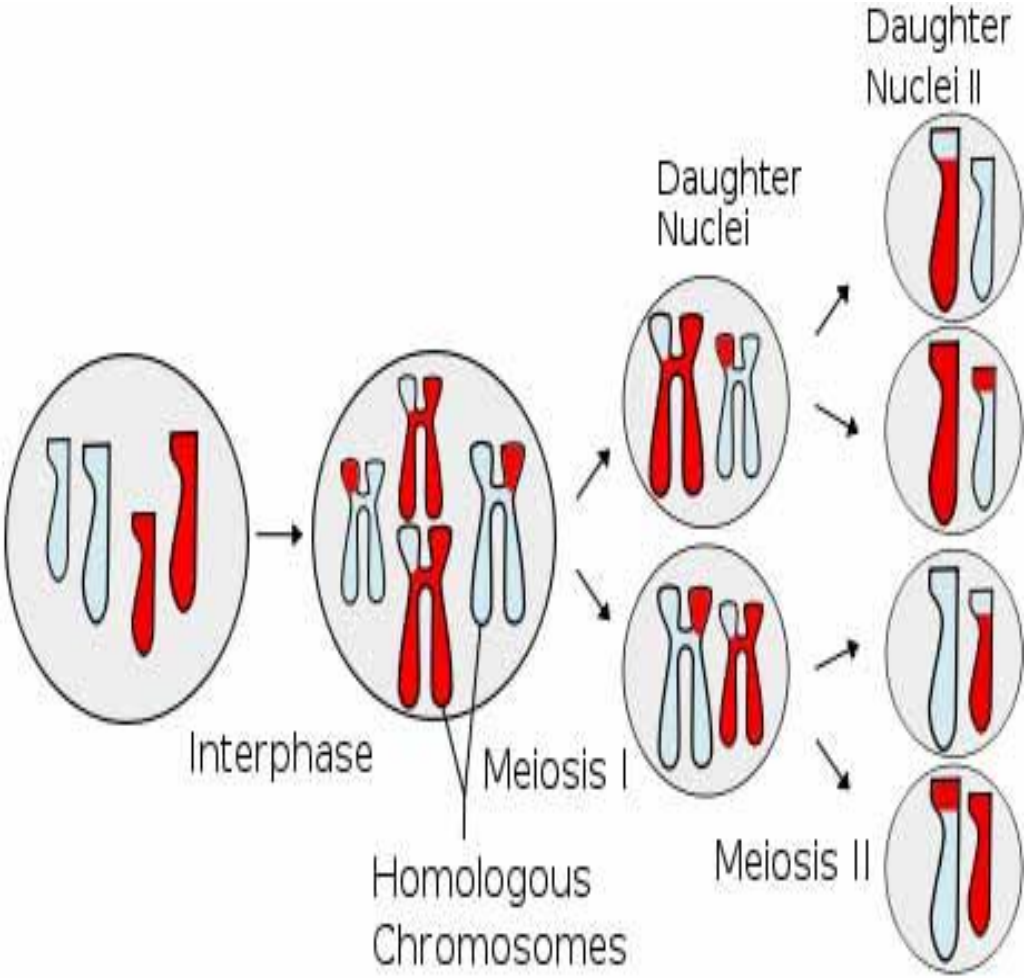
Meiosis - Sex Cell (Gamete) Formation

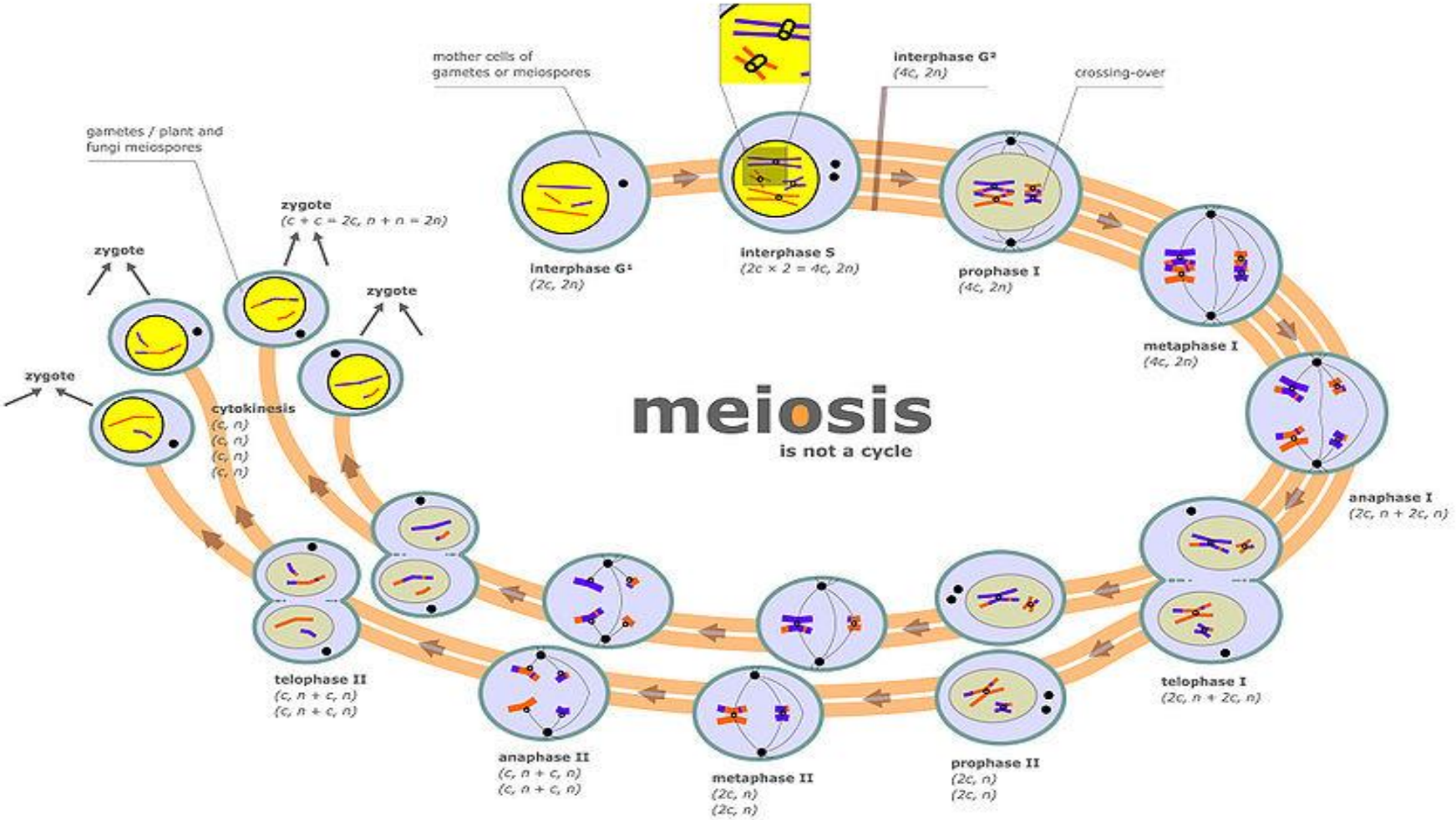
In meiosis, there are **2** divisions of the nucleus:

meiosis I

&

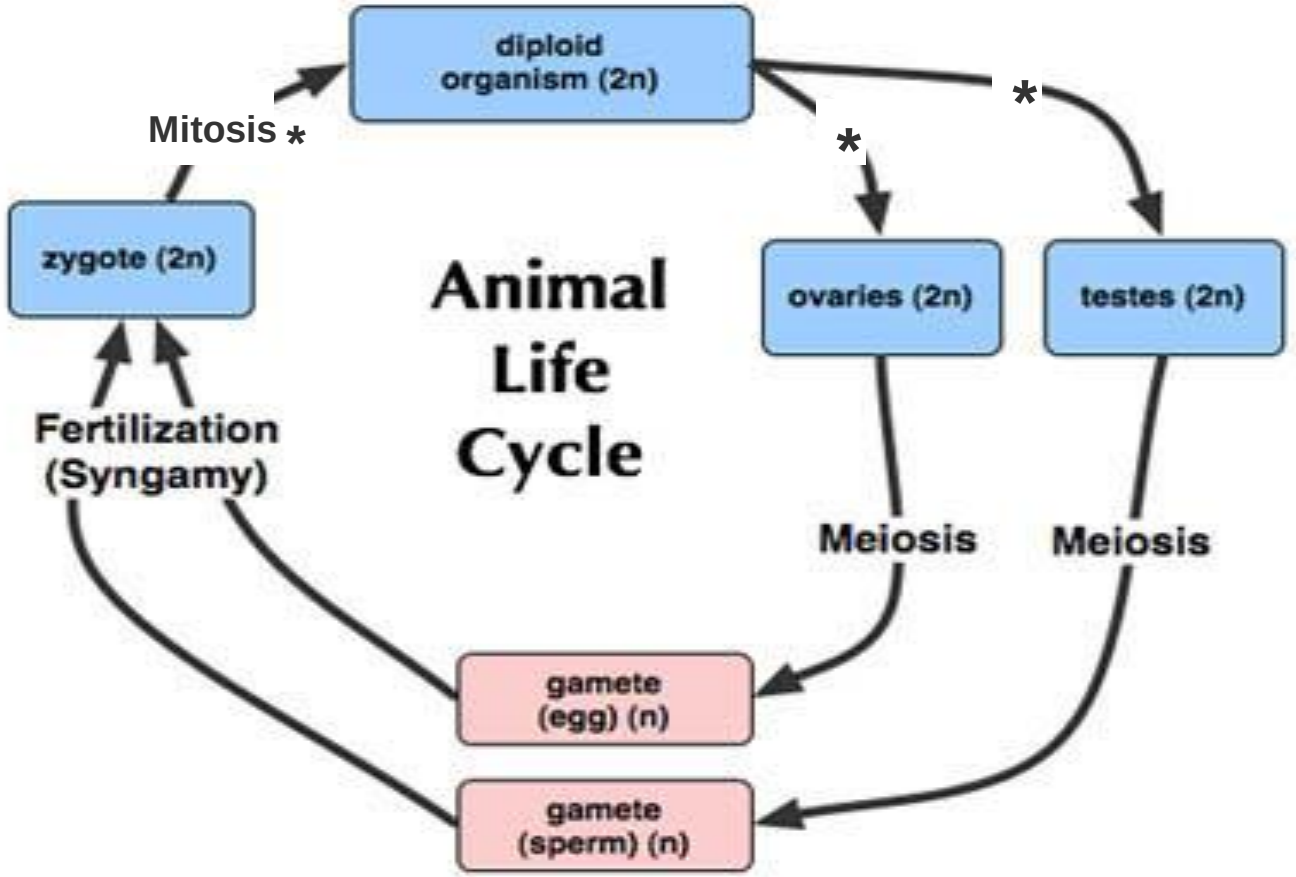
meiosis II




mother cells of
gametes or meiospores
interphase G²
(4c, 2n)
crossing-over
gametes / plant and
fungi meiospores
zygote
(c + c = 2c, n + n = 2n)
zygote
zygote
zygote
interphase G¹
(2c, 2n)
interphase S
(2c × 2 = 4c, 2n)
prophase I
(4c, 2n)
metaphase I
(4c, 2n)
meiosis
is not a cycle
cytokinesis
(c, n)
(c, n)
(c, n)
(c, n)
anaphase I
(2c, n + 2c, n)
telophase II
(c, n + c, n)
(c, n + c, n)
telophase I
(2c, n + 2c, n)
anaphase II
(c, n + c, n)
(c, n + c, n)
metaphase II
(2c, n)
(2c, n)
prophase II
(2c, n)
(2c, n)

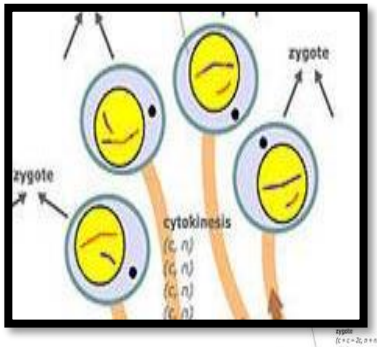
Meiosis & Sexual Reproduction

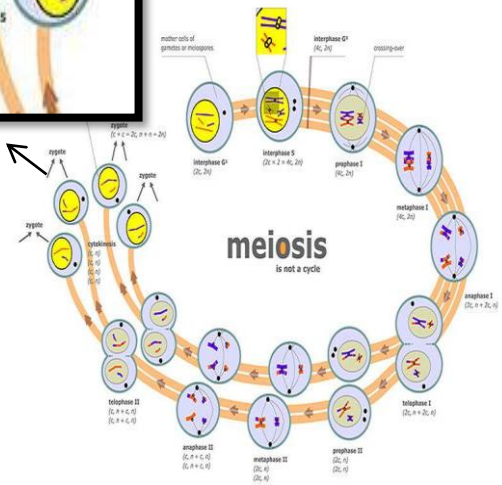
Life Cycle



Genetic Variation in Diploid Organisms

- Fusion of sperm and egg results in unique offspring.
- But not only because the young are a product of two individuals with different genetic makeup.
- Meiosis "shuffles" the genes so that the an individual's gametes are genetically different from one another.





How is this shuffling accomplished?

Genetic shuffling of Meiosis I

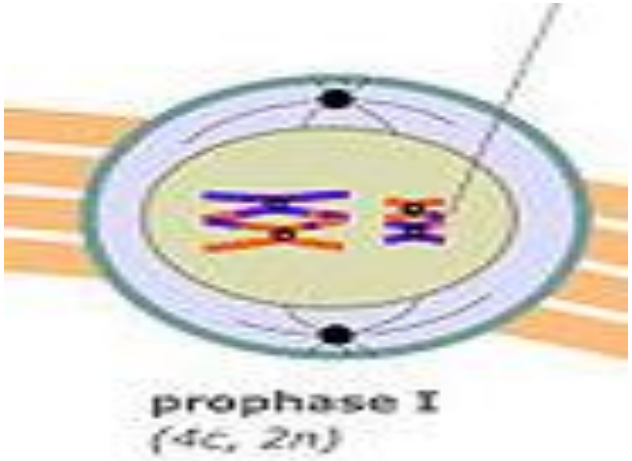
In addition to a new combination of chromosomes resulting from **fertilization**, there are also events in Meiosis I that shuffle the genes.

1. **Crossing over** in Prophase I.

2. **Independent assortment** in Metaphase I.

Crossing Over

- Homologues break at identical locations, then rejoin opposite partners.
- This creates new combinations of the alleles on each chromosome.
- Occurs randomly several times on every chromosome.
- Results in mixing of the genes you inherited from your parents.



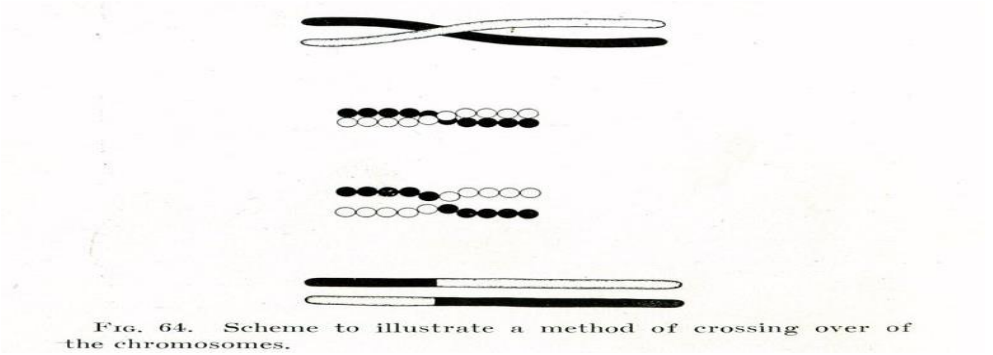
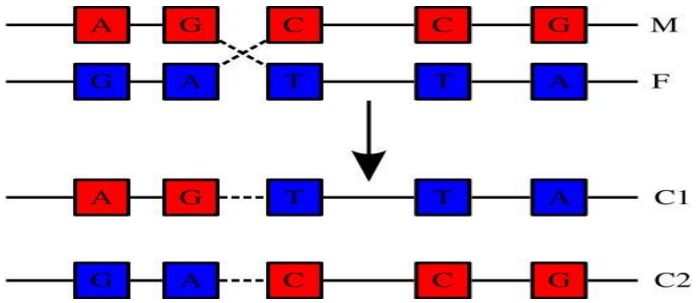
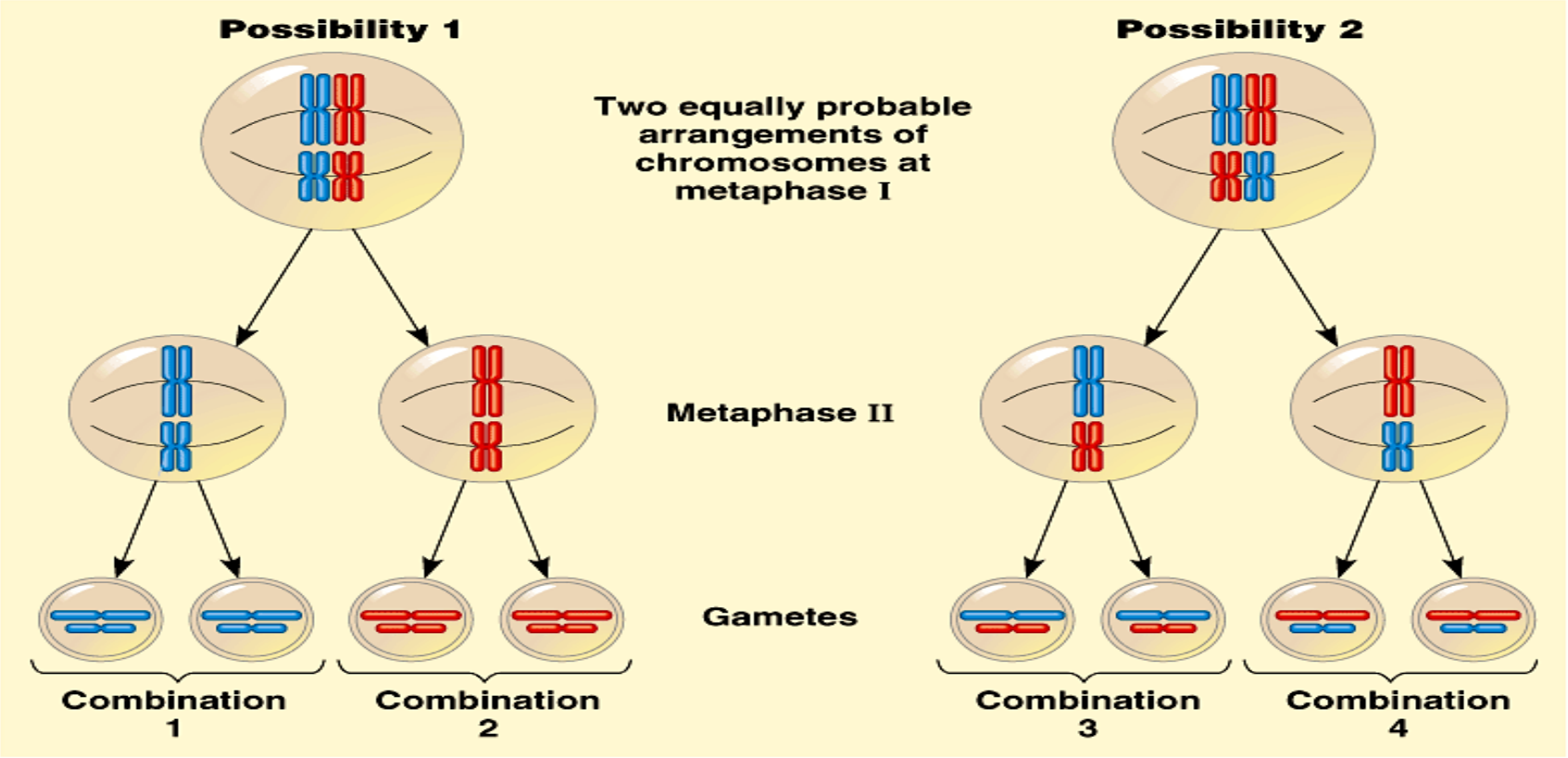


FIG. 64. Scheme to illustrate a method of crossing over of the chromosomes.

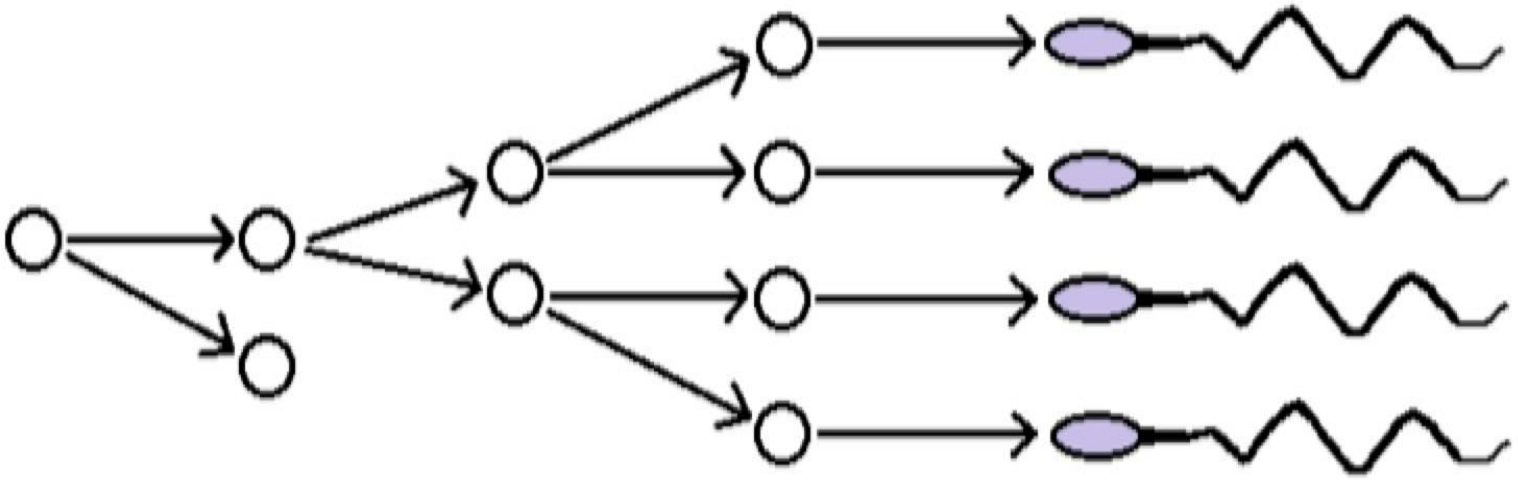


Independent Assortment



Spermatogenesis

Males produce sperm throughout life, after the onset of puberty, about 1,500 sperm per second.



Spermatogonium *Spermatocyte I* *Spermatocyte II* *Spermatid* *Spermatozoa*

Clark et al. (2004)
Eguizabel et al. (2011)

Easley et al. (2012)

Gejisen et al. (2004)

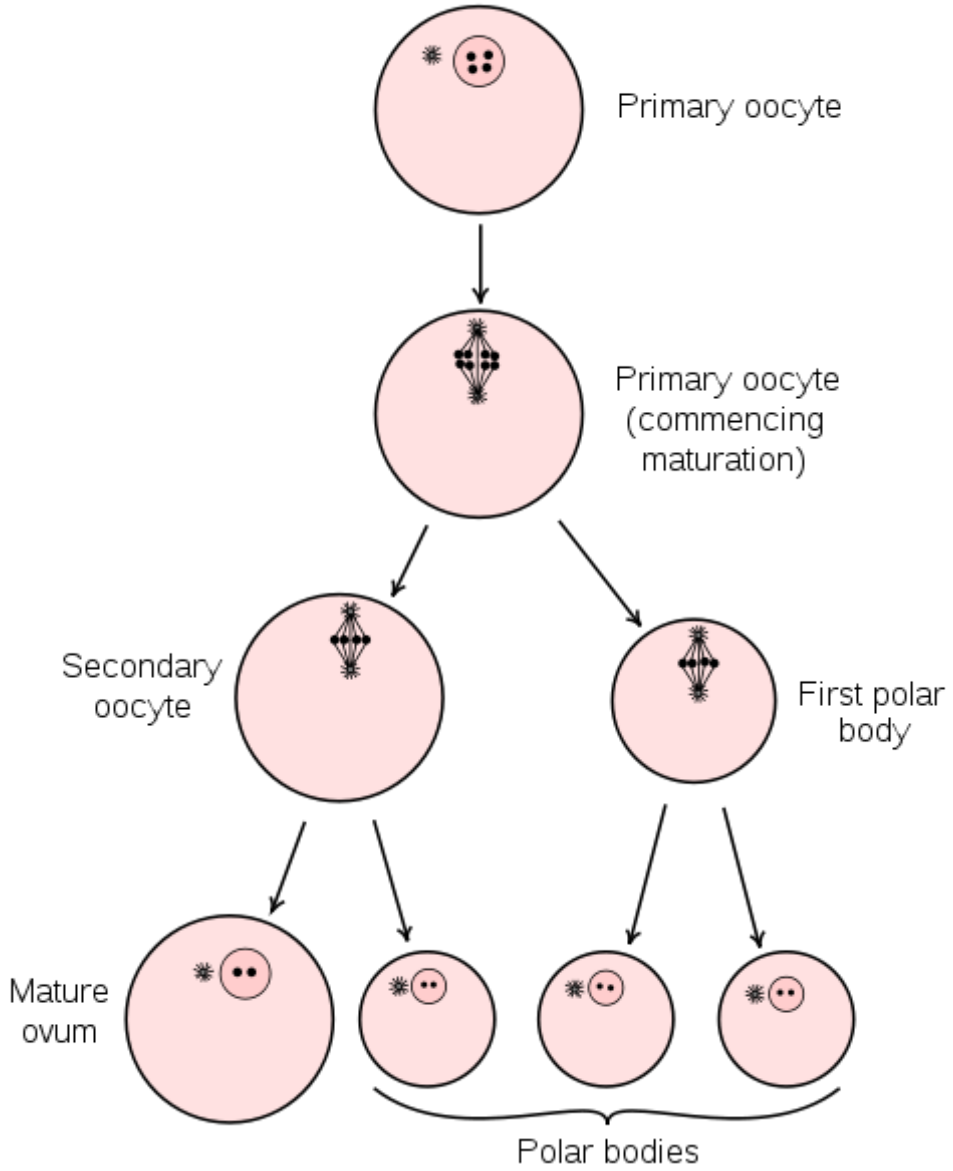
Hayashi et al. (2011)
Toyooka et al. (2003)

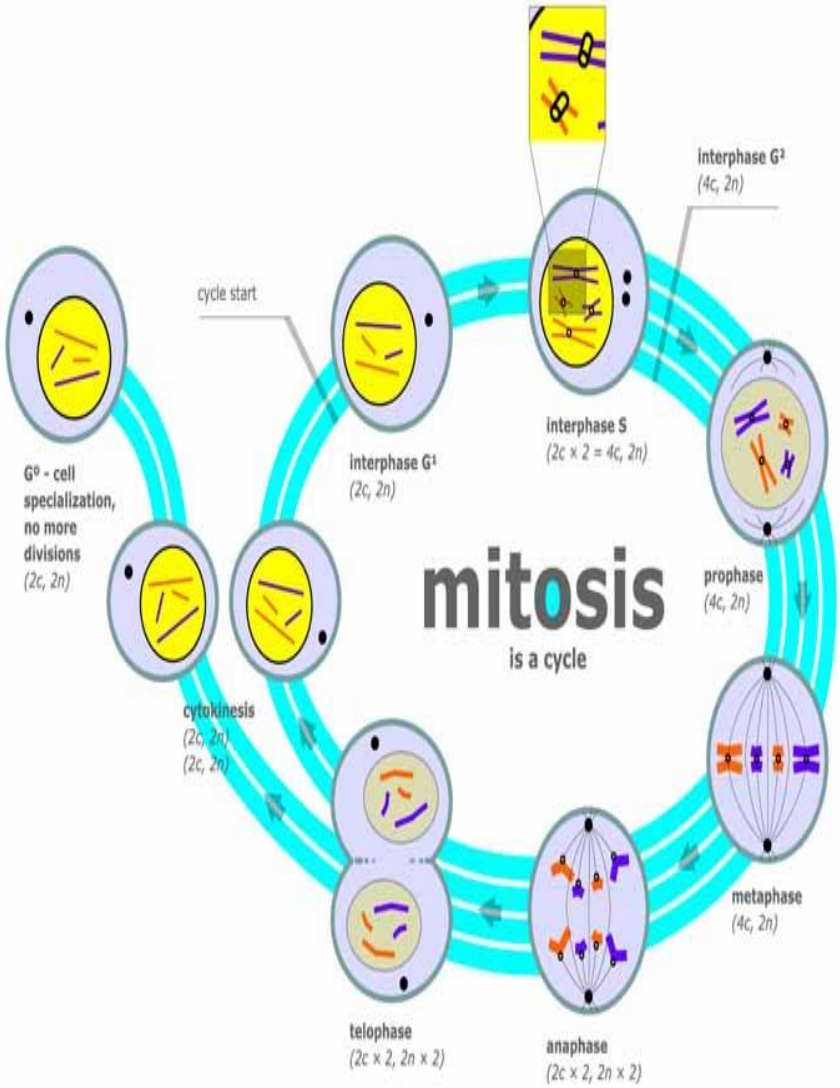
Oogenesis

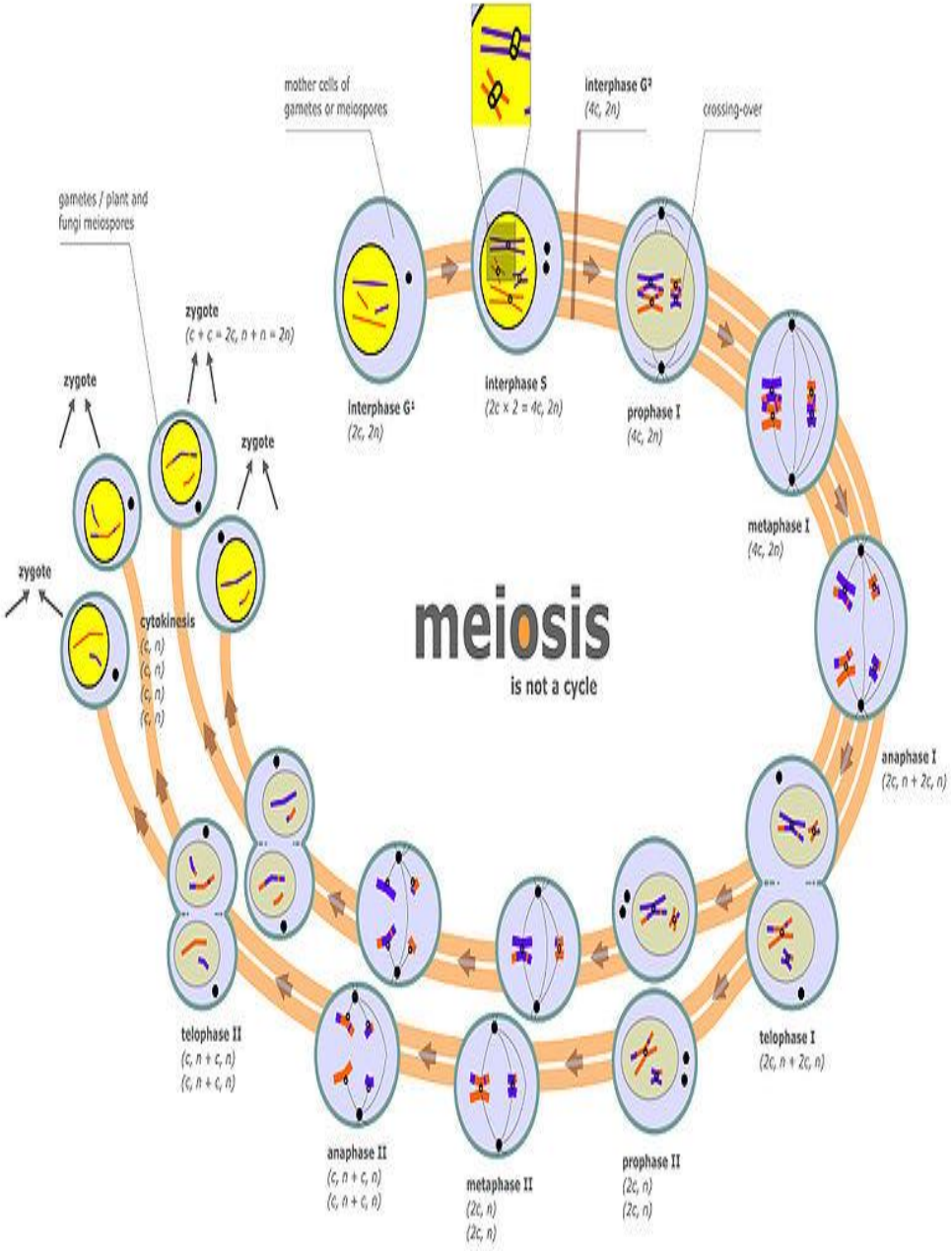
Oogenesis in females is probably complete either before or shortly after birth.

During oogenesis, three polar bodies develop as the mature ovum is generated.

Polar bodies contain little cytoplasm and eventually degenerate.



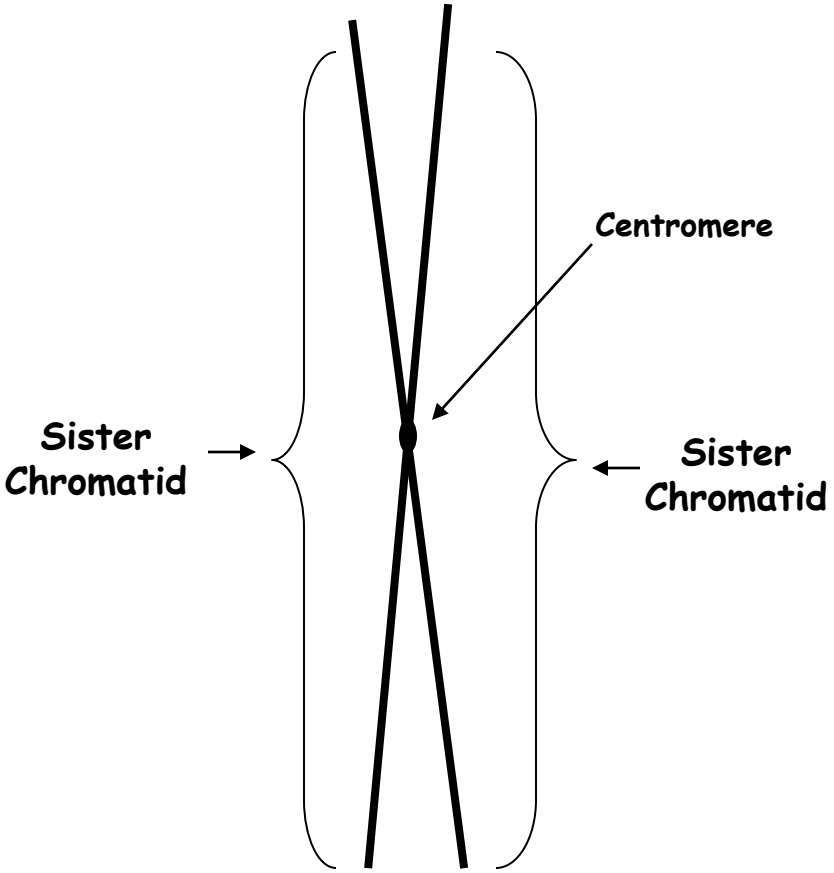

mitosis
is a cycle
cycle start
G⁰ - cell specialization, no more divisions
(2c, 2n)
interphase G¹
(2c, 2n)
interphase S
(2c × 2 = 4c, 2n)
interphase G²
(4c, 2n)
prophase
(4c, 2n)
metaphase
(4c, 2n)
anaphase
(2c × 2, 2n × 2)
telophase
(2c × 2, 2n × 2)
cytokinesis
(2c, 2n)
(2c, 2n)


meiosis
is not a cycle
mother cells of gametes or meiospores
interphase G¹
(2c, 2n)
interphase S
(2c × 2 = 4c, 2n)
interphase G²
(4c, 2n)
crossing-over
prophase I
(4c, 2n)
metaphase I
(4c, 2n)
anaphase I
(2c, n + 2c, n)
telophase I
(2c, n + 2c, n)
prophase II
(2c, n)
(2c, n)
metaphase II
(2c, n)
(2c, n)
anaphase II
(c, n + c, n)
(c, n + c, n)
telophase II
(c, n + c, n)
(c, n + c, n)
cytokinesis
(c, n)
(c, n)
(c, n)
(c, n)
gametes / plant and fungi meiospores
zygote
(c + c = 2c, n + n = 2n)
zygote
zygote
zygote

Drawing and Labeling Chromosomes

Unreplicated
Uncondensed
Chromosome

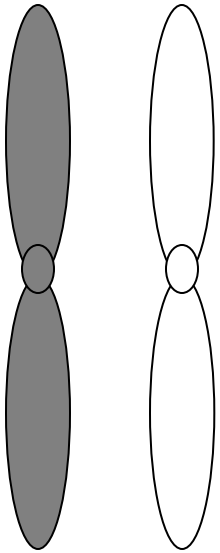
(chromatin)



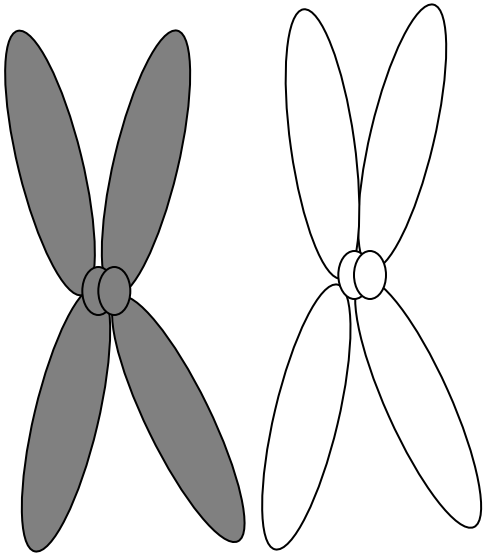
Replicated
Uncondensed
Chromosome

(chromatin)

Drawing & Labeling Homologous Chromosomes



Unreplicated, Condensed, Homologous Chromosomes



Replicated, Condensed, Homologous Chromosomes