

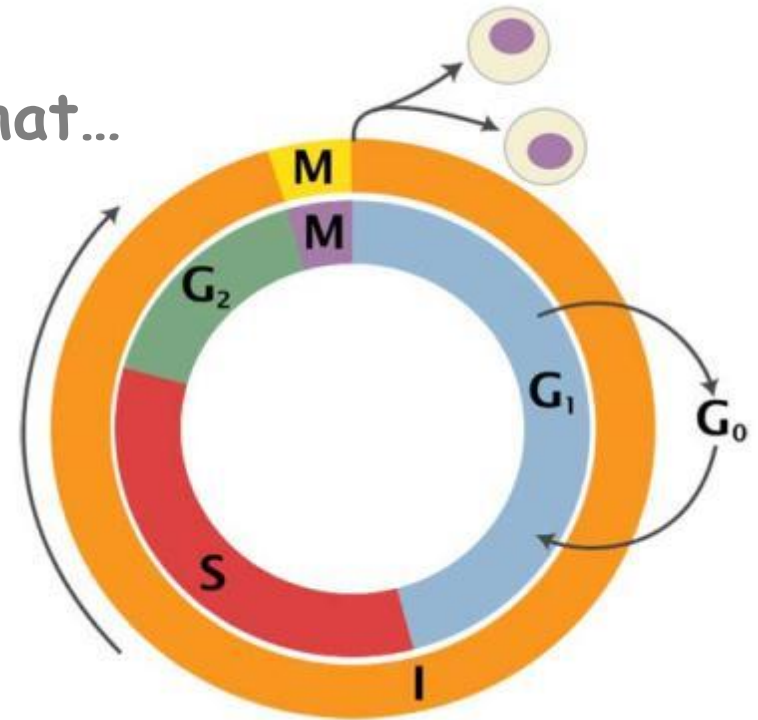
Cell Division

Mitosis & Meiosis

Eukaryotic Cell Cycle

Like prokaryotic cell cycle, in that...

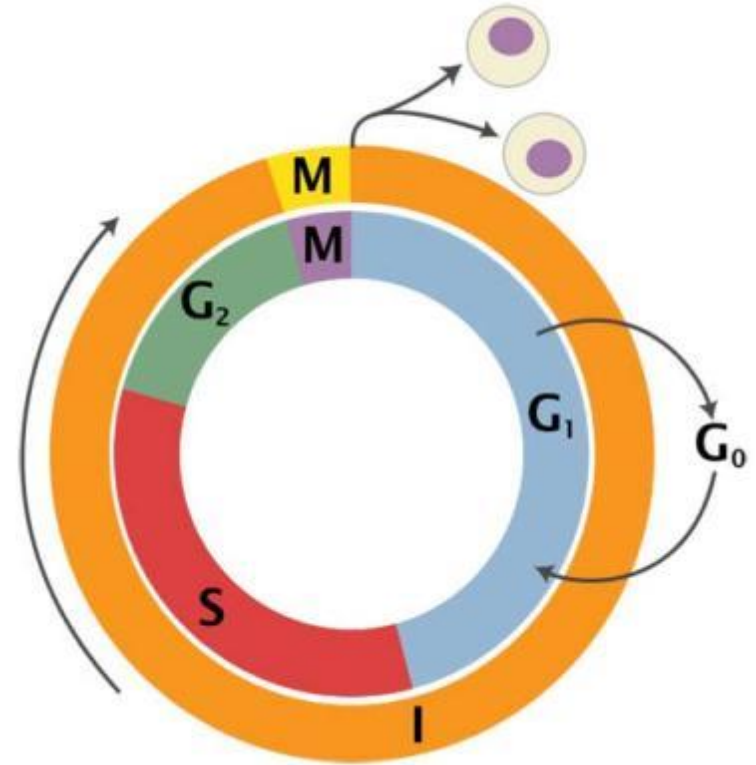
- Cell grows.
- DNA is replicated.
- Mitotic cell division produces daughter cell identical to the parent.
- The timing of replication and cell division is highly regulated.

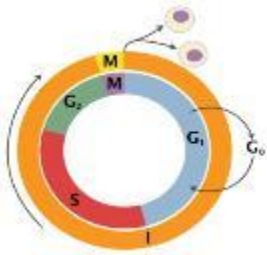


Eukaryotic Cell Cycle

2 major phases:

- **Interphase** (3 stages)
 - DNA uncondensed
- **Mitosis** (4 stages + cytokinesis)
 - Nuclear division & division of cytoplasm
 - DNA condensed





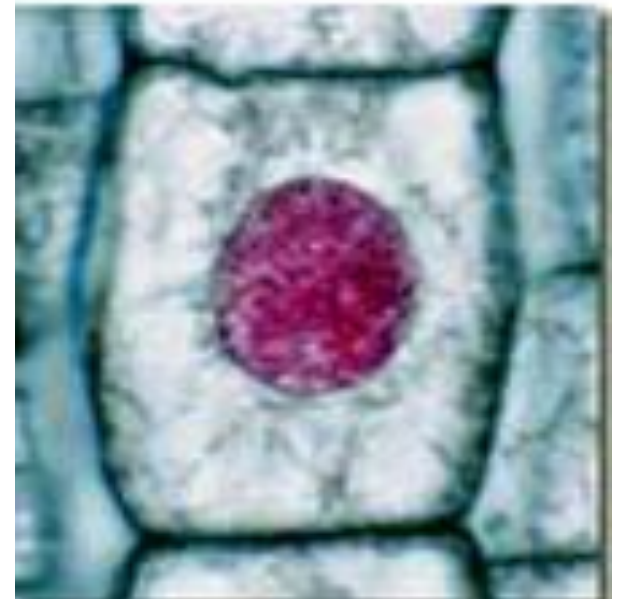
Interphase

Non-dividing state
With 3 sub-stages:

Gap 1 - cell grows in size
- organelles replicated

Synthesis - replication of DNA
- synthesis of proteins
associated with DNA

Gap 2 - synthesis of proteins
associated with mitosis

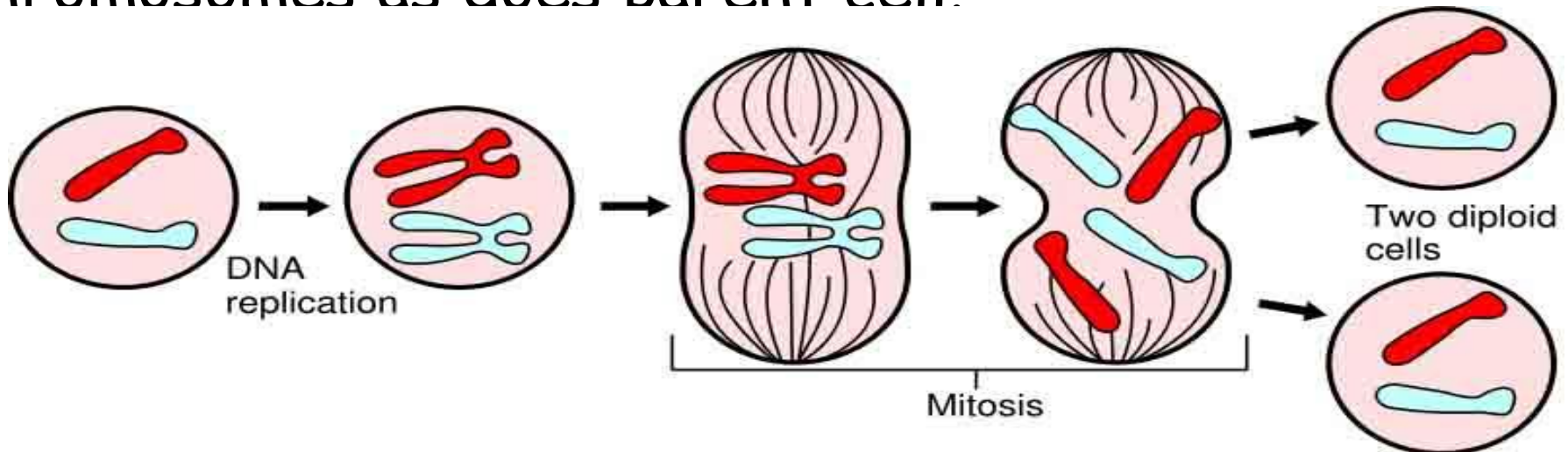
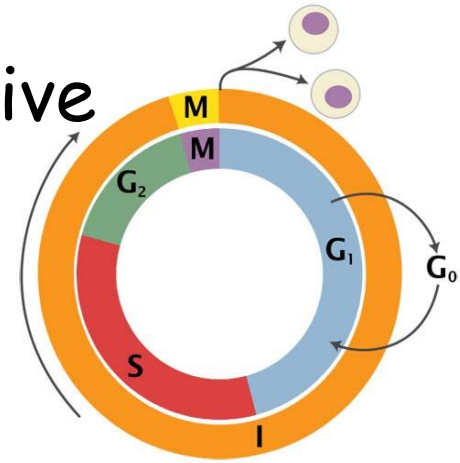


Mitosis

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



Dude, mitosis starts in five minutes...
I can't believe you're not condensed yet.

Mitosis

4 sub-phases:

1st - Prophase

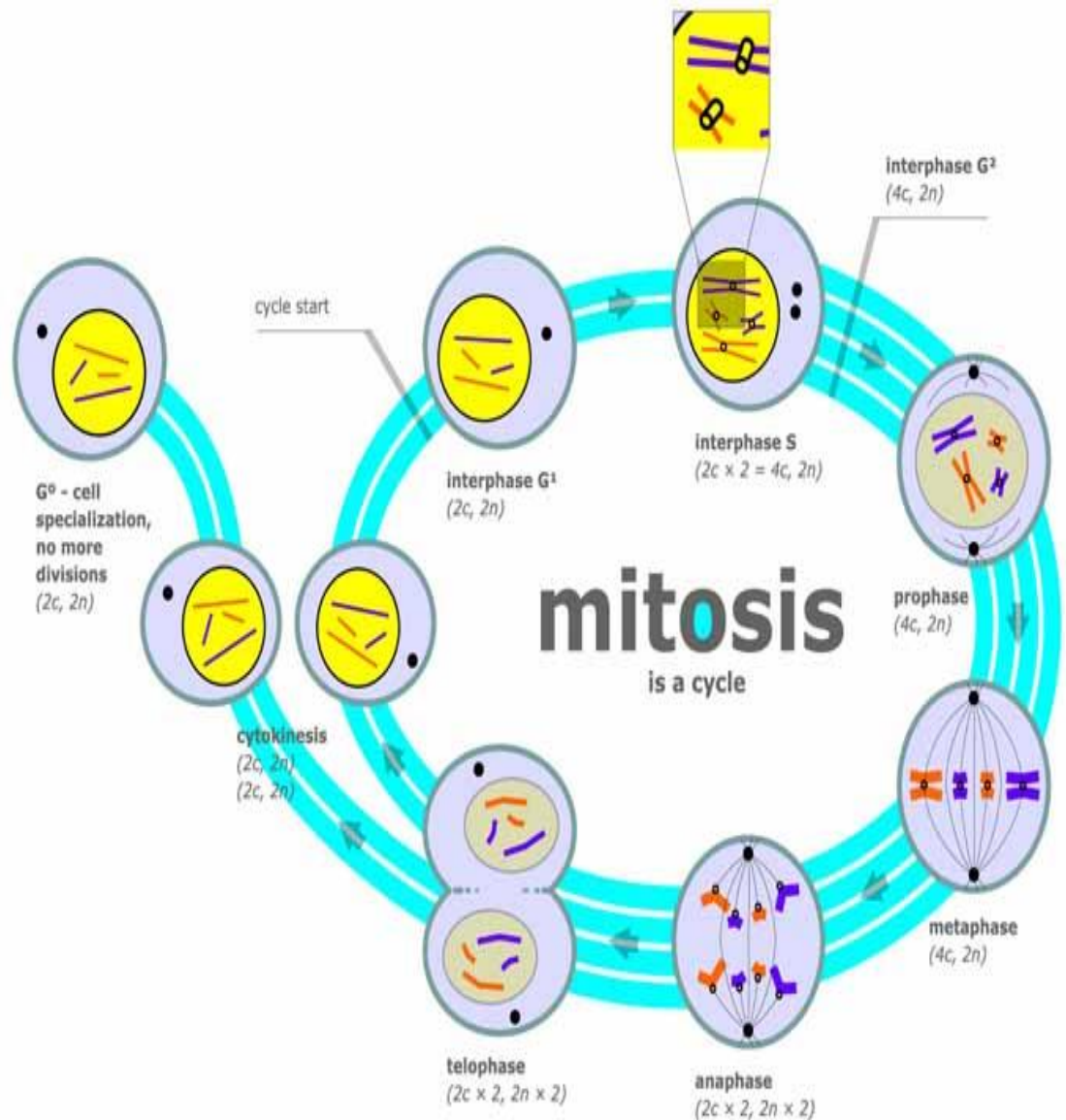
2nd - Metaphase

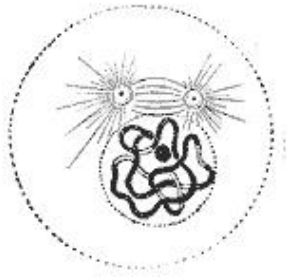
3rd - Anaphase

4th - Telophase

followed by

Cytokinesis

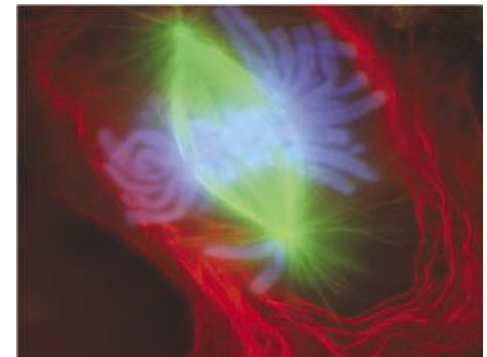
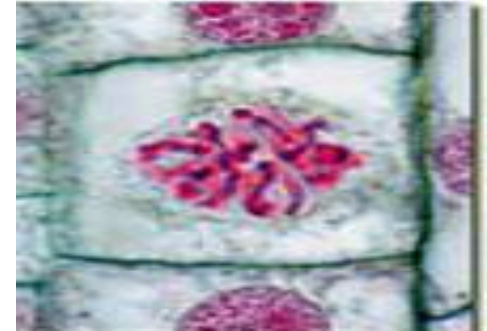




1. Prophase

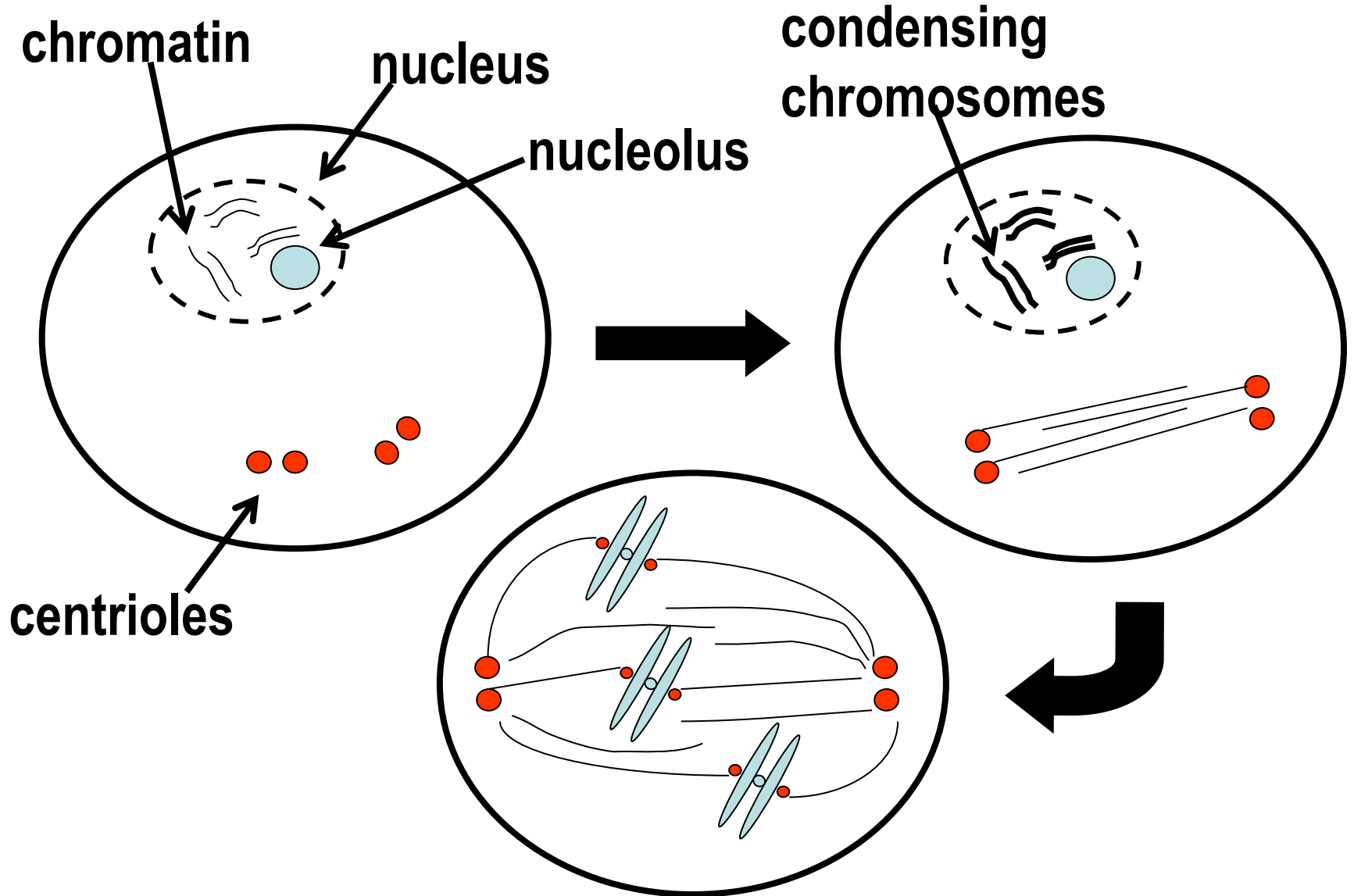
3 Major Events

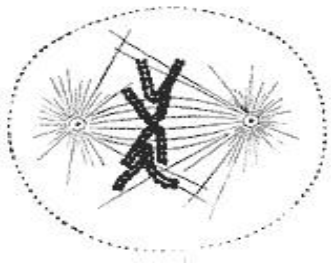
- chromosomes condense
- spindle fibers form
(spindle fibers are specialized microtubules radiating out from centrioles)
- chromosomes are captured by spindle



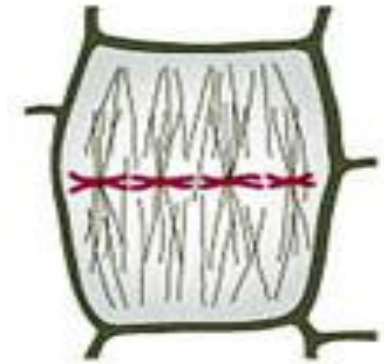
Fluoresced eukaryotic cell.
Chromosomes in blue. Mitotic spindle apparatus in green.

Prophase

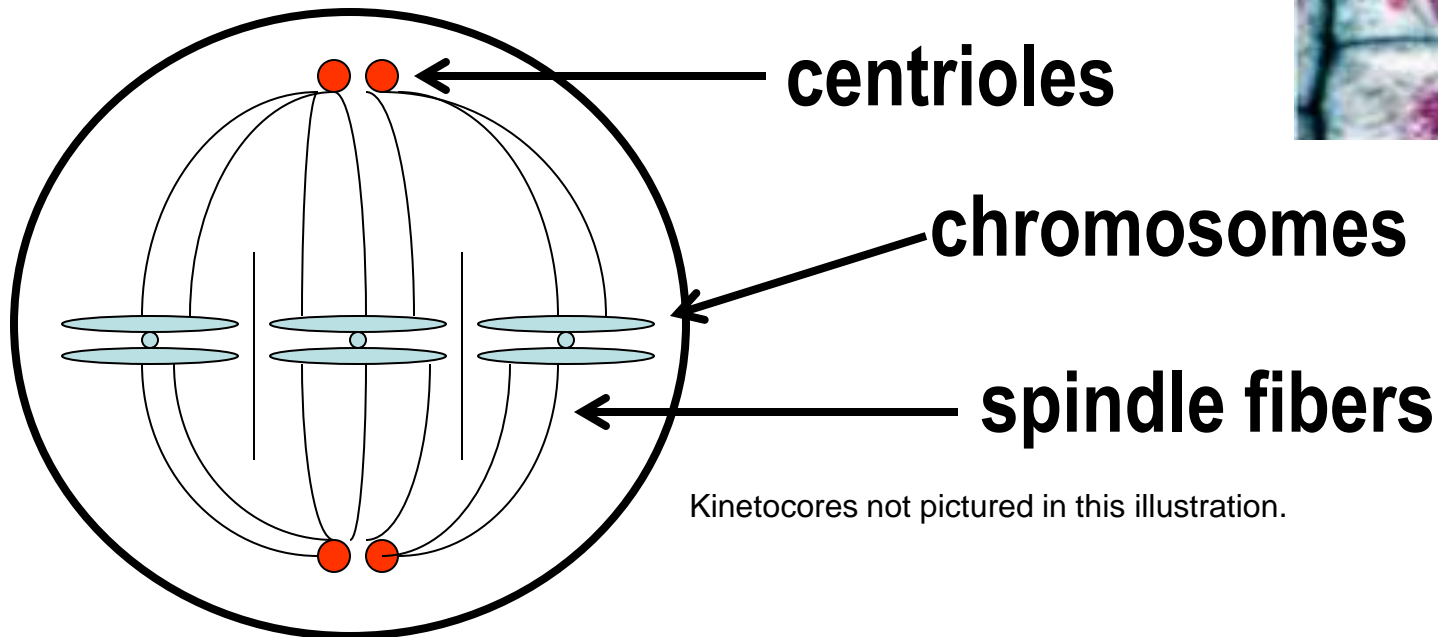
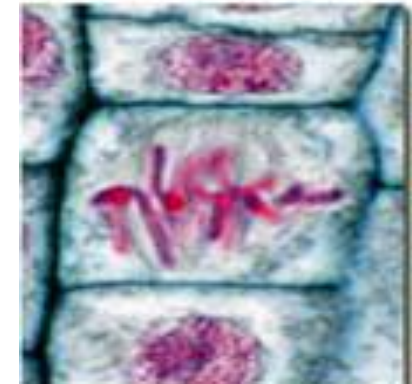


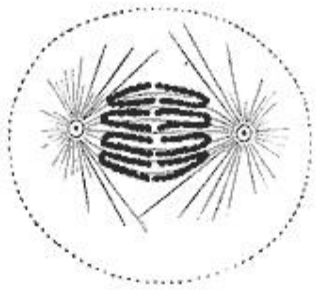


2. Metaphase



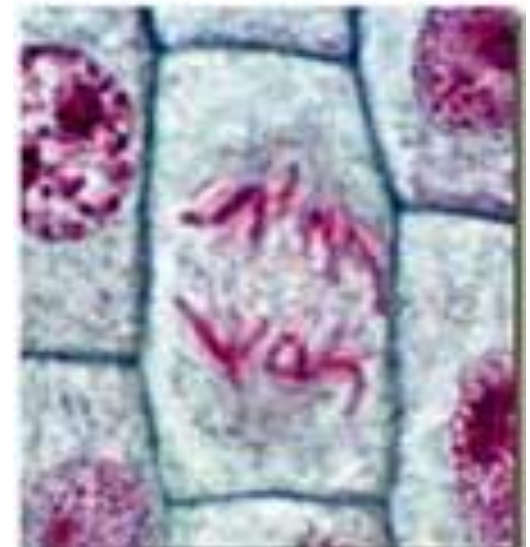
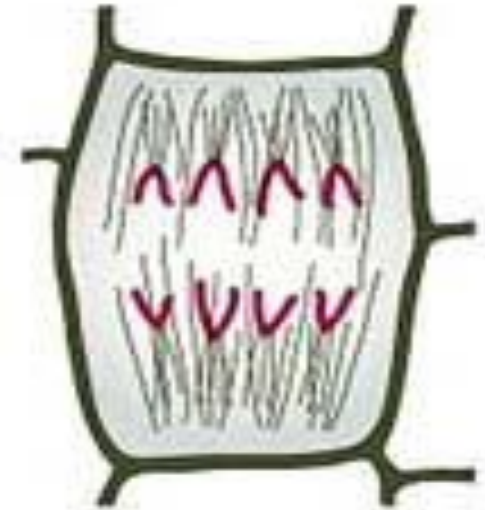
- chromosomes align along equator of the cell, with one kinetochore facing each pole

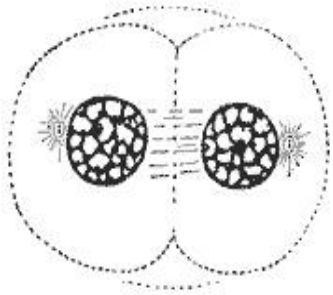




3. Anaphase

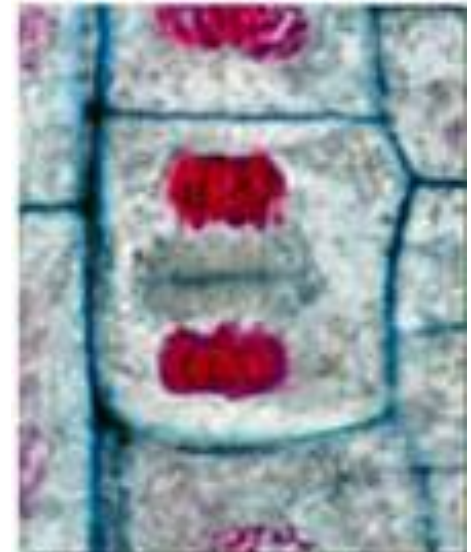
- sister chromatids separate
- spindle fibers attached to kinetochores **shorten** and **pull** chromatids towards the poles.
- free spindle fibers **lengthen** and **push** poles of cell apart

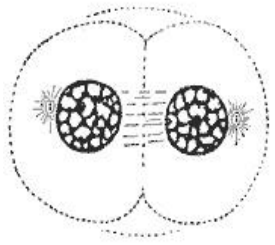




4. Telophase

- 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



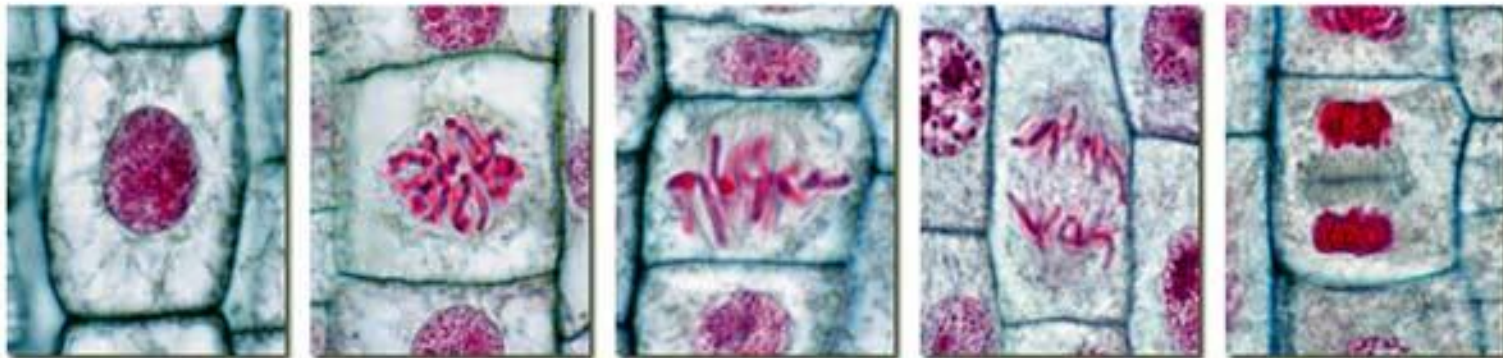
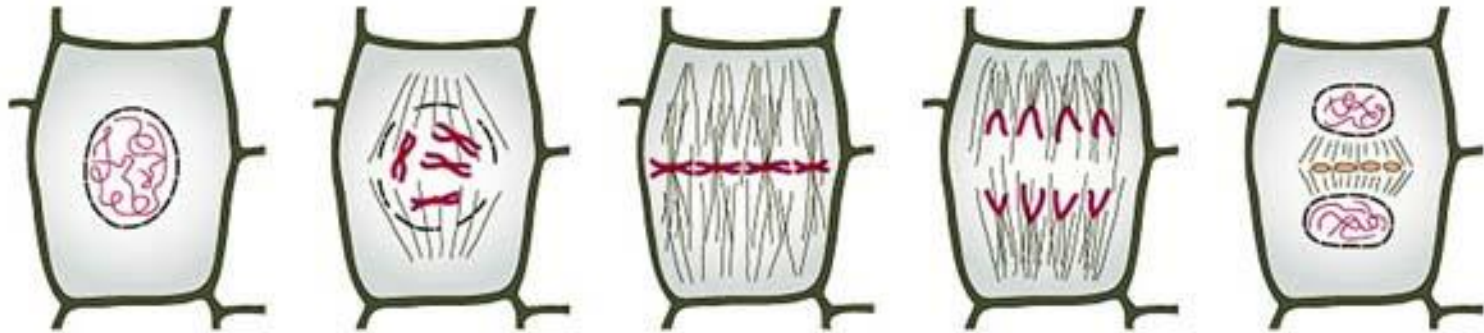


Cytokinesis - Plant vs. Animal Cell



- 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

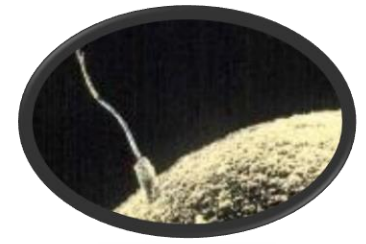


REVIEW!

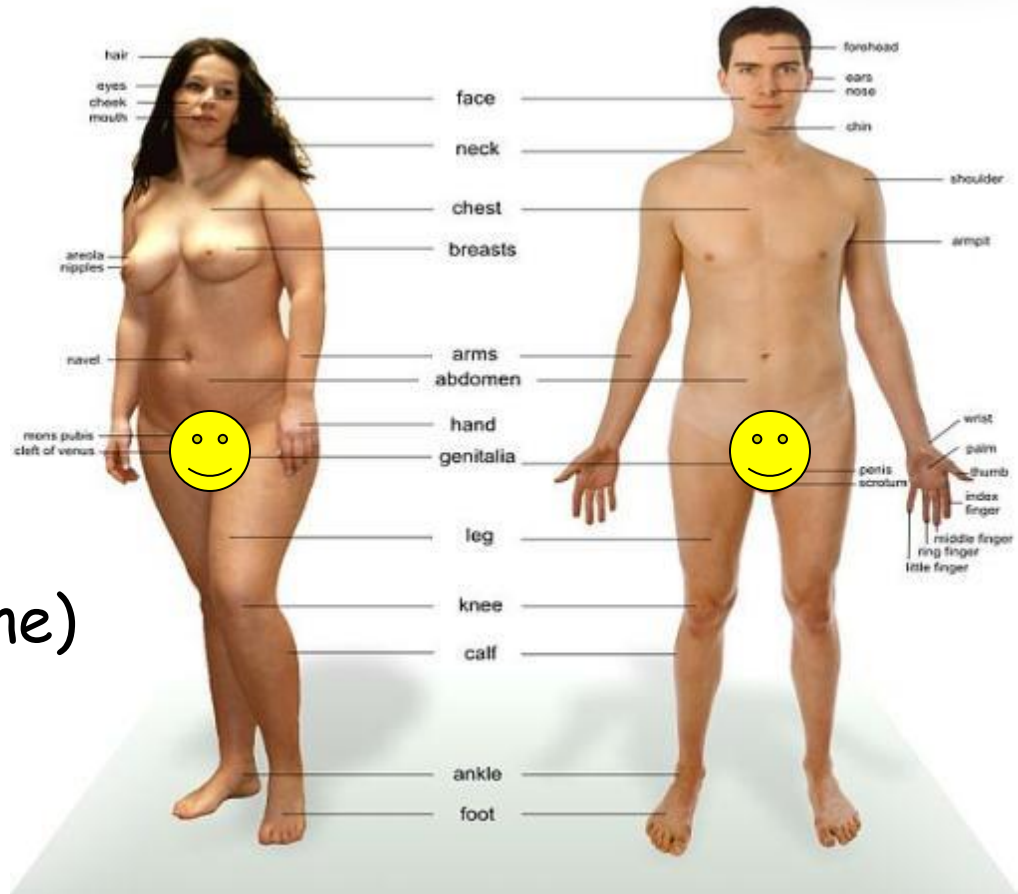
Mitosis Animations

1. [Mitosis & Cytokinesis](#) from McGraw-Hill
2. [Mitosis Interactive Animation](#) from Cells Alive

Genetics Terminology



SEXually reproducing eukaryotes, have 2 types of body cells...



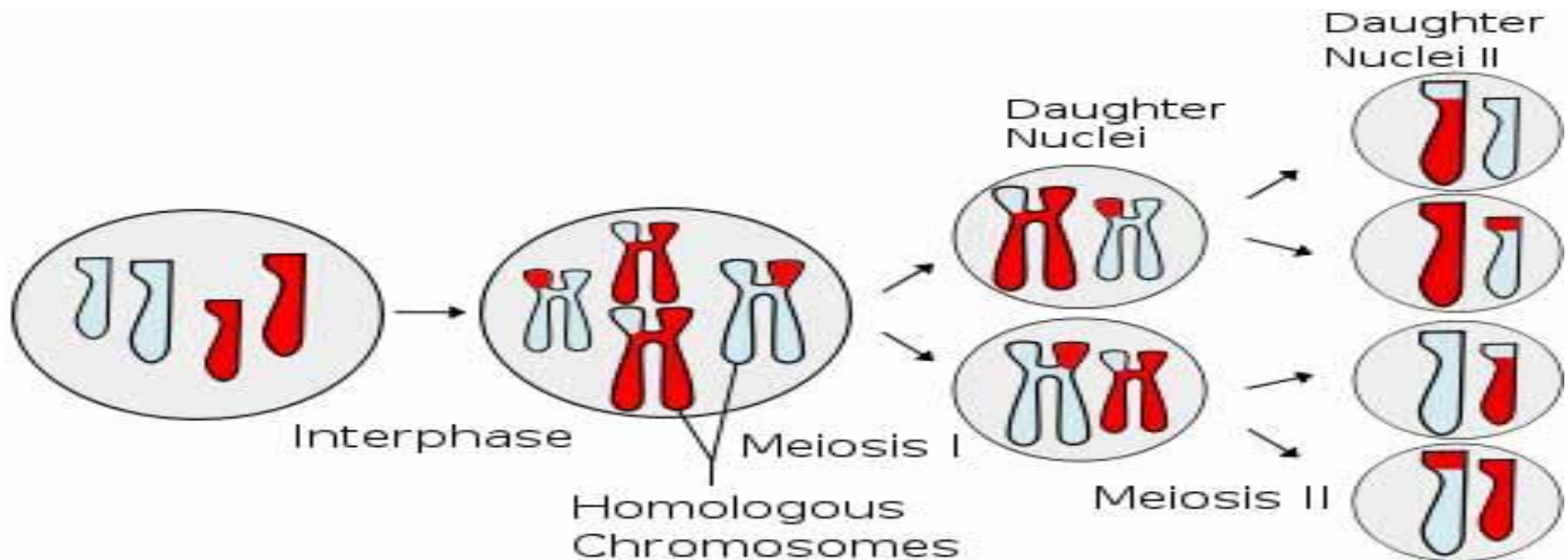
1. somatic cells

2. sex cells
(a.k.a. gametes, germline)

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**.

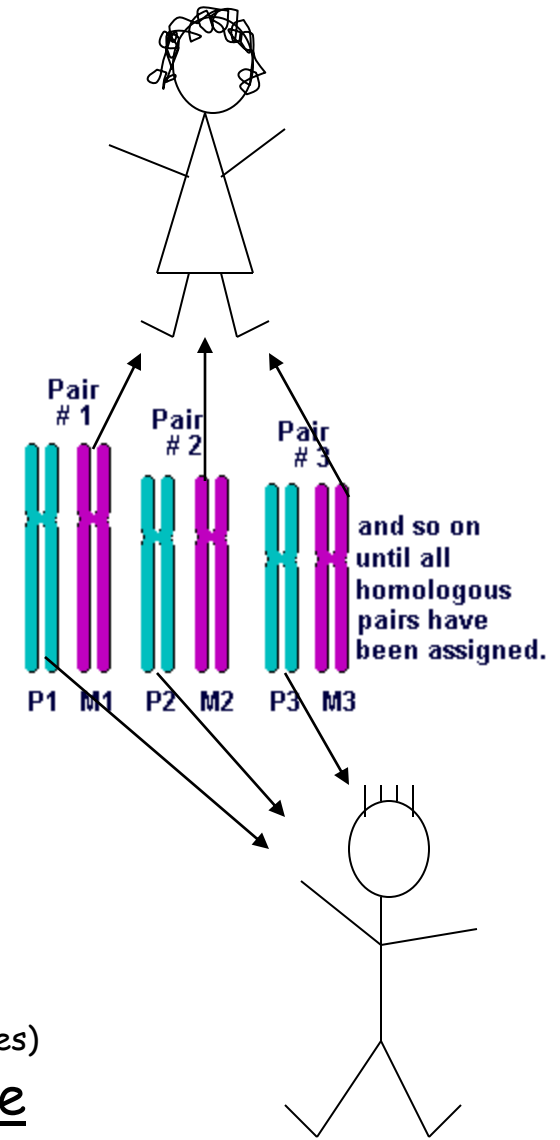


Genetics Terminology: Ploidy

Refers to the number of sets of chromosomes in cells.

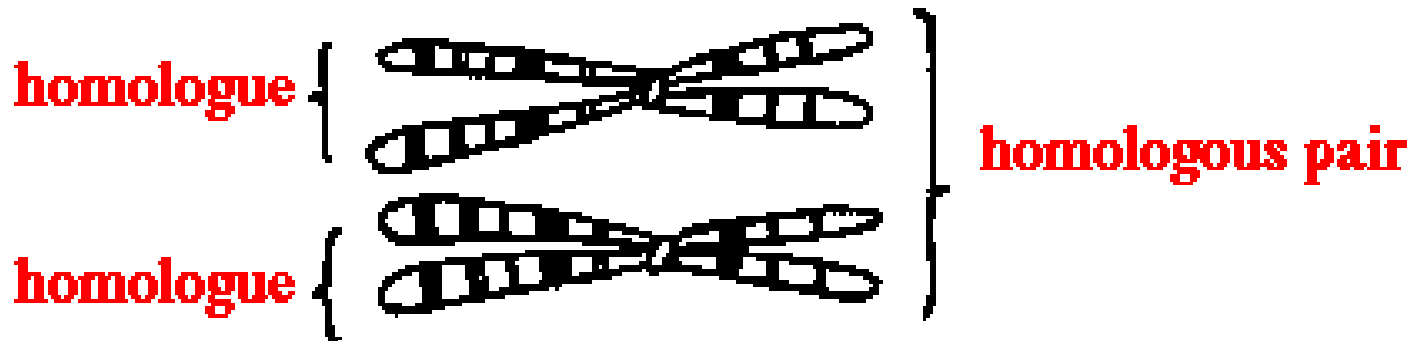
- **Haploid** - one copy of each chromosome
 - designated as "n", the number of chromosomes in one "set"
 - gametes
- **Diploid** - two sets of chromosomes
 - two of each chromosome
 - designated as "2n"
 - somatic cells

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.

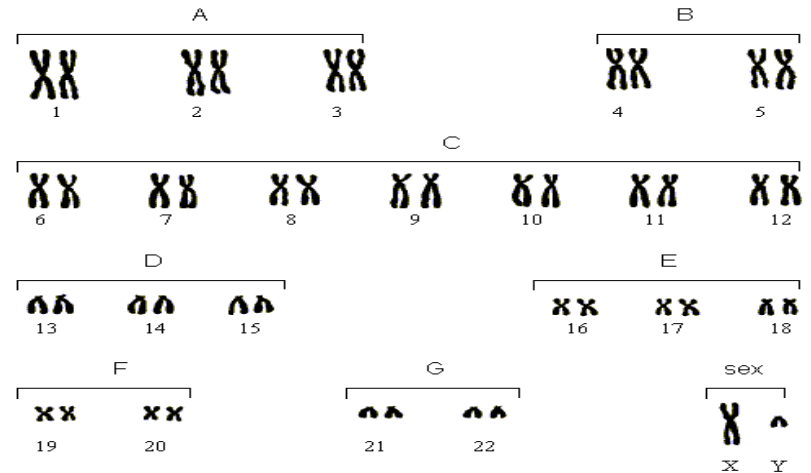
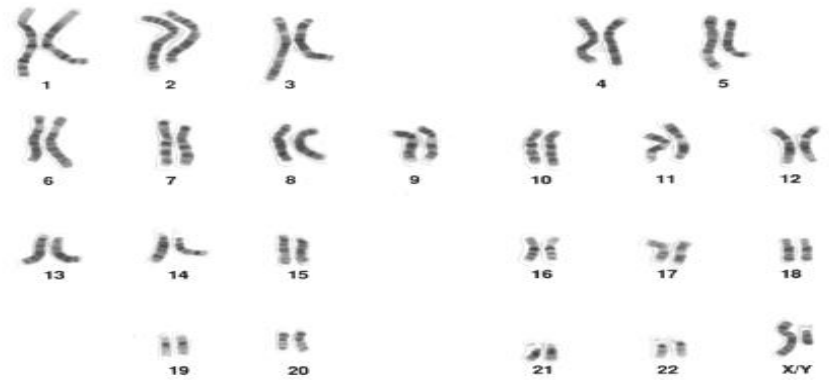


Exception: **Sex chromosomes** (X, Y).

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

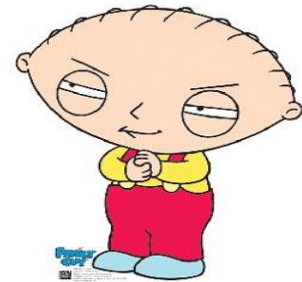
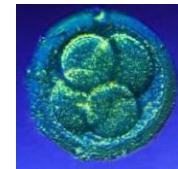
Karyotype

- 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?



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.



Peter + Lois = Stewie

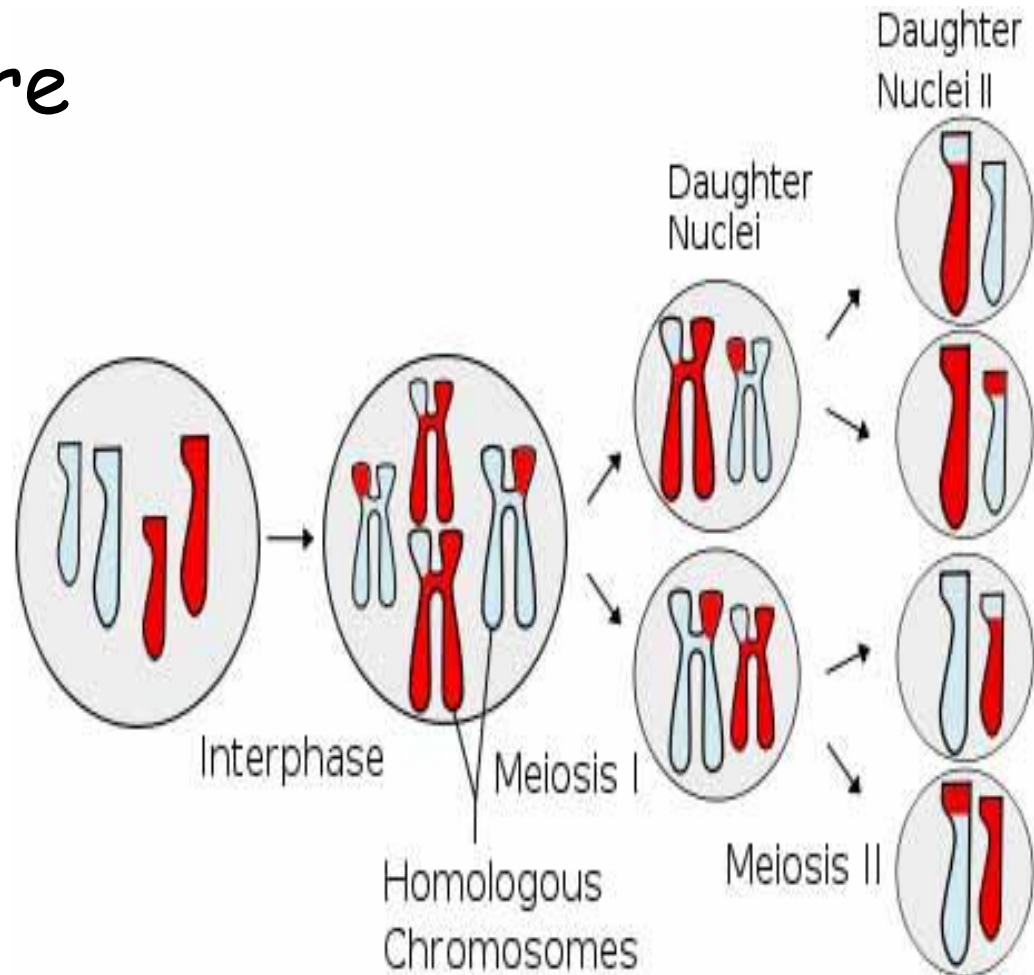
Sexual reproduction in humans ...

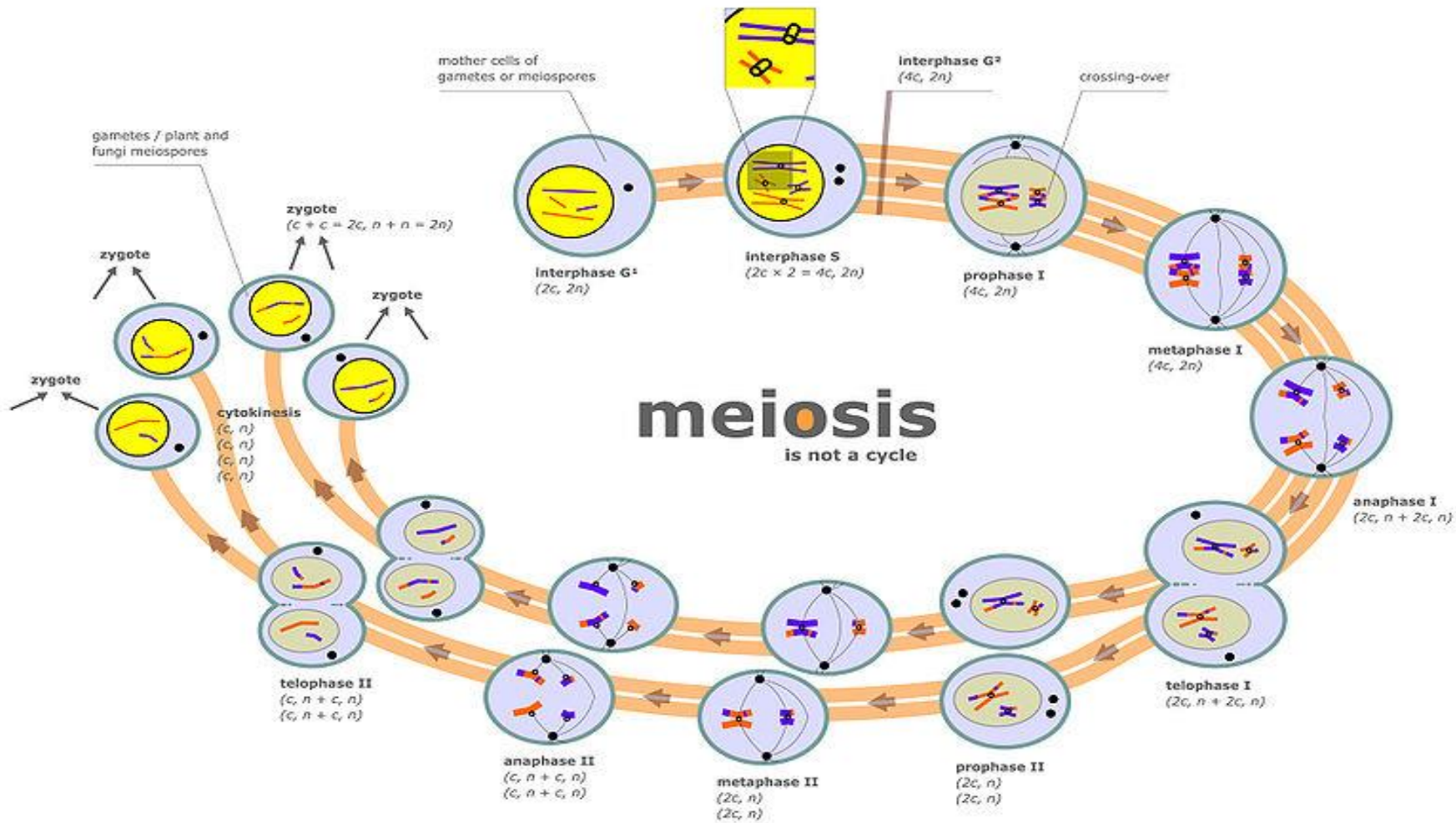
- At fertilization, 23 chromosomes are donated by each parent.
(total = 46 or 23 pairs).
- **Gametes** (sperm/ova):
 - Contain 22 autosomes and 1 sex chromosome.
 - Are haploid (haploid number " n " = 23 in humans).
- Fertilization results in diploid zygote.
 - Diploid cell; $2n = 46$. ($n = 23$ in humans)
- **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



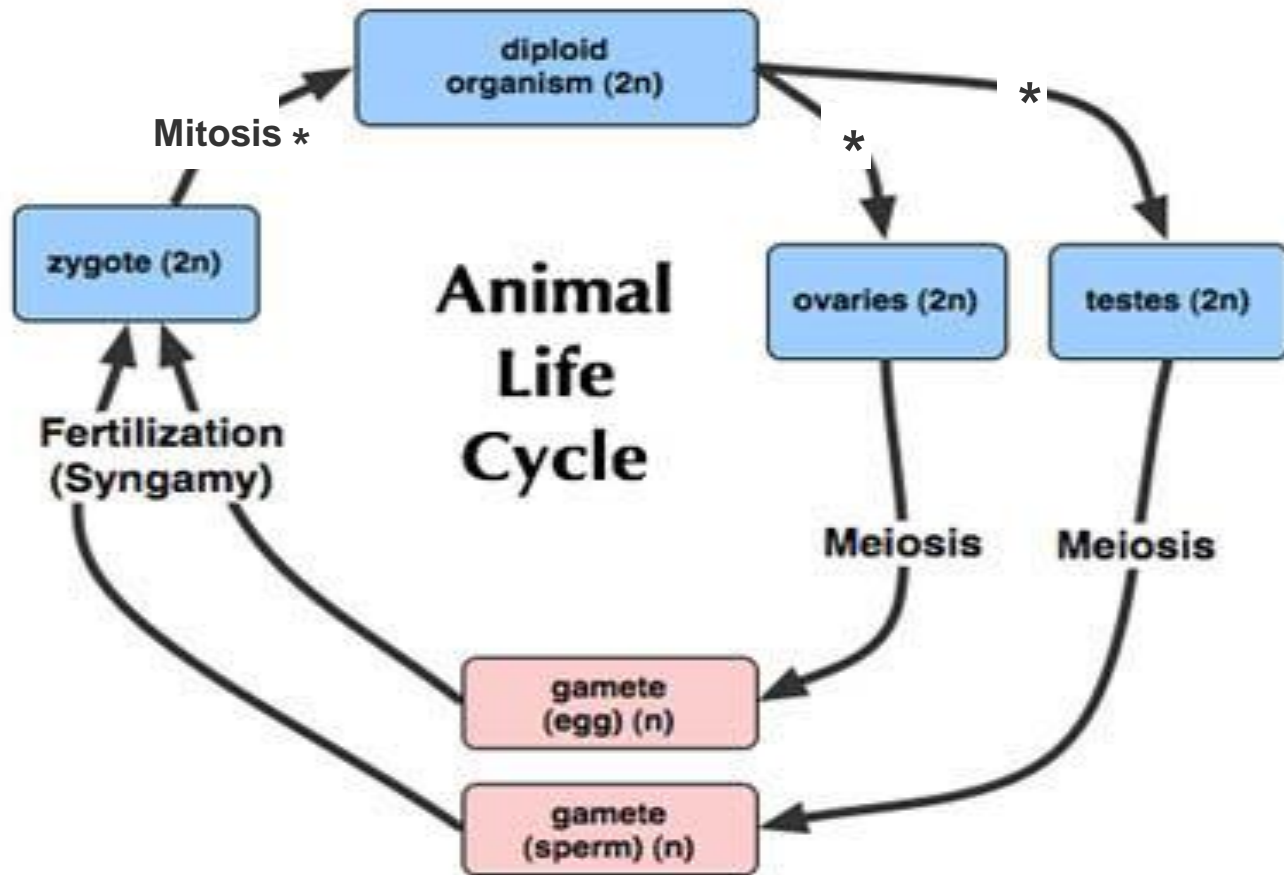


REVIEW!

Meiosis Animations

1. [How Meiosis Works](#) from McGraw-Hill
2. [Meiosis Interactive Animation](#) from Cells Alive

Meiosis & Sexual Reproduction Life Cycle

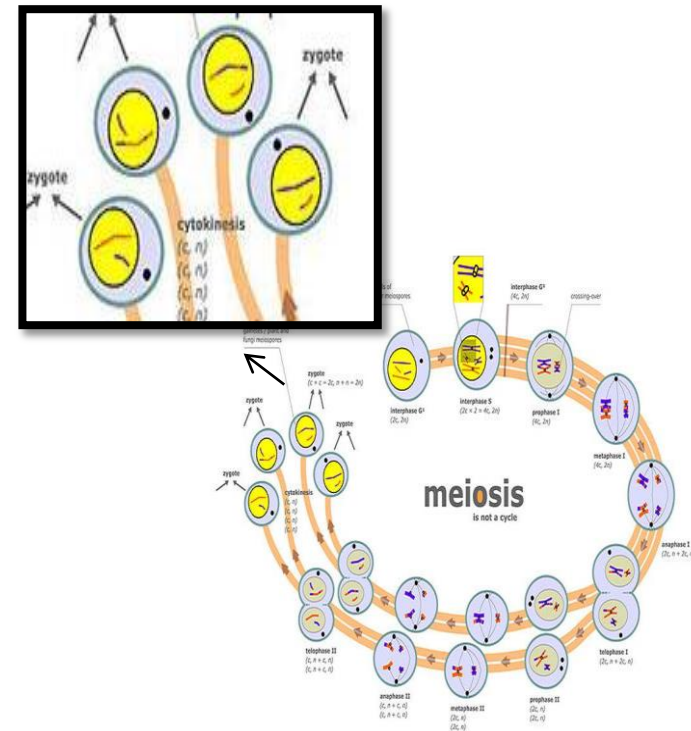


Genetic Variation in Diploid Organisms



- 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.

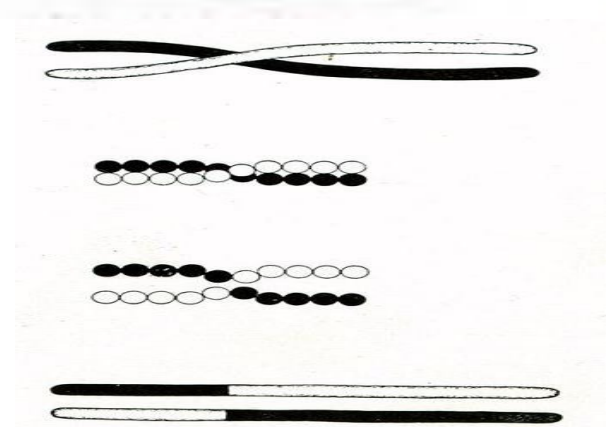
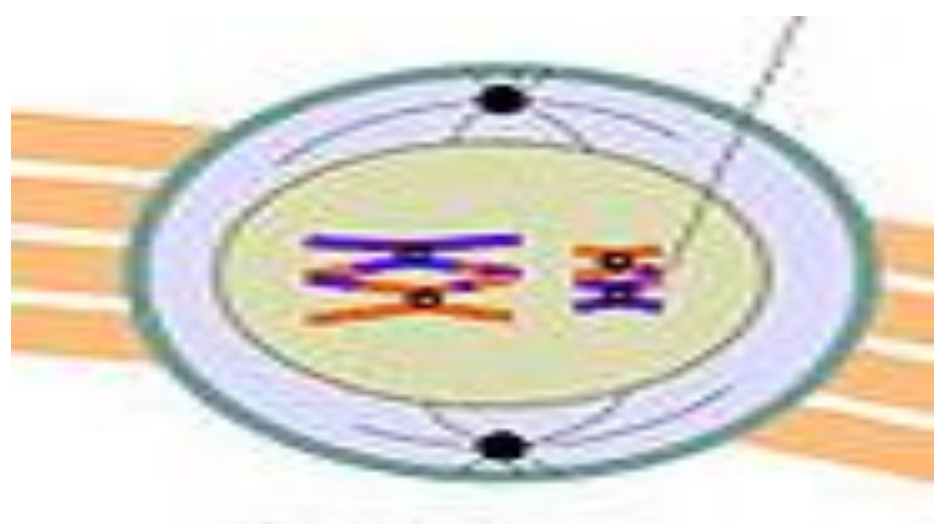
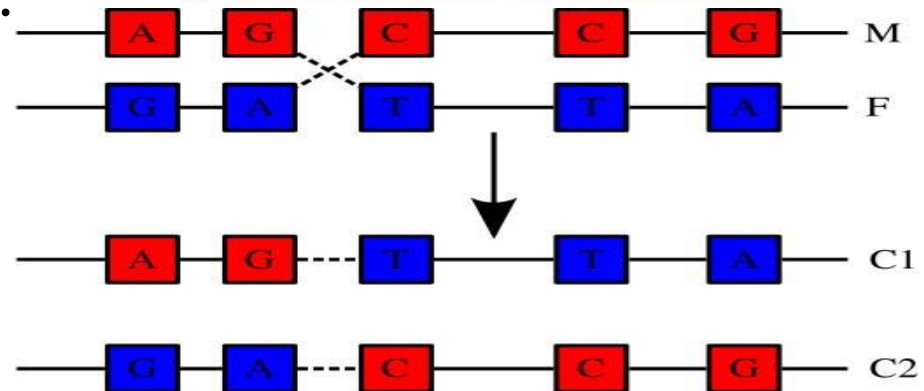
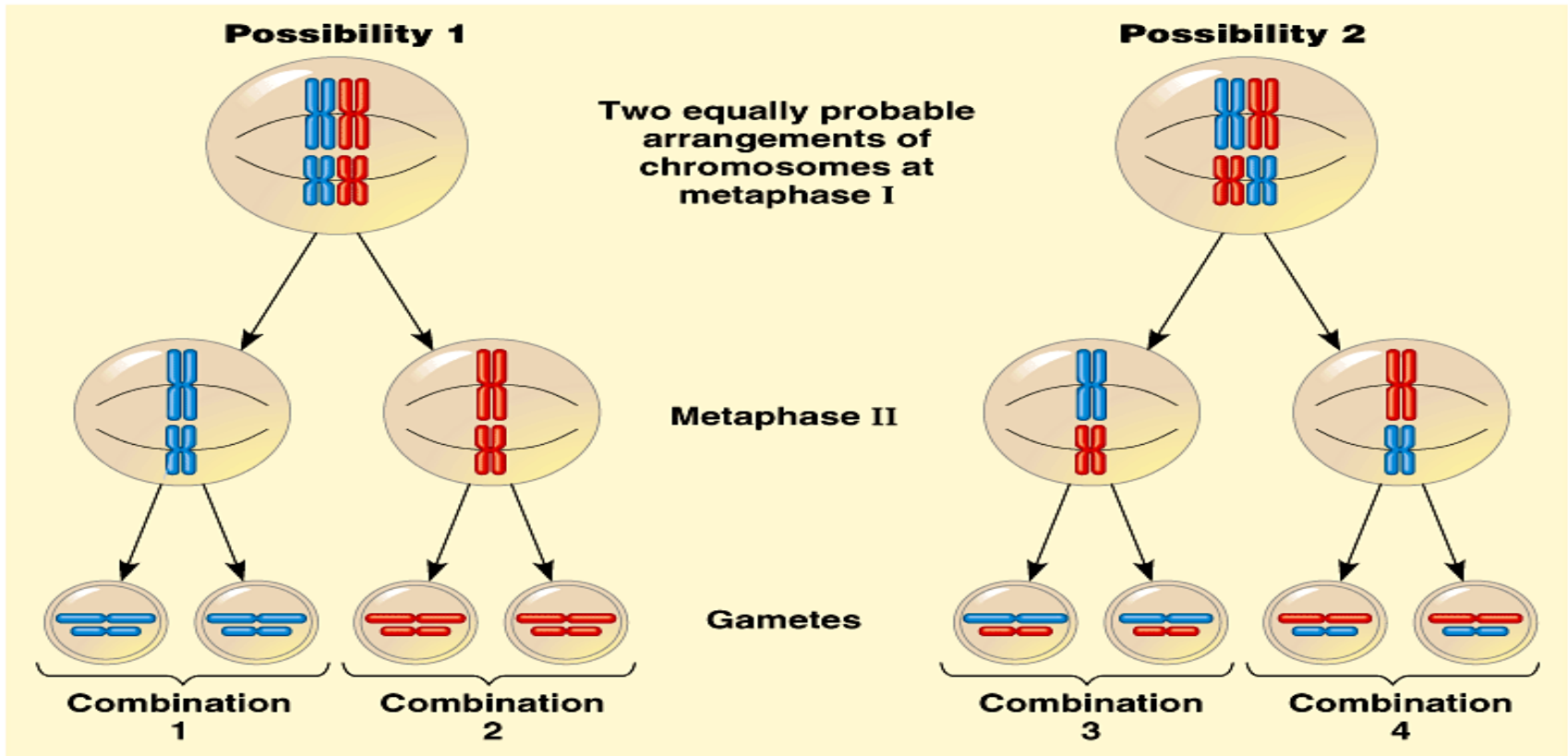


Diagram to illustrate a method of crossing over.



Independent Assortment



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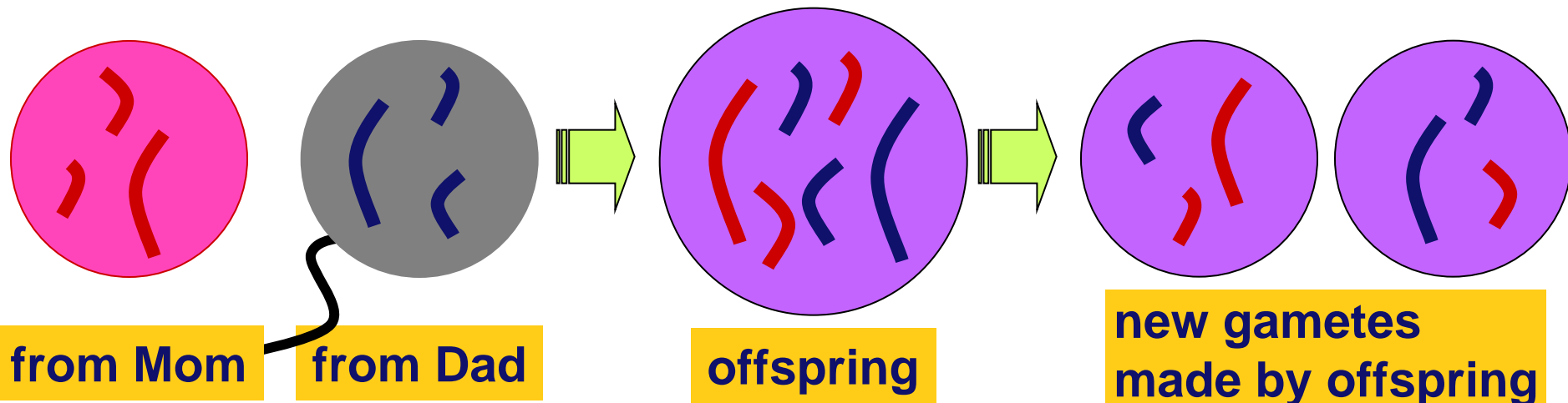
REVIEW!

Independent Assortment Animations

1. [Independent Assortment](#) from Sinauer Associates
2. [Random Orientation of Chromosomes During Meiosis](#) from McGraw-Hill

Variation from genetic recombination

- Independent assortment of chromosomes
 - meiosis introduces genetic variation
 - gametes of offspring do not have same combination of genes as gametes from parents
 - random assortment in humans produces 2^{23} (8,388,608) different combinations in gametes



Mitosis

- $2n$
- Clone
- Same genetic information in parent cell and daughter cell.
- Give me another one just like the other one!



vs.

Meiosis

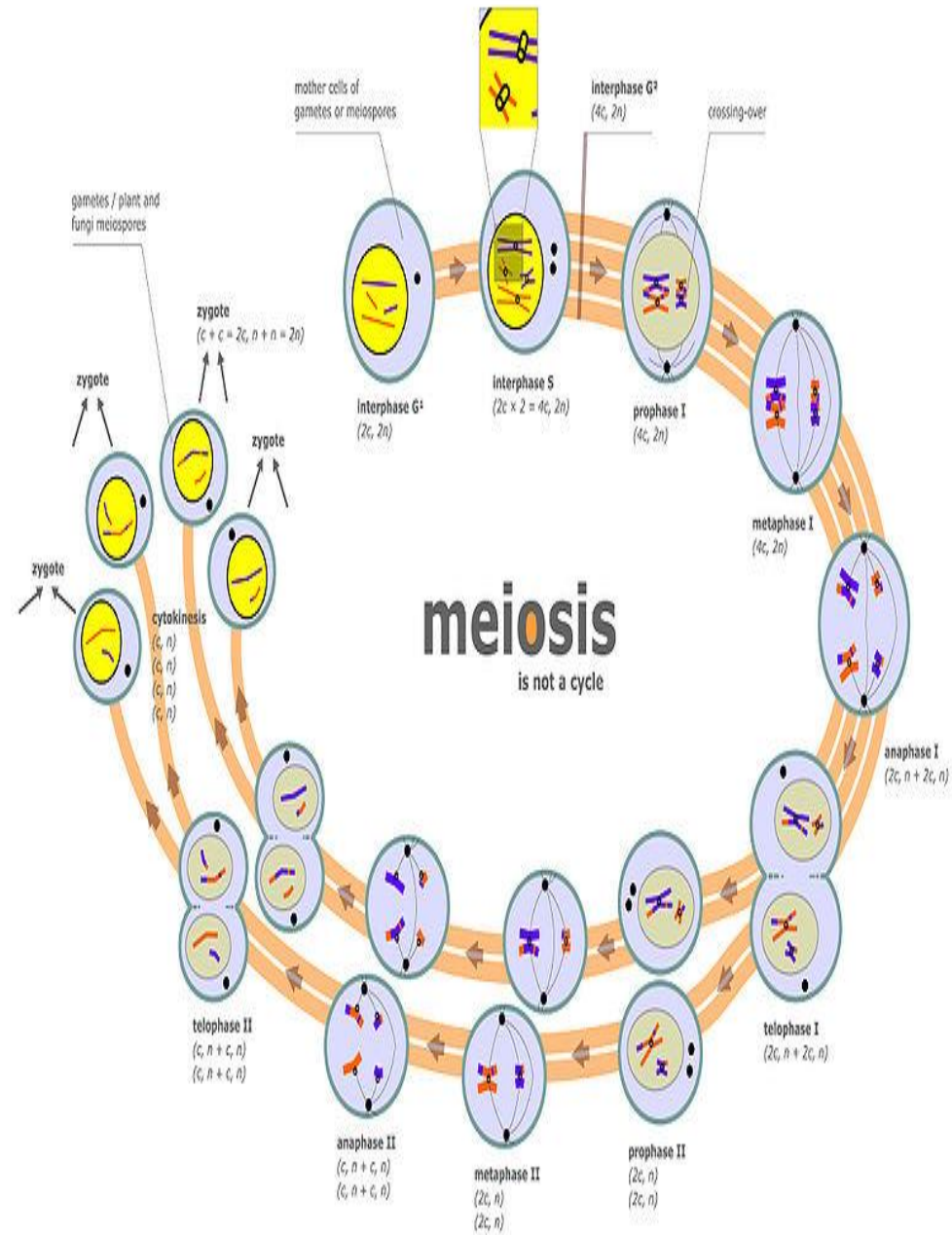
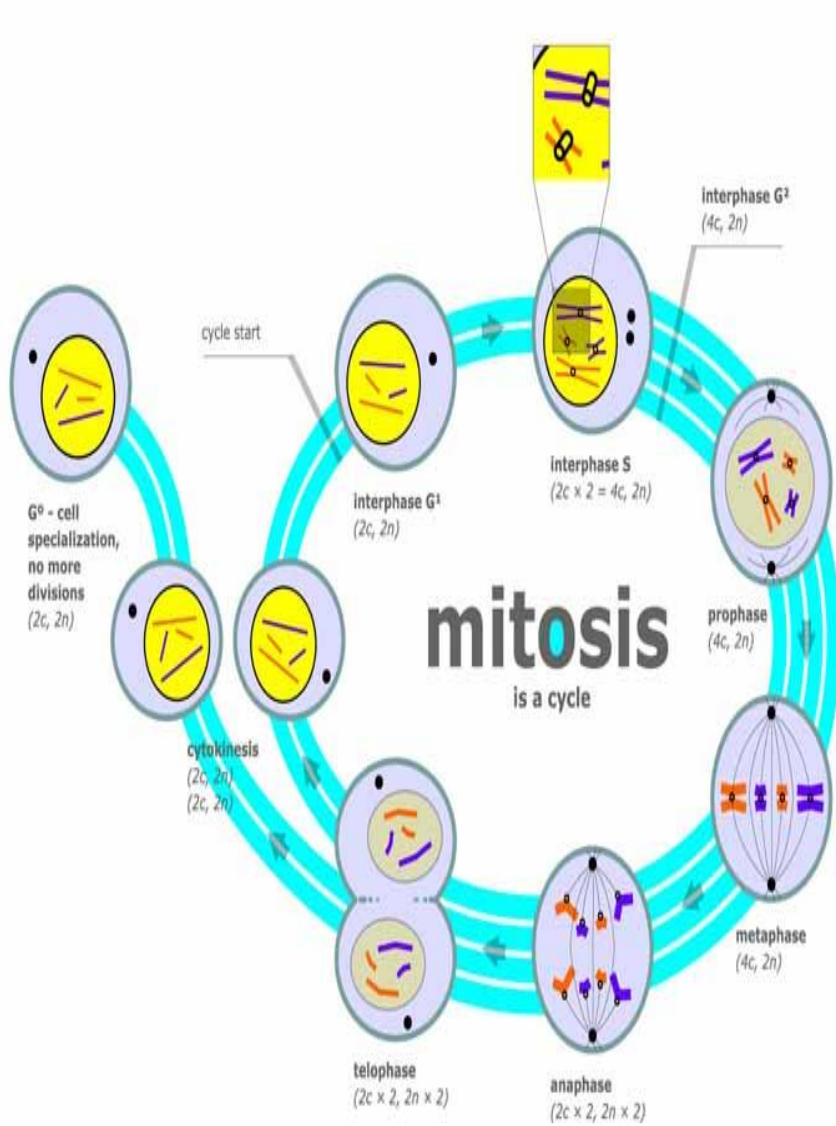
- $1n$
- Daughter cells different from parent cell and from each other.
- Daughter cells have $\frac{1}{2}$ the number of chromosomes as somatic cell.
- Shuffling the genes
(Mix it up!)
- See animation "[Unique Features of Meiosis](#)" from McGraw-Hill

REVIEW!

Animations Comparing Mitosis & Meiosis

[Quiz 1](#) and [Quiz 2](#)

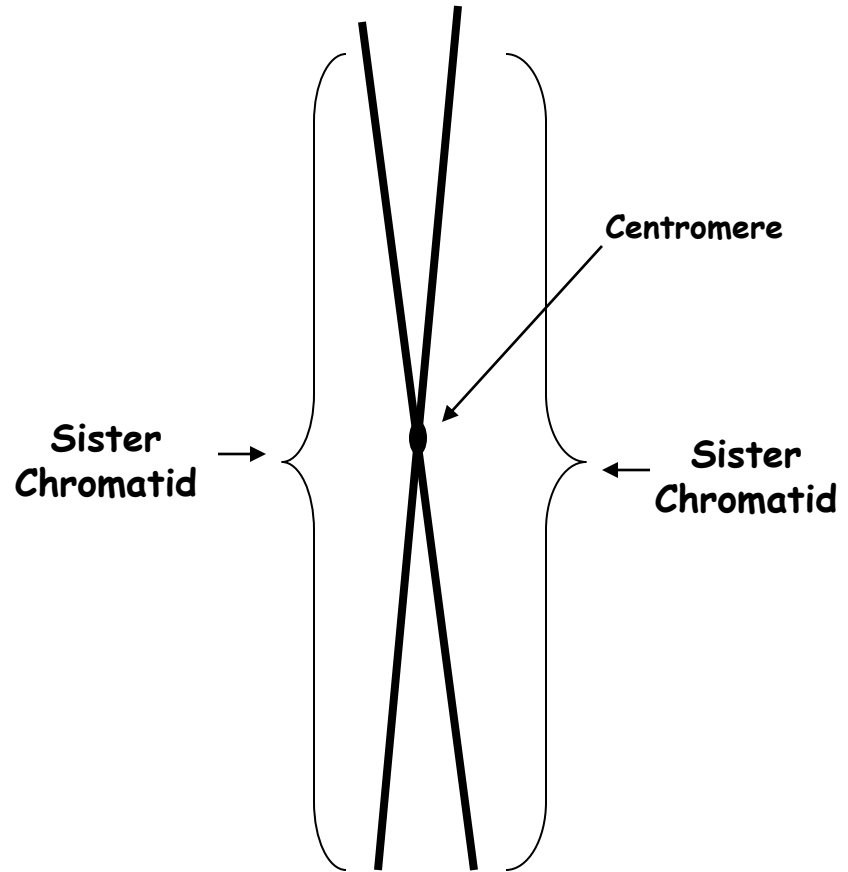
from McGraw-Hill



Drawing and Labeling Chromosomes

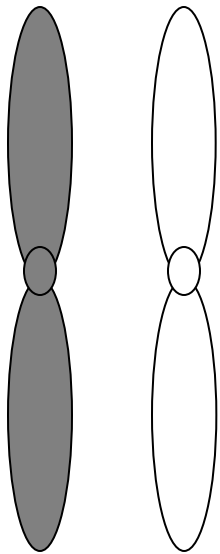


**Unreplicated
Uncondensed
Chromosome
(chromatin)**

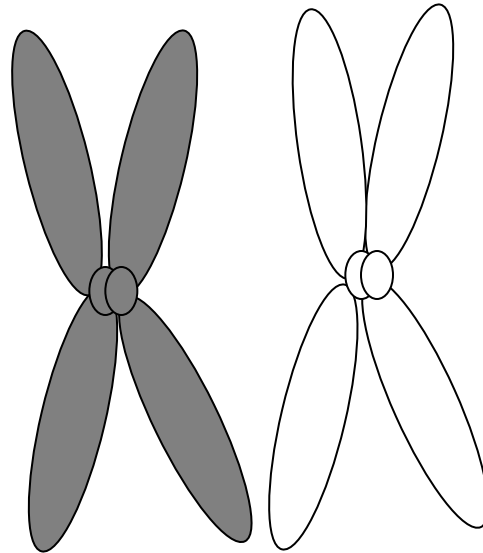


**Replicated
Uncondensed
Chromosome
(chromatin)**

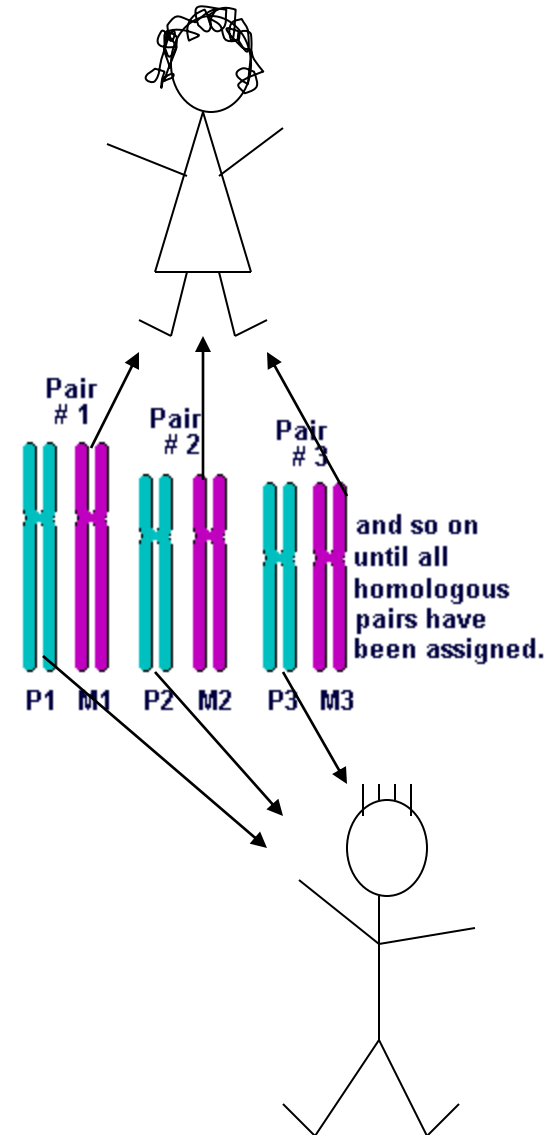
Drawing & Labeling Homologous Chromosomes



Unreplicated,
Condensed,
Homologous
Chromosomes



Replicated,
Condensed,
Homologous
Chromosomes



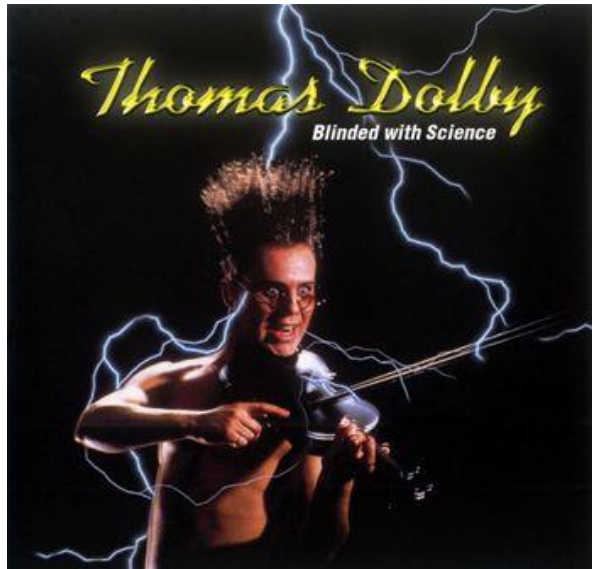
Confused?

Here are links to fun resources that further explain meiosis:

- [Meiosis Main Page](#) on the Virtual Cell Biology Classroom of [Science Prof Online](#).
- "[Meiosis: Where the Sex Starts](#)", video from Crash Course Biology
- [Meiosis](#) animation, step-through and quiz, Sadava, et al., *Life: The Science of Biology*, 9th Edition, Sinauer Associates.
- [Meiosis](#) step through animation from CellsAlive.com.
- [Meiosis](#) animation from McGraw-Hill.
- [Independent Assortment](#) animation from Sinauer Associates.

Smart Links





Are you feeling blinded by science?

Do yourself a favor. Use the...

Virtual Cell Biology Classroom (VCBC)!

The VCBC is full of resources to help you succeed,
including:



- practice test questions
- review questions
- study guides and learning objectives
- PowerPoints on other topics

You can access the [Virtual Cell Biology Classroom](http://www.ScienceProfOnline.com) (VCBC) on the Science Prof Online website www.ScienceProfOnline.com