

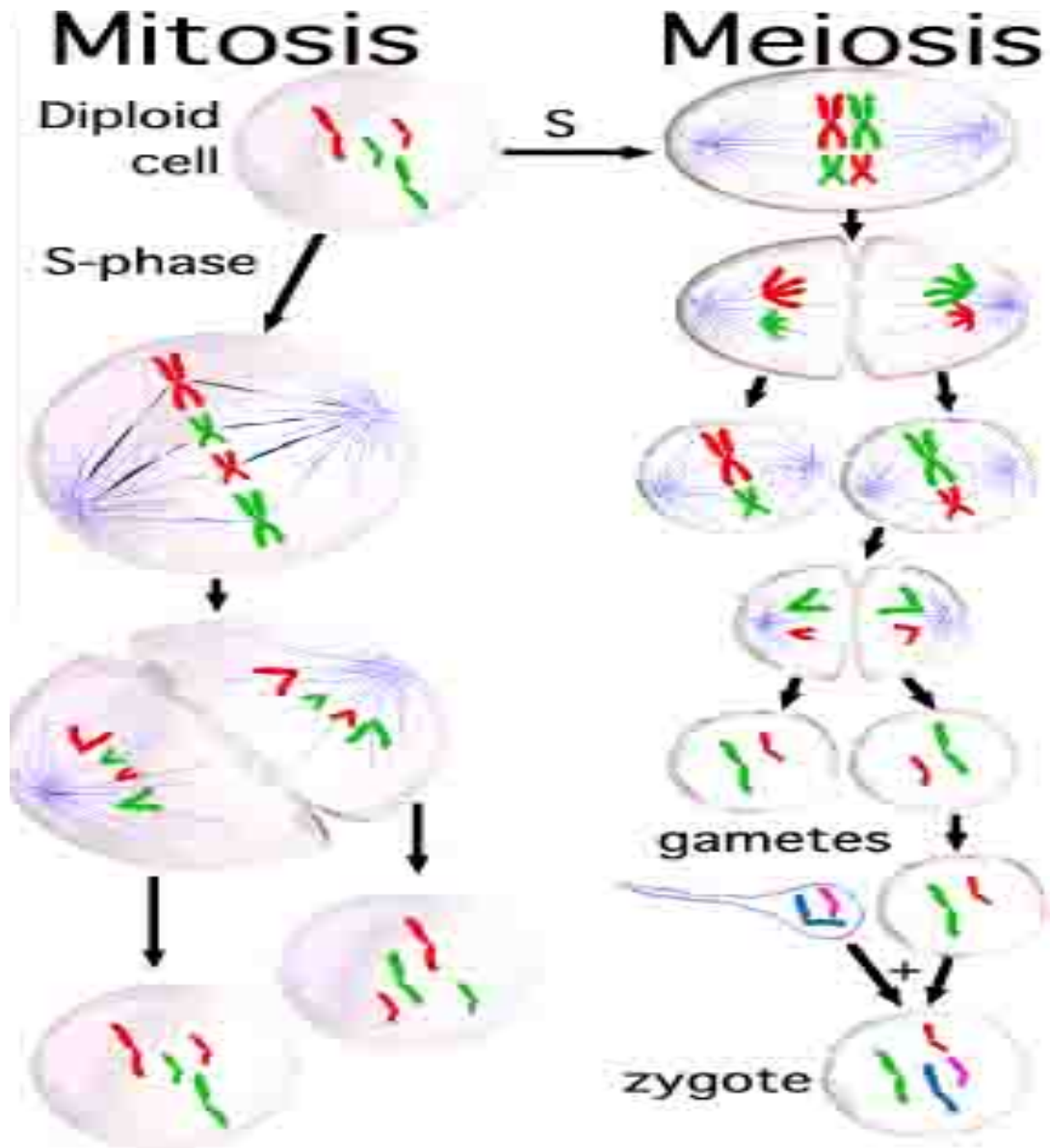


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Alicia Cepaitis, MS
Chief Creative Nerd
Science Prof Online
Online Education Resources, LLC
alicia@scienceprofonline.com

Tami Port, MS
Creator of Science Prof Online
Chief Executive Nerd
Science Prof Online
Online Education Resources, LLC
info@scienceprofonline.com



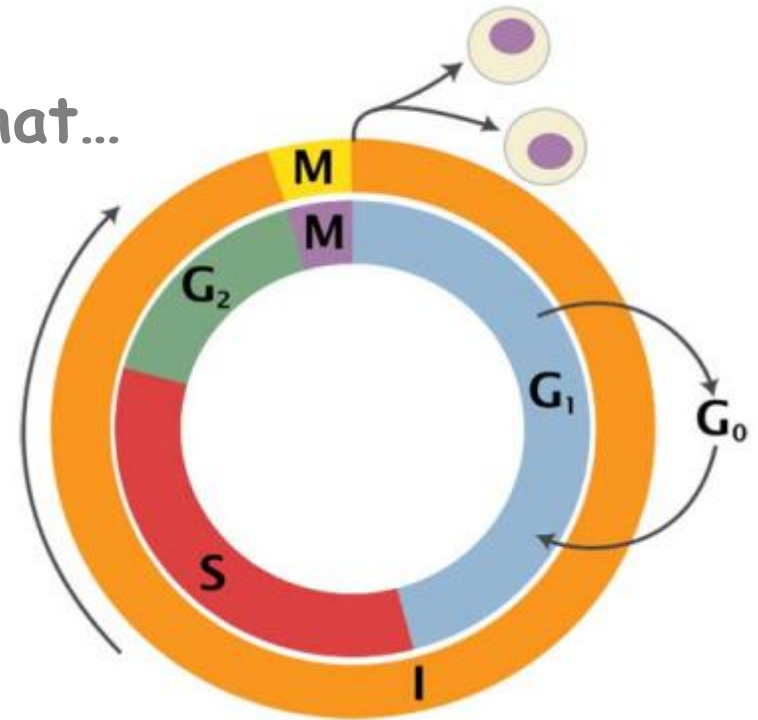
Cell Division

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.



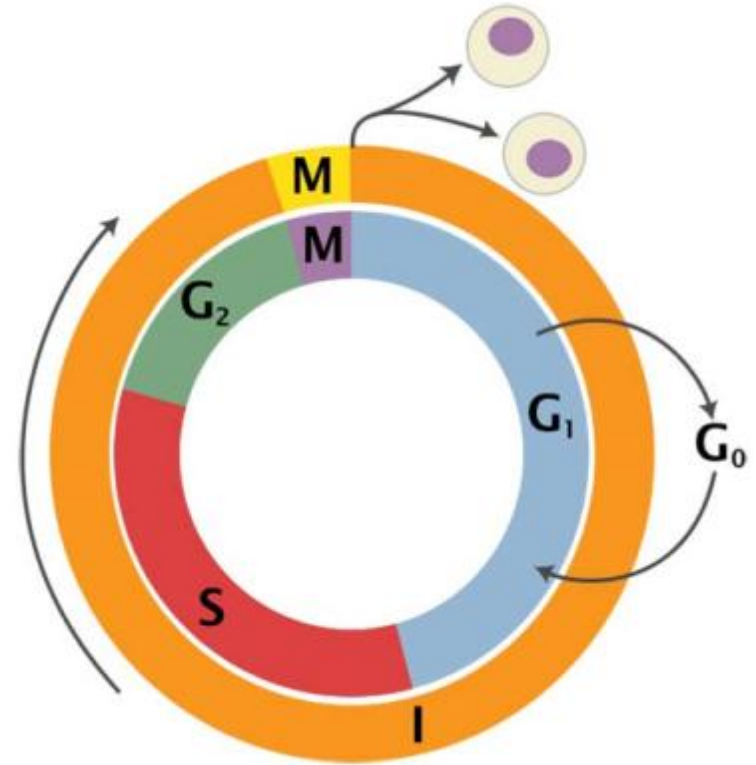
Different from prokaryotic cell cycle, in that...

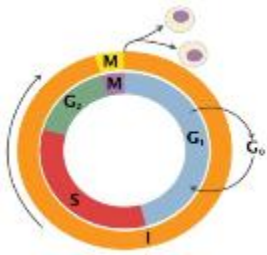
- Eukaryotic cells have more DNA on many linear chromosomes.
(Q: How many do humans have?).
- The timing of replication and cell division is highly regulated.

Eukaryotic Cell Cycle

2 major phases:

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





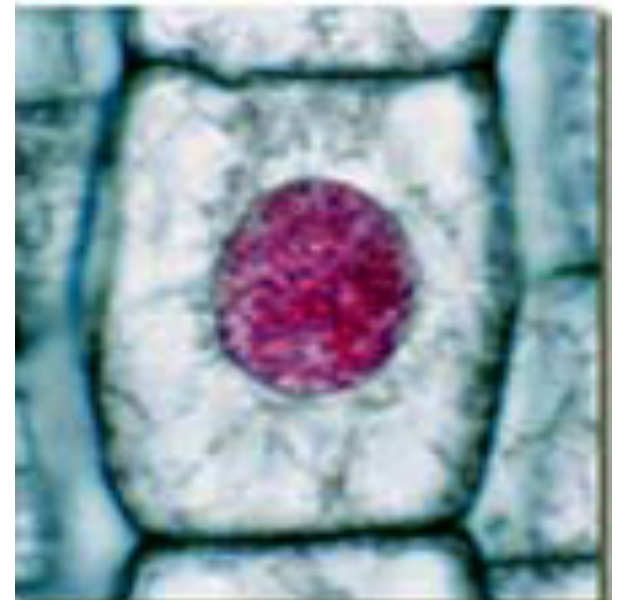
Interphase

Non-dividing state
With 3 sub-stages:

- ___ - cell grows in size
- ___ - organelles replicated

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

- ___ - synthesis of proteins associated with mitosis

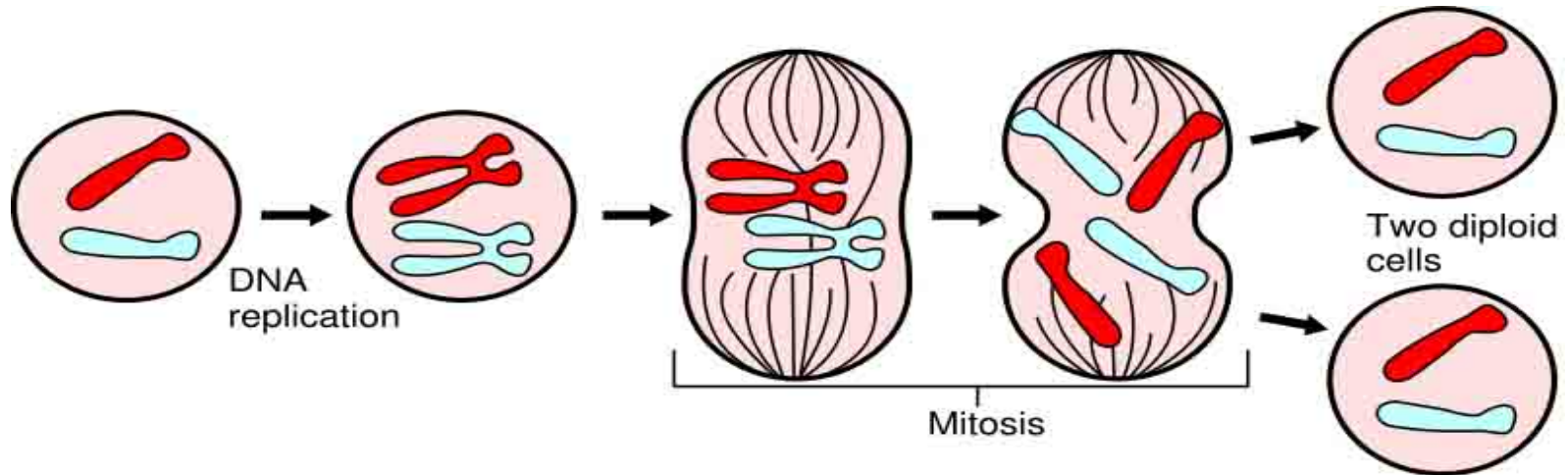
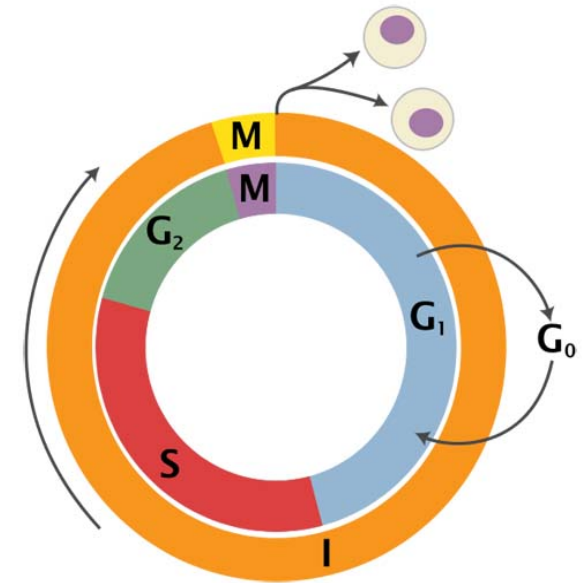


Mitosis

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.



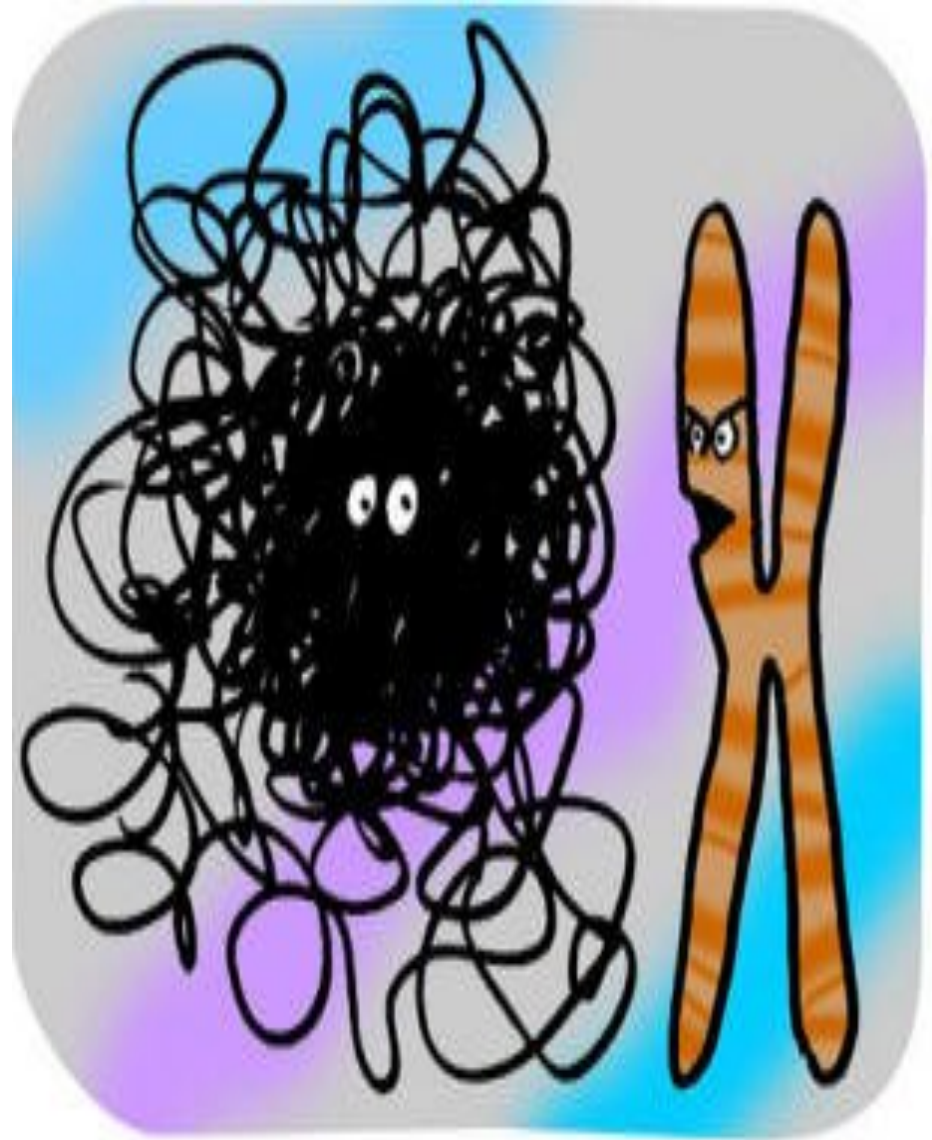
Packing for the move...

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

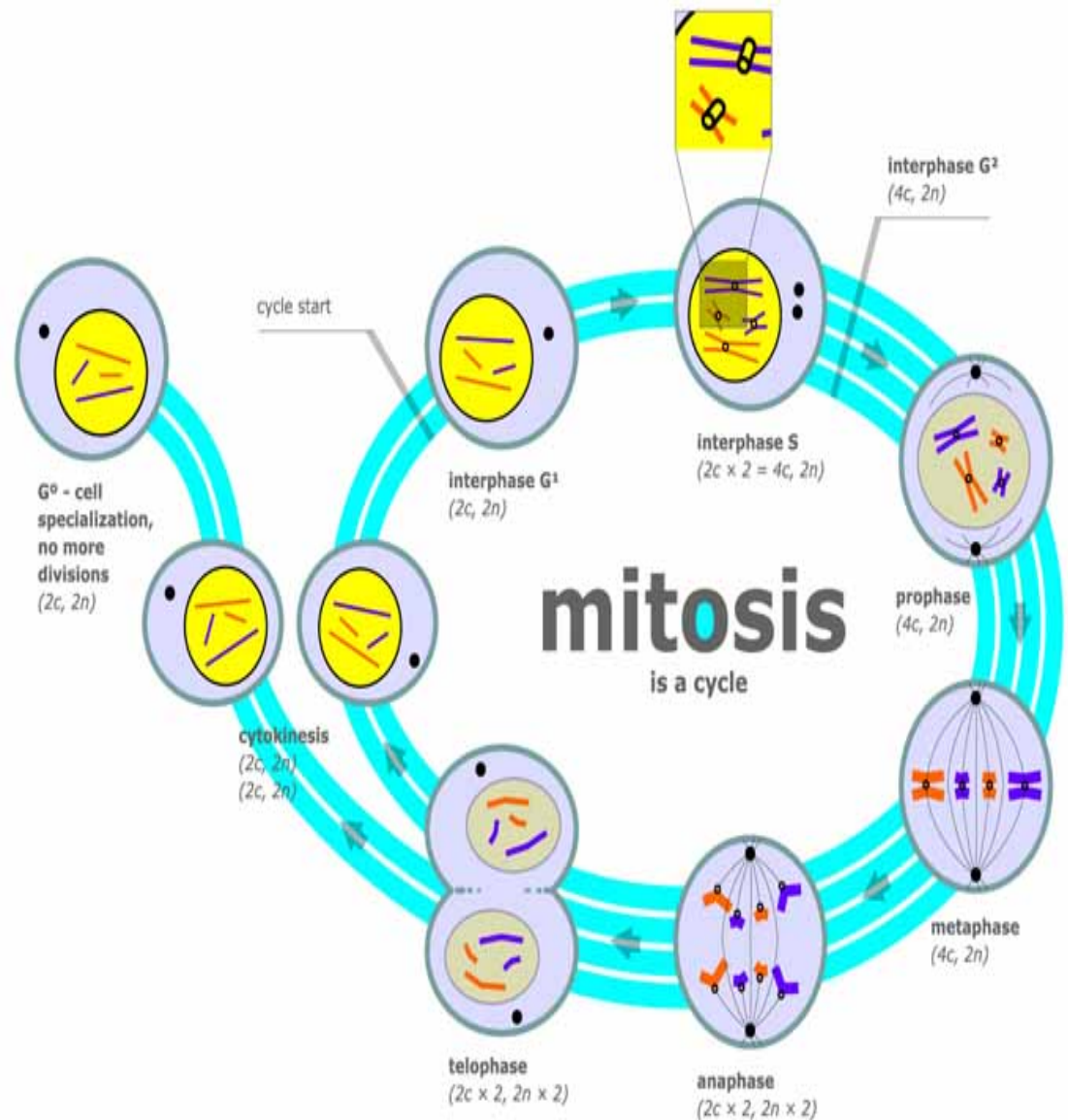
2nd - Metaphase

3rd - Anaphase

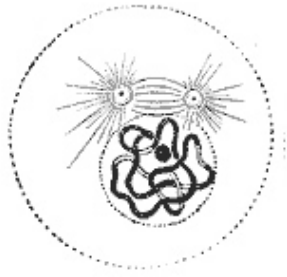
4th - Telophase

followed by

Cytokinesis



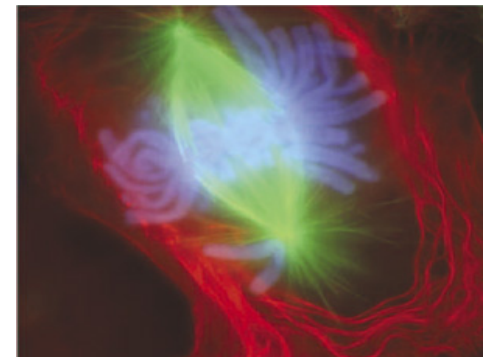
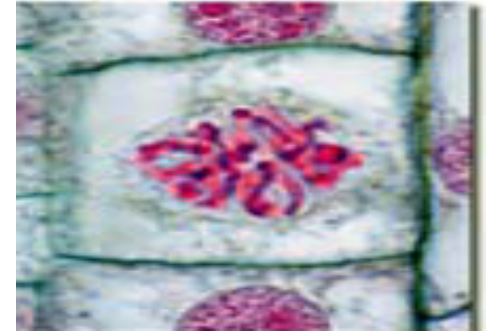
Secret to remembering phases in order...



1. Prophase

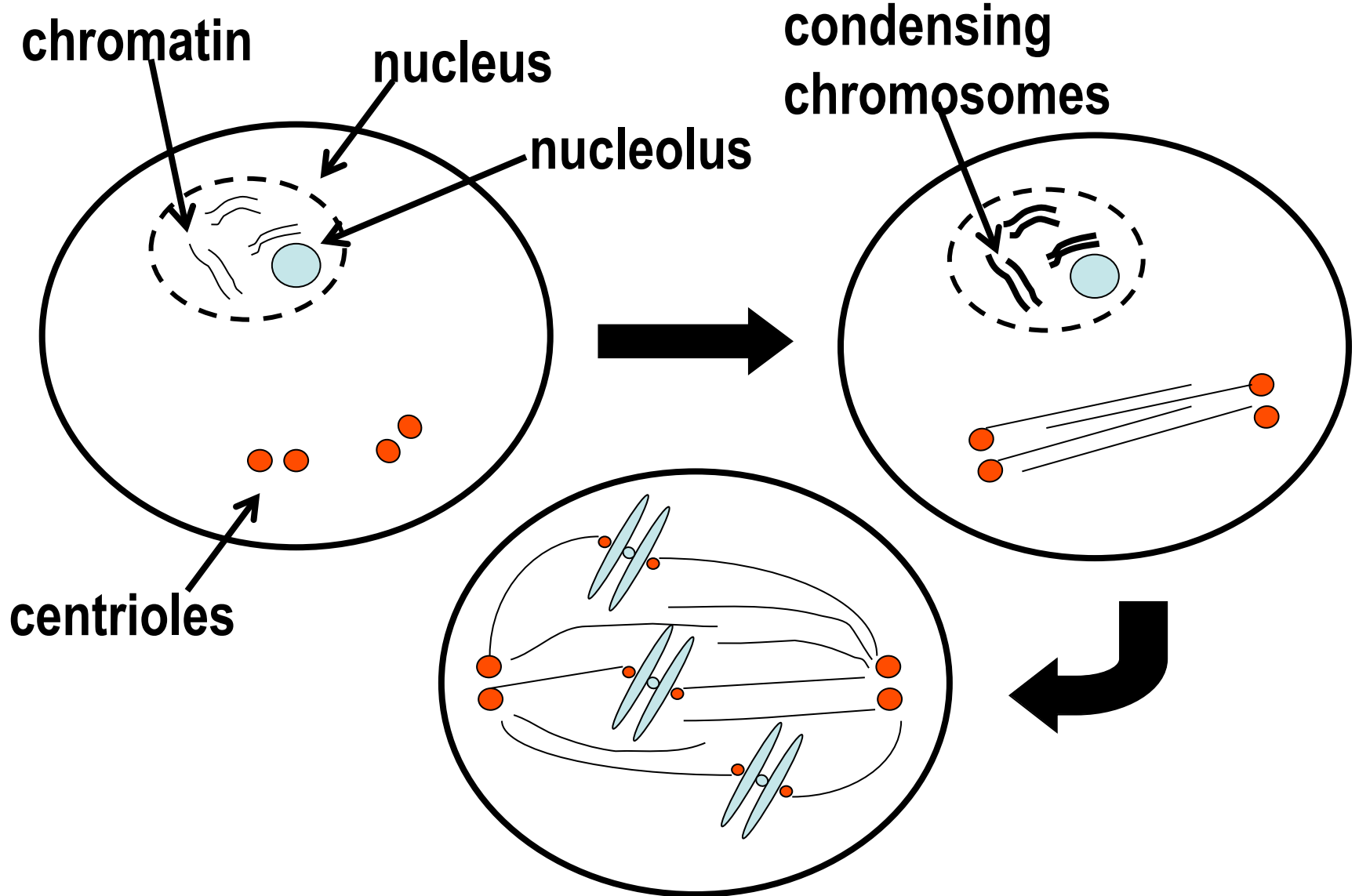
3 Major Events

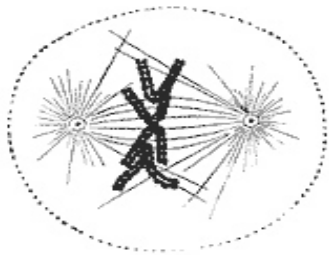
- chromosomes condense
- spindle fibers form
(spindle fibers are specialized microtubules radiating out from centrioles)
- chromosomes are captured by spindle



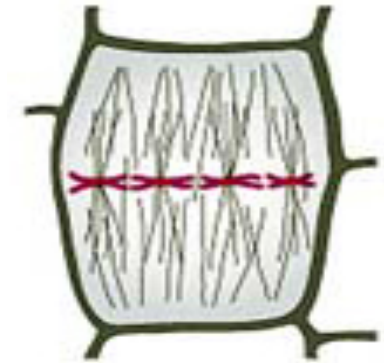
Fluoresced eukaryotic cell.
Chromosomes in blue. Mitotic spindle apparatus in green.

Prophase

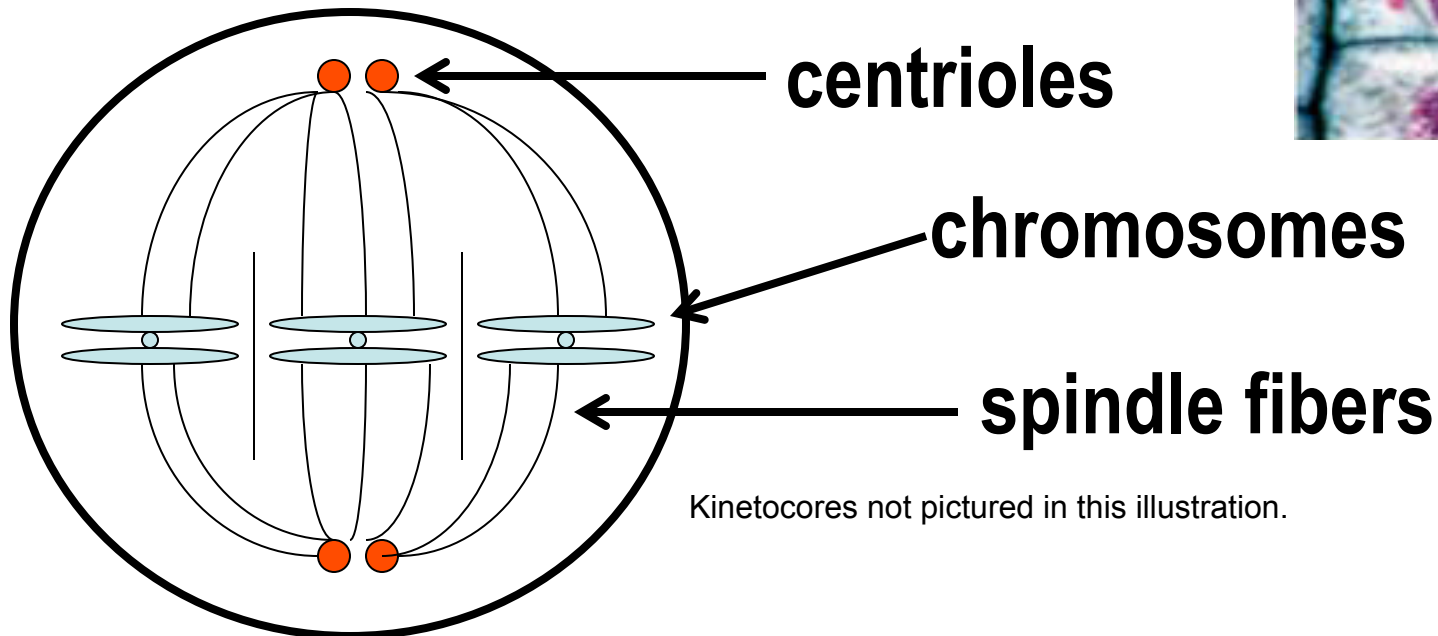
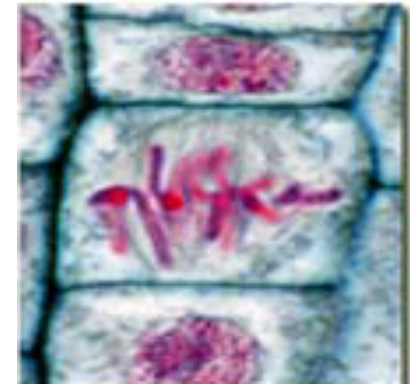


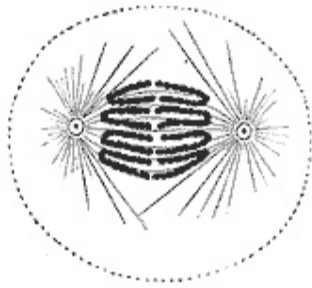


2. Metaphase



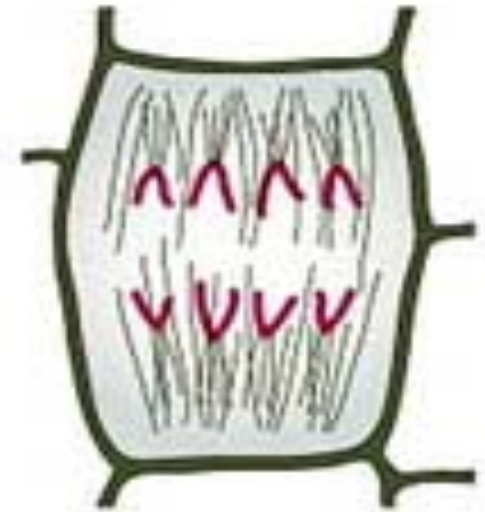
- chromosomes align along equator of the cell, with one kinetochore facing each pole

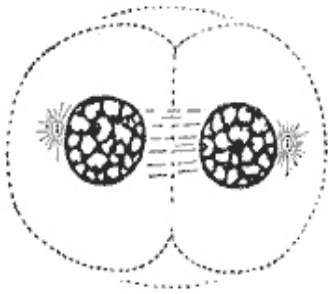




3. Anaphase

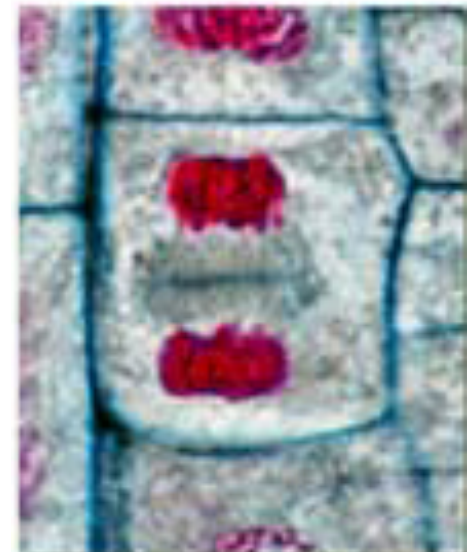
- sister chromatids separate
- spindle fibers attached to kinetochores **shorten** and **pull** chromatids towards the poles.
- free spindle fibers **lengthen** and **push** poles of cell apart

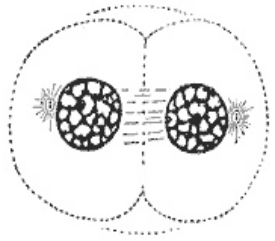




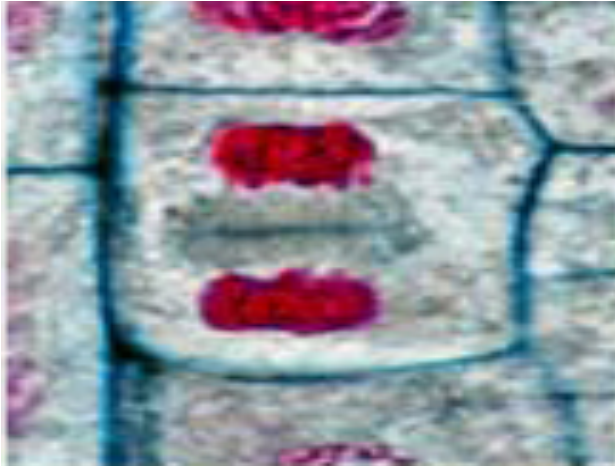
4. Telophase

- 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

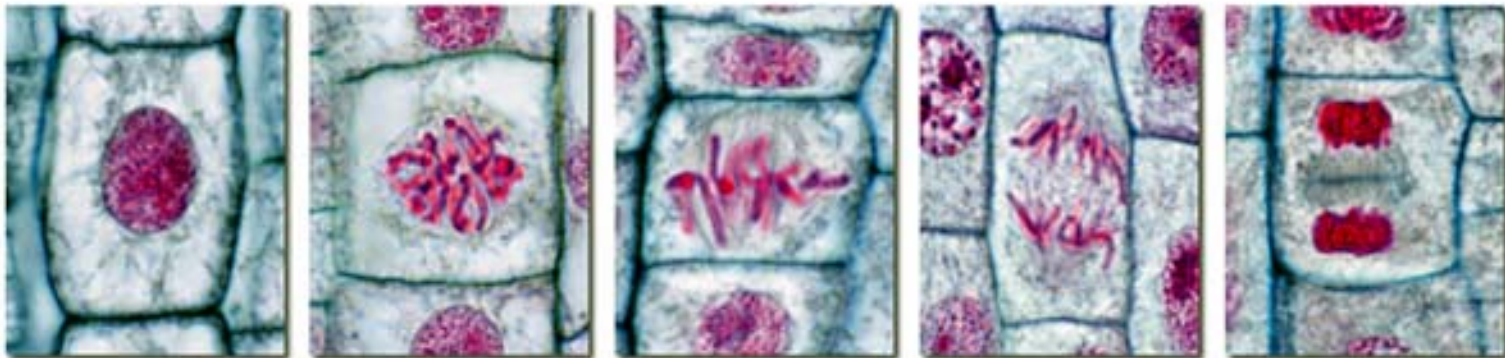
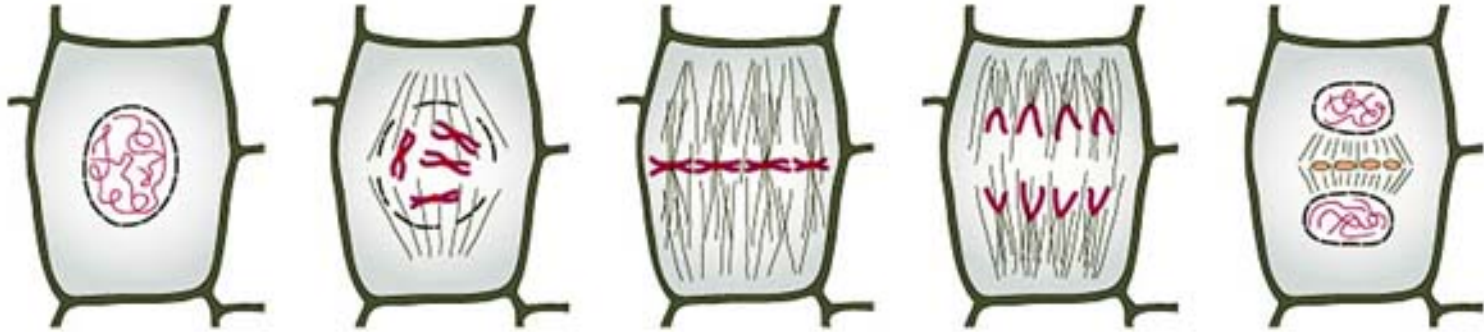


- Plant cells undergo cytokinesis by forming a cell plate between the two daughter nuclei.



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

Stages of Mitosis

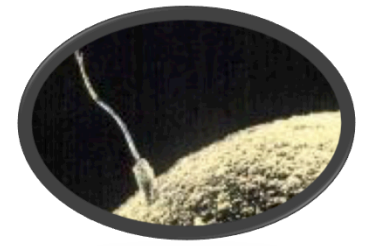


REVIEW!

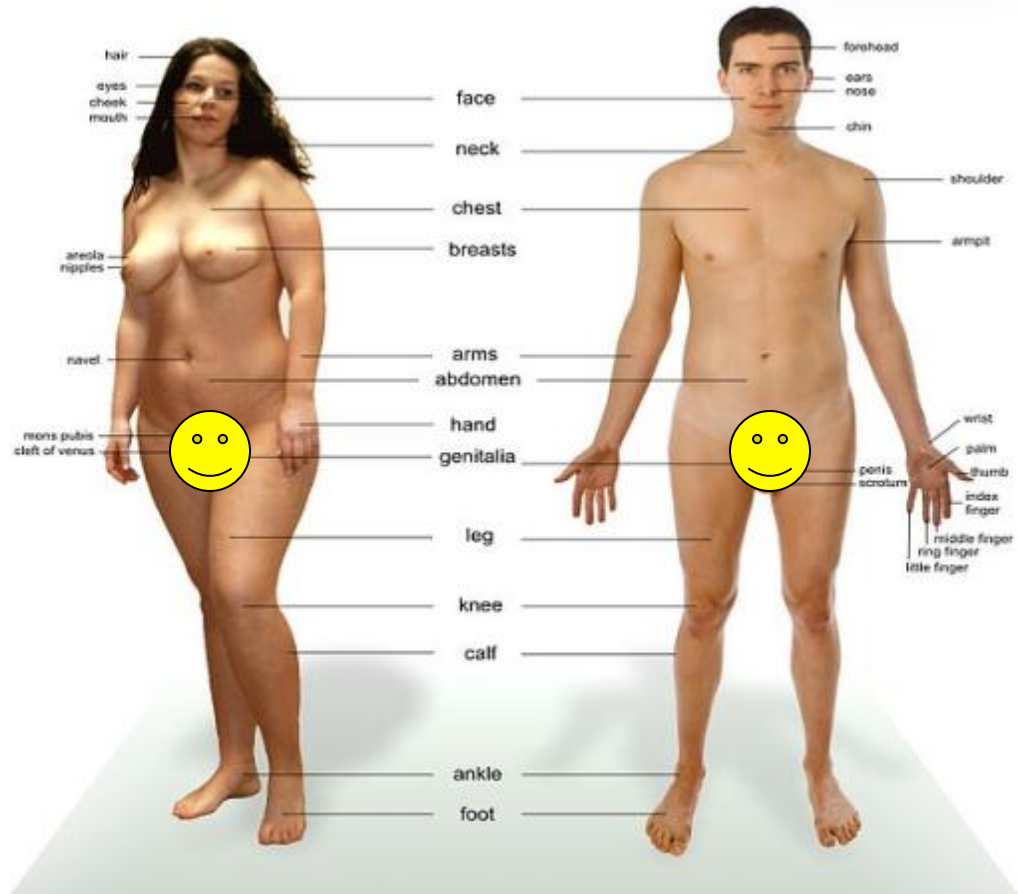
Mitosis Animations

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

Genetics Terminology



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



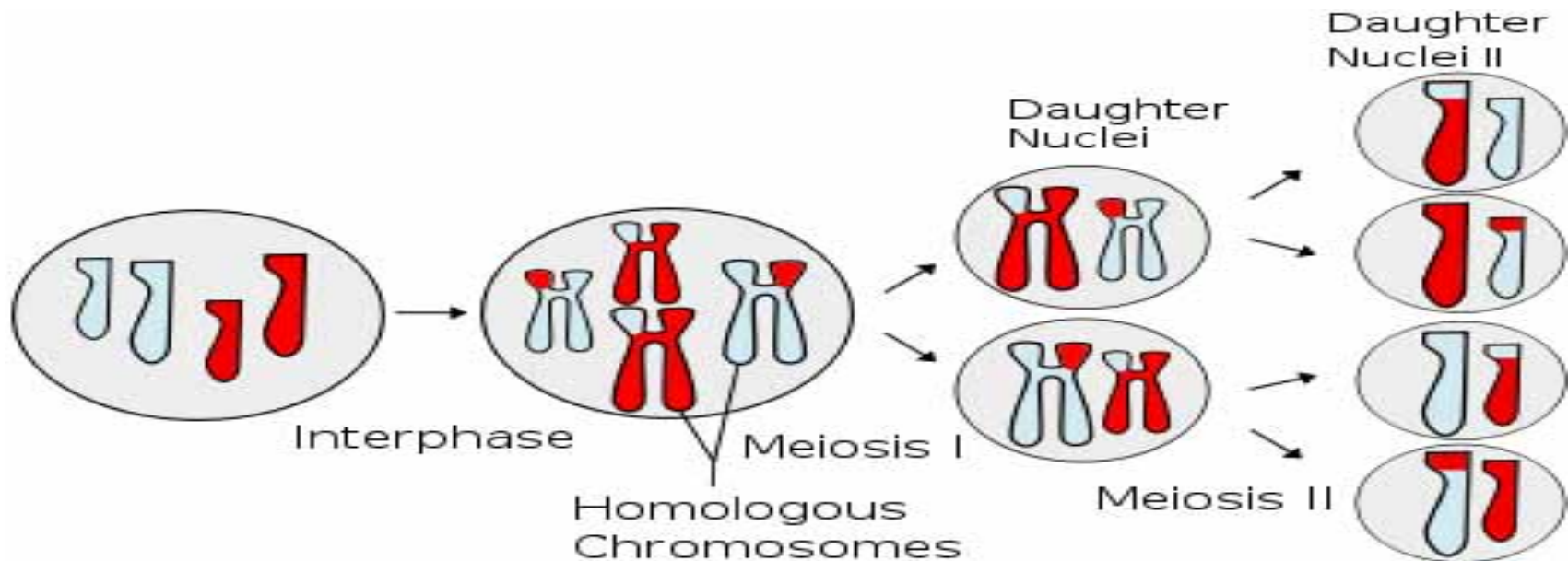
1. somatic cells

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

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**.

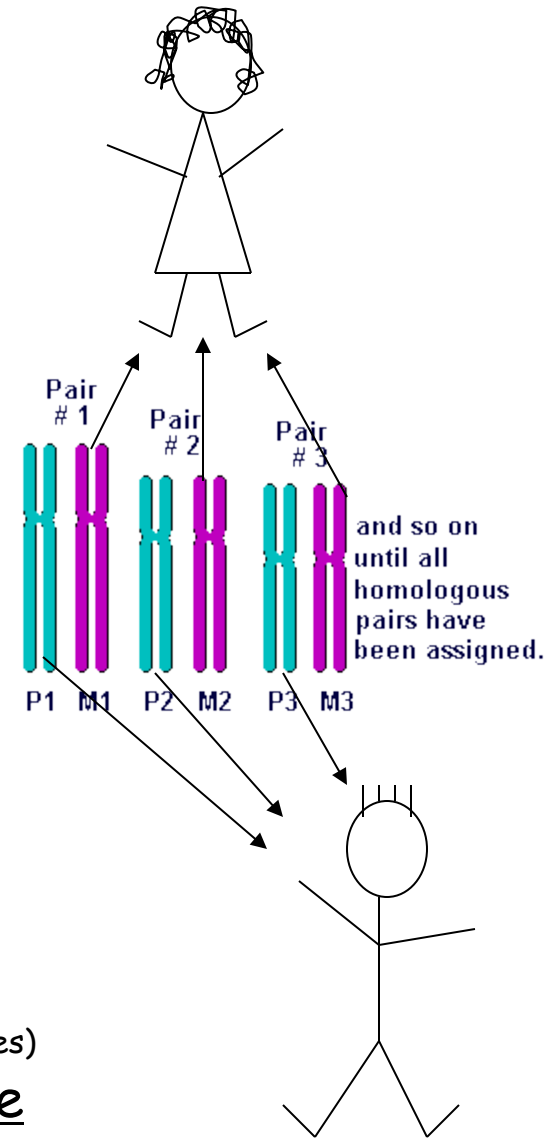


Genetics Terminology: Ploidy

Refers to the number of sets of chromosomes in cells.

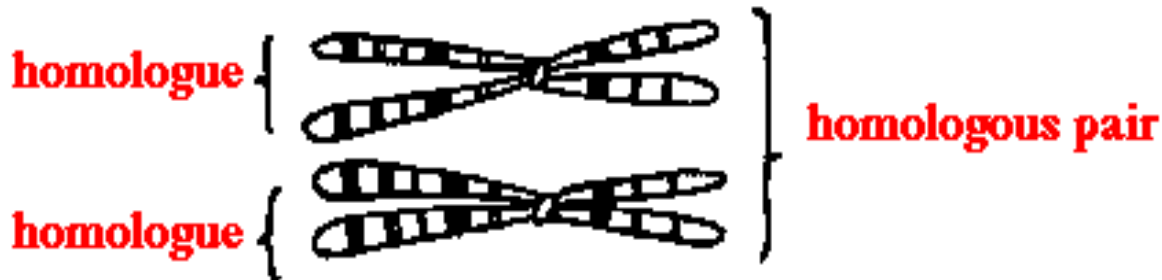
- **Haploid** - one copy of each chromosome
 - designated as "n", the number of chromosomes in one "set"
 - gametes
- **Diploid** - two sets of chromosomes
 - two of each chromosome
 - designated as "2n"
 - somatic cells

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.

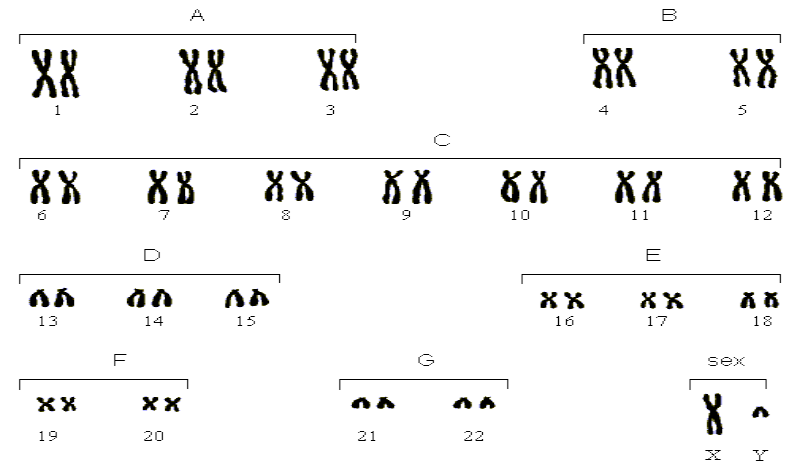
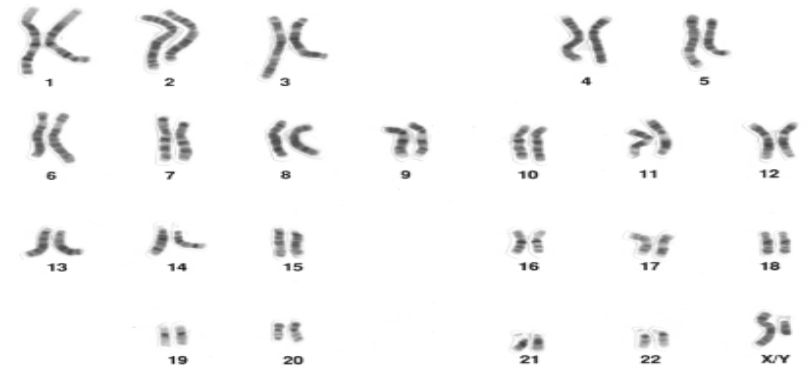


Exception: **Sex chromosomes** (X, Y).

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?



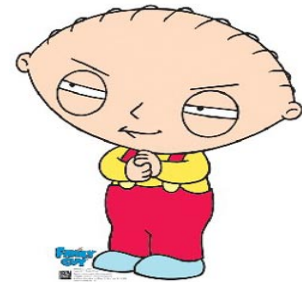
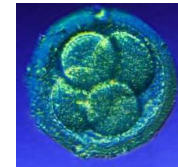
Asexual Reproduction

- Many single-celled organisms reproduce by splitting, budding.
- Some multicellular organisms can reproduce asexually, produce **clones** (*offspring genetically identical to parent*).
- **Q:** What type of cell division is asexual reproduction?



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 ...

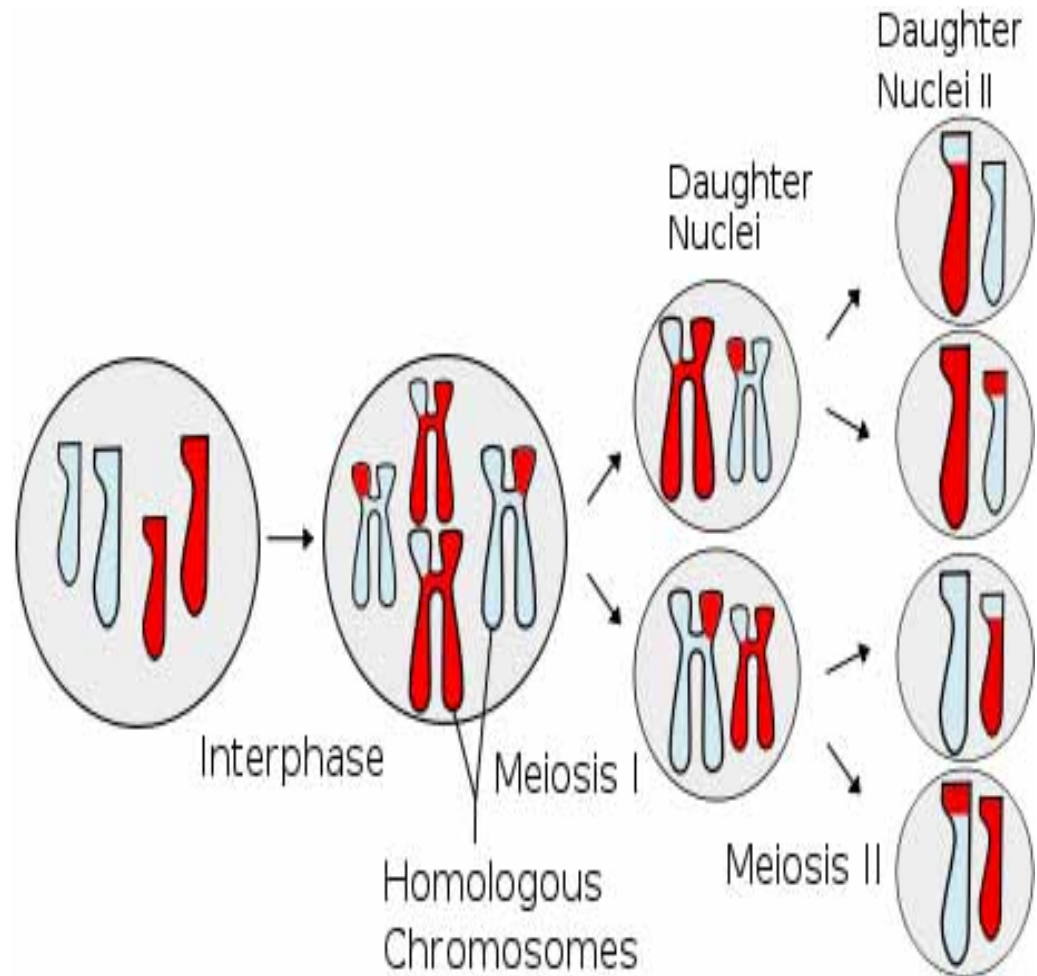
- At fertilization, 23 chromosomes are donated by each parent.
(total = 46 or 23 pairs).
- **Gametes** (sperm/ova):
 - Contain 22 autosomes and 1 sex chromosome.
 - Are haploid (haploid number " n " = 23 in humans).
- Fertilization results in diploid zygote.
 - Diploid cell; $2n = 46$. ($n = 23$ in humans)
- **Q:** Most cells in the body are produced through what type of cell division?
- Only gametes are produced through **meiosis**.

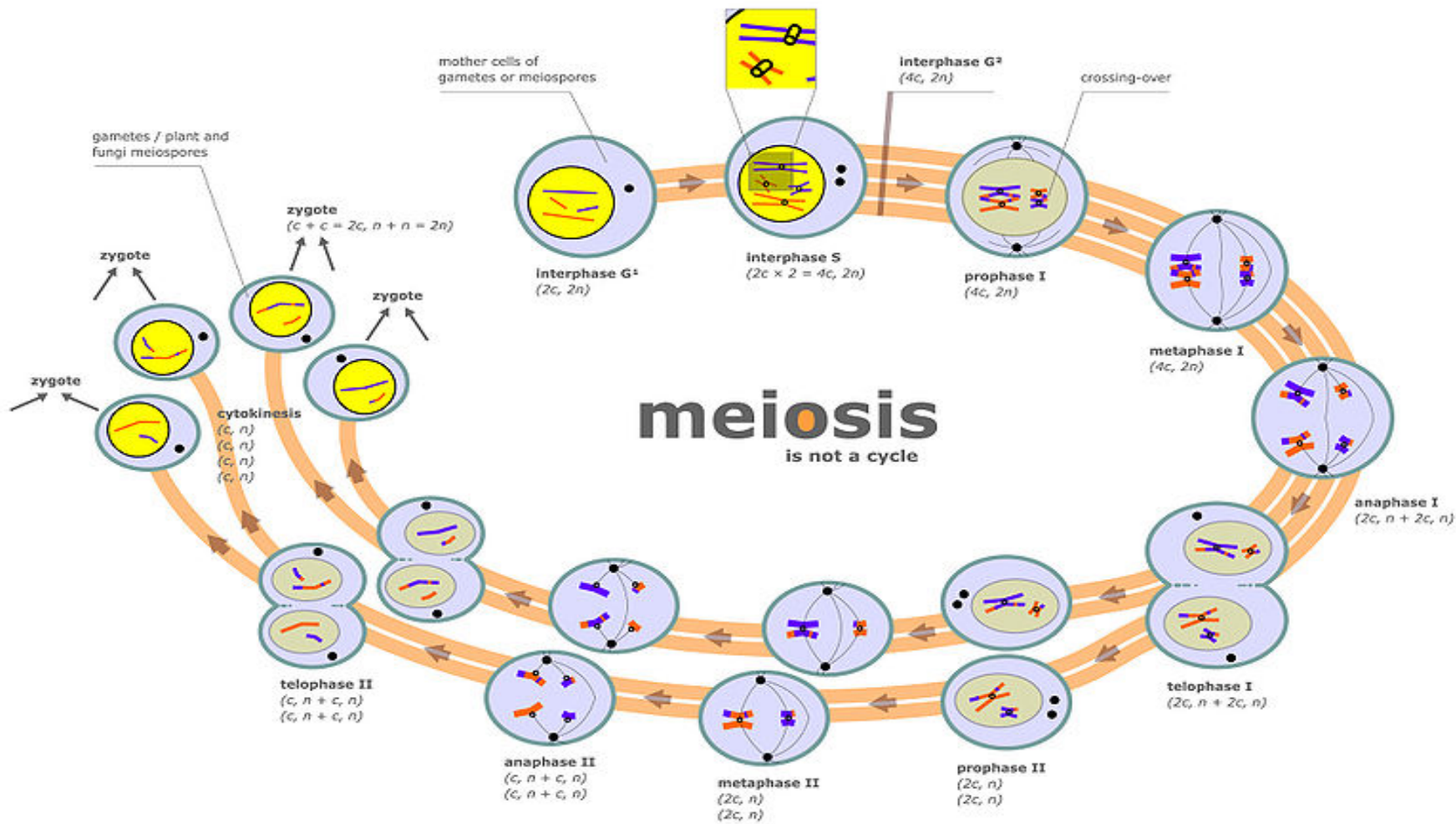


Meiosis - Sex Cell (Gamete) Formation

In meiosis, there are 2 divisions of the nucleus:

meiosis I
&
meiosis II



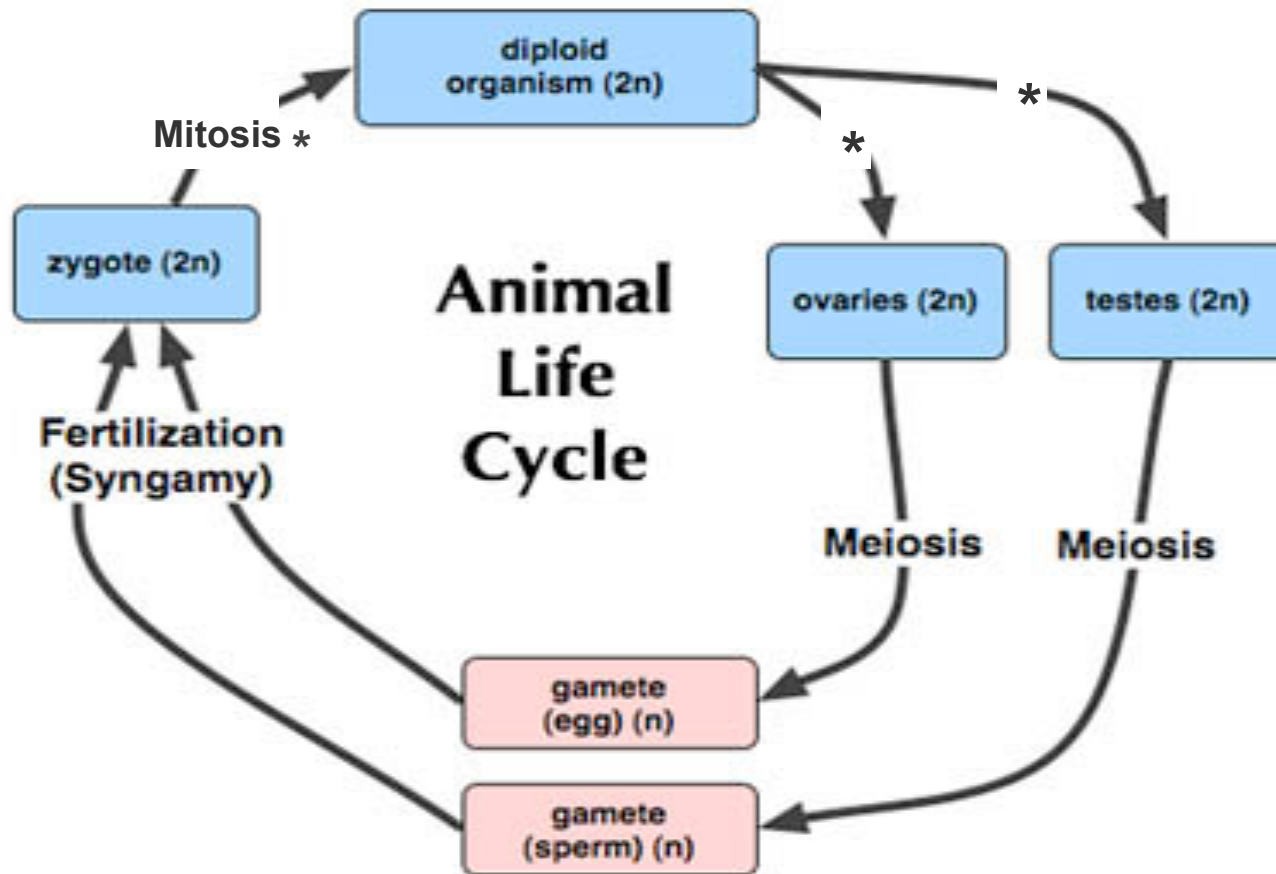


REVIEW!

Meiosis Animations

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

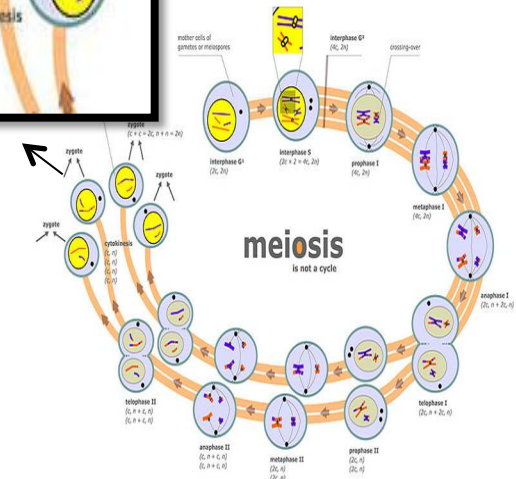
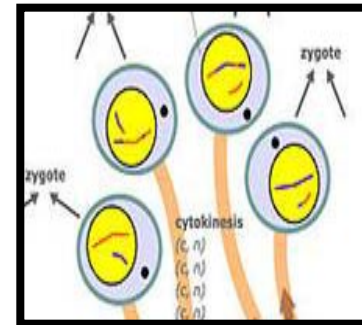
Meiosis & Sexual Reproduction Life Cycle



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

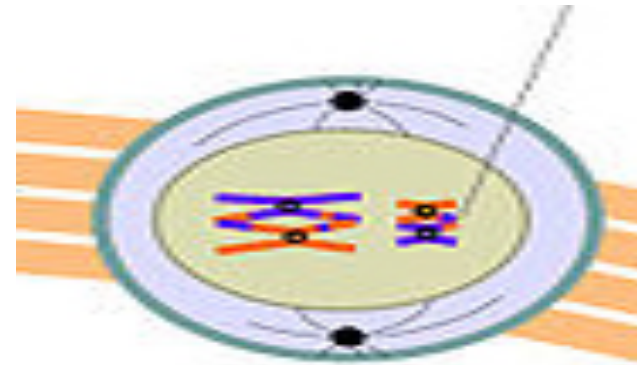
In addition to a new combination of chromosomes resulting from **fertilization**, there are also events in Meiosis I that shuffle the genes.

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.



prophase I
(4c, 2n)

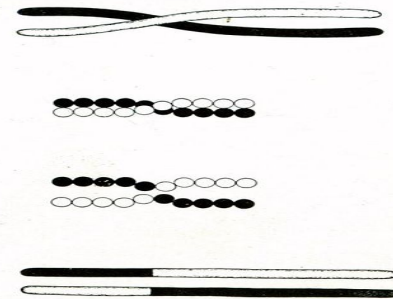
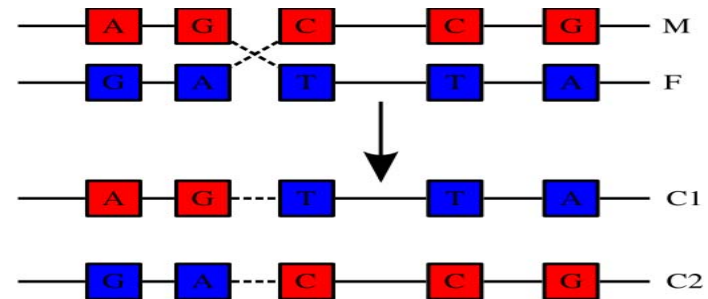
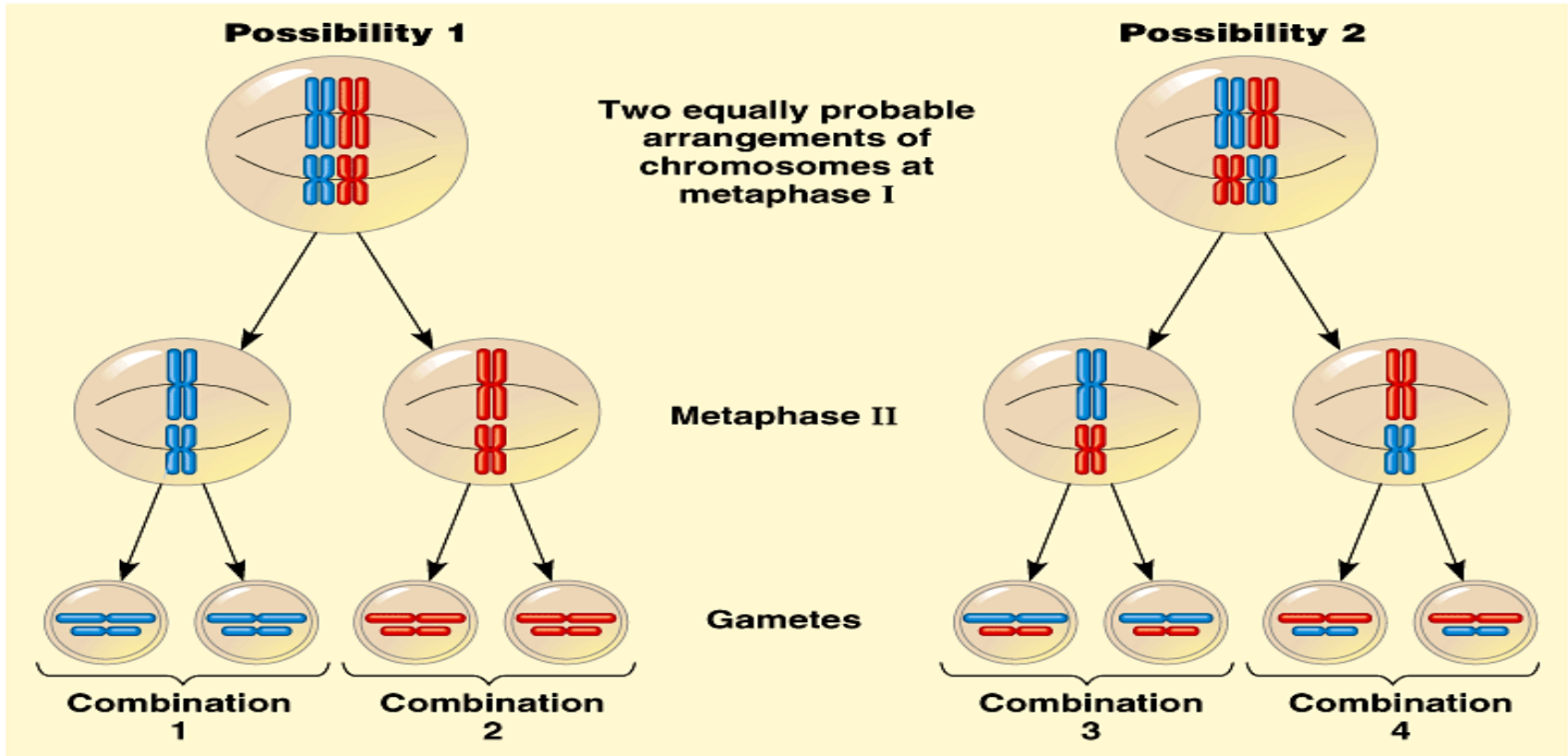


FIG. 64. Scheme to illustrate a method of crossing over of the chromosomes.



Independent Assortment



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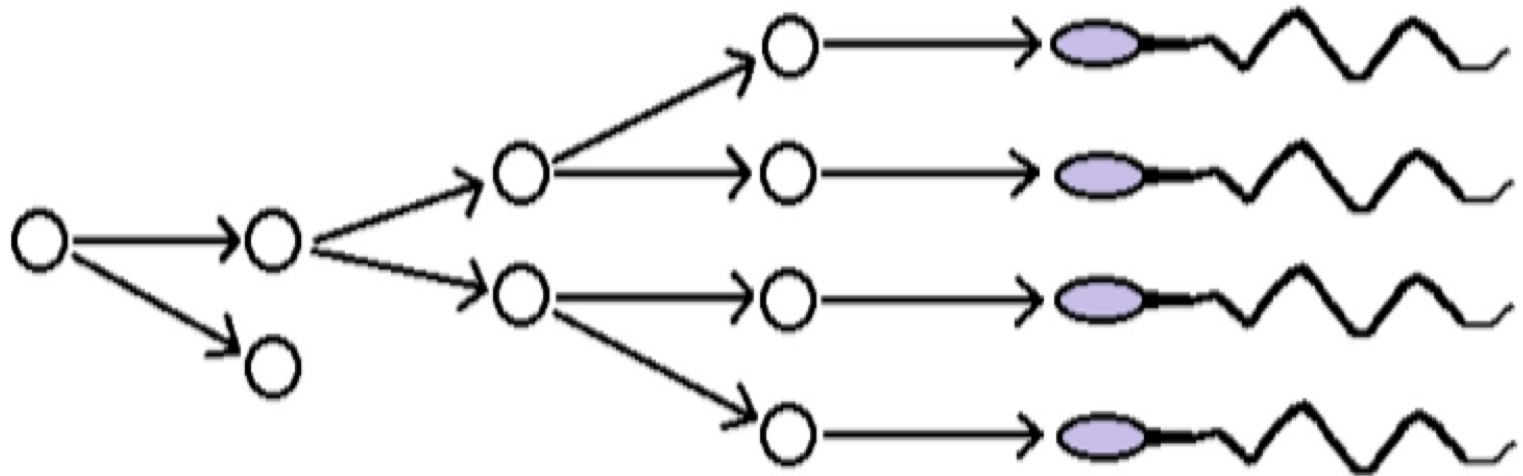
REVIEW!

Independent Assortment Animations

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

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

Spermatogenesis



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)

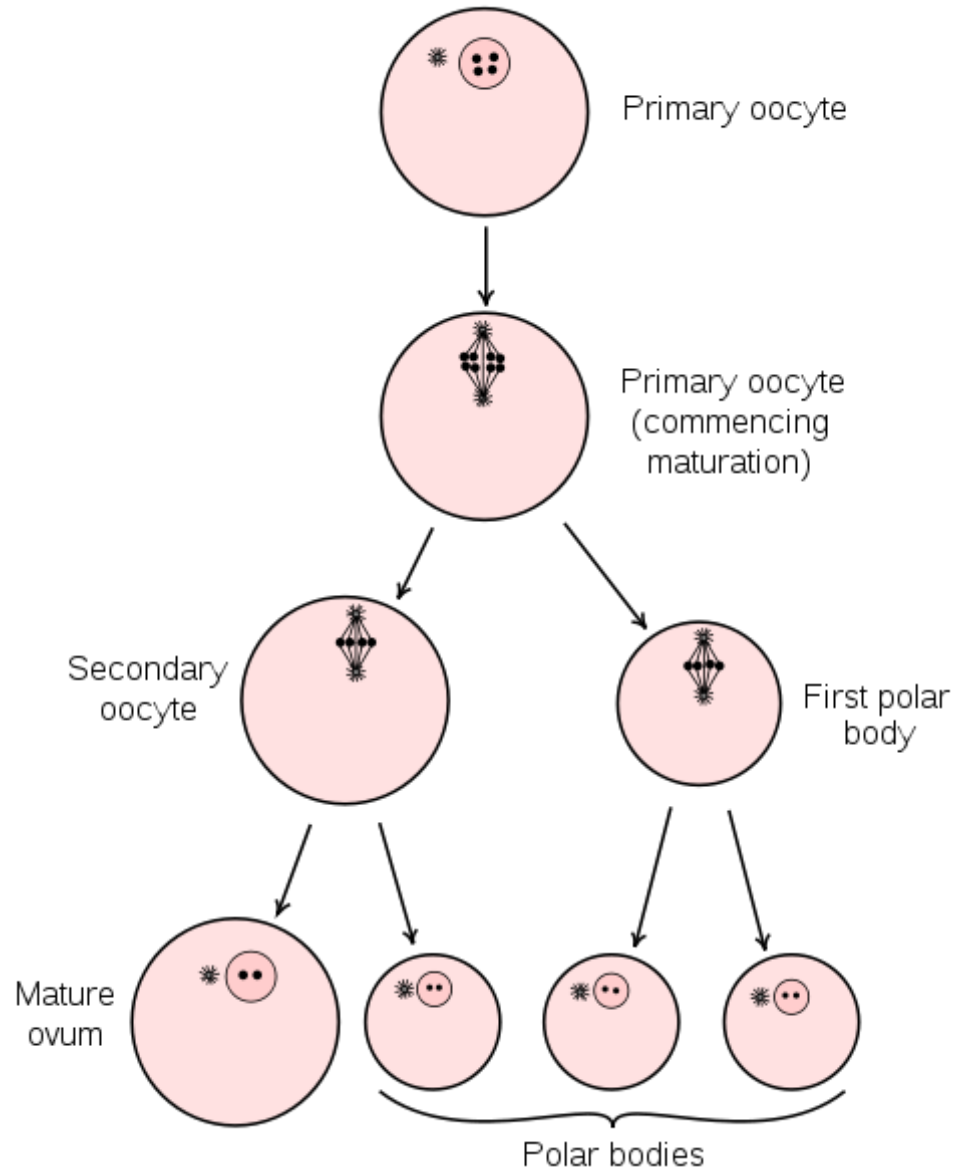
Toyooka et al. (2003)

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

vs.

Meiosis

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



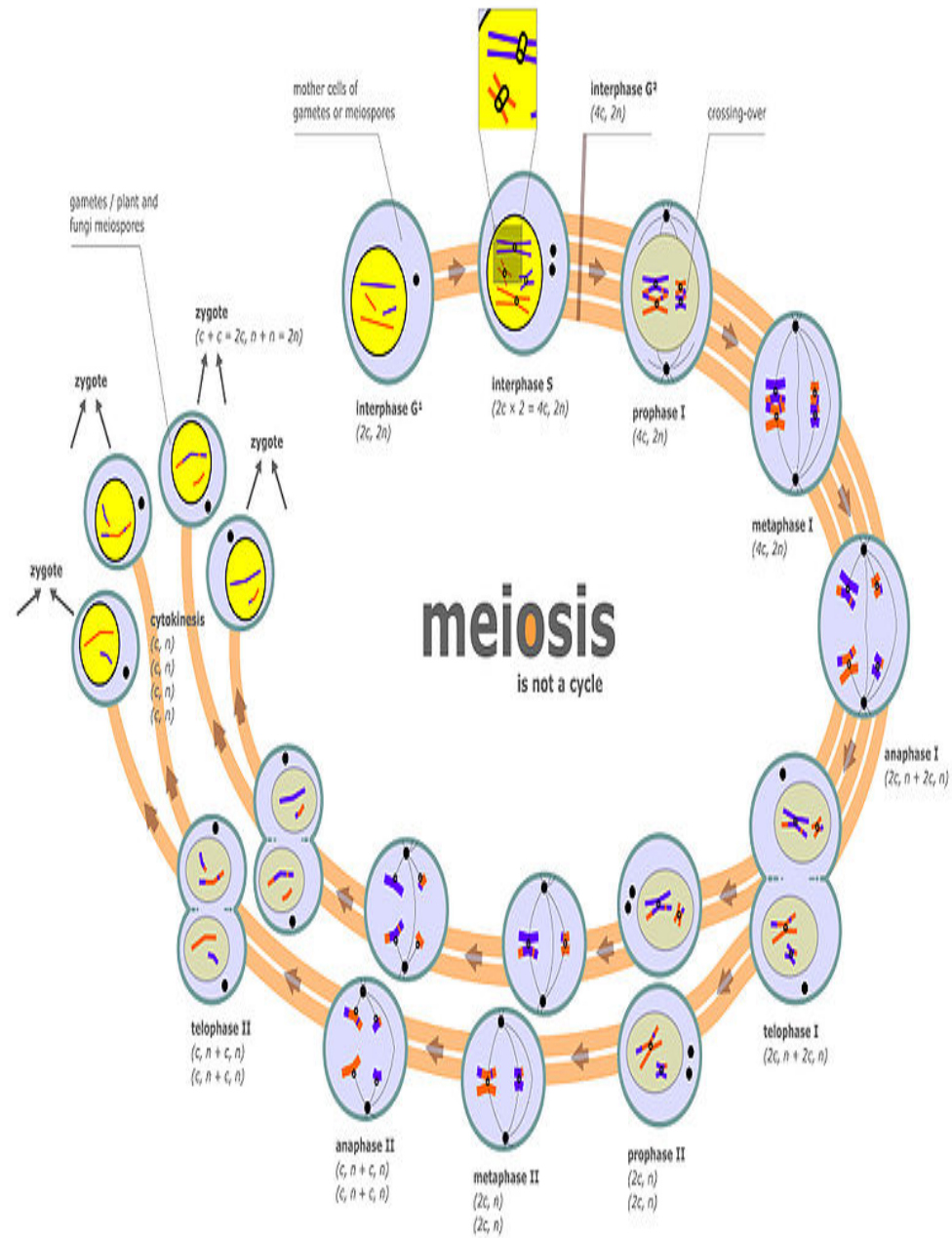
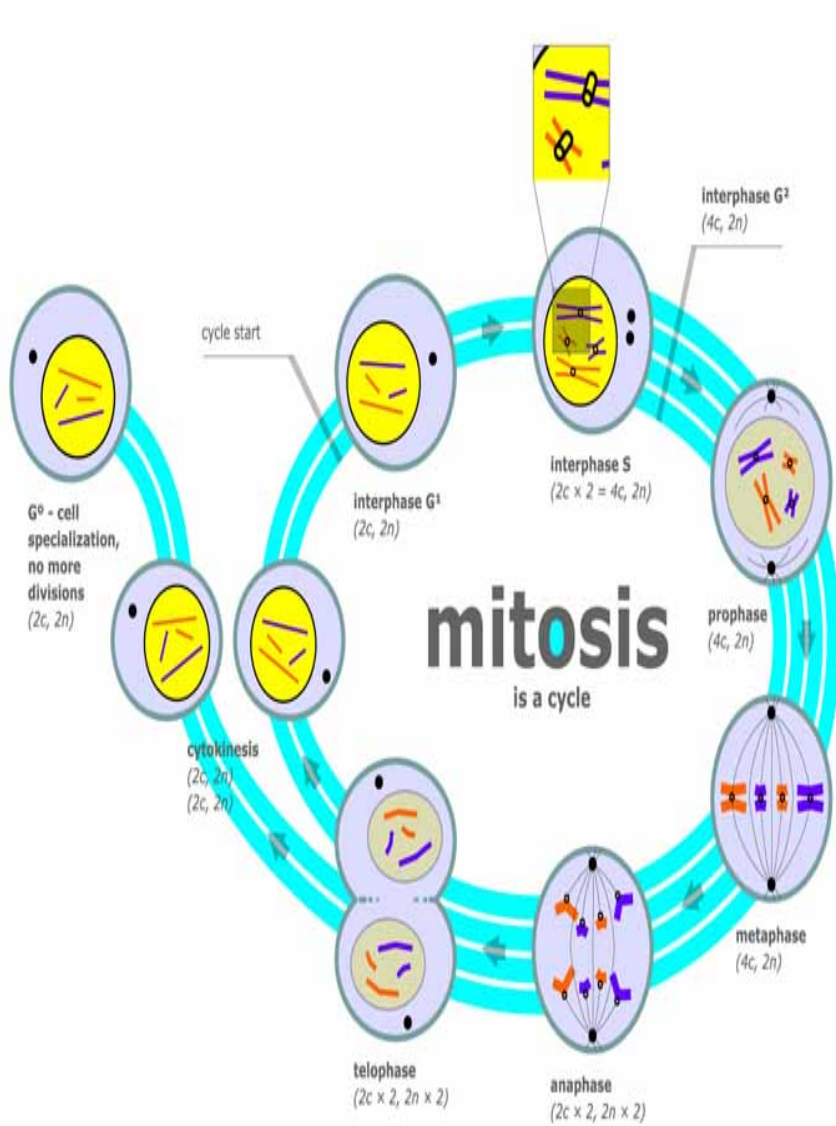
- $1n$
- Daughter cells different from parent cell and from each other.
- Daughter cells have $\frac{1}{2}$ the number of chromosomes as somatic cell.
- Shuffling the genes
(Mix it up!)
- See animation "[Unique Features of Meiosis](#)" from McGraw-Hill

REVIEW!

Animations Comparing Mitosis & Meiosis

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

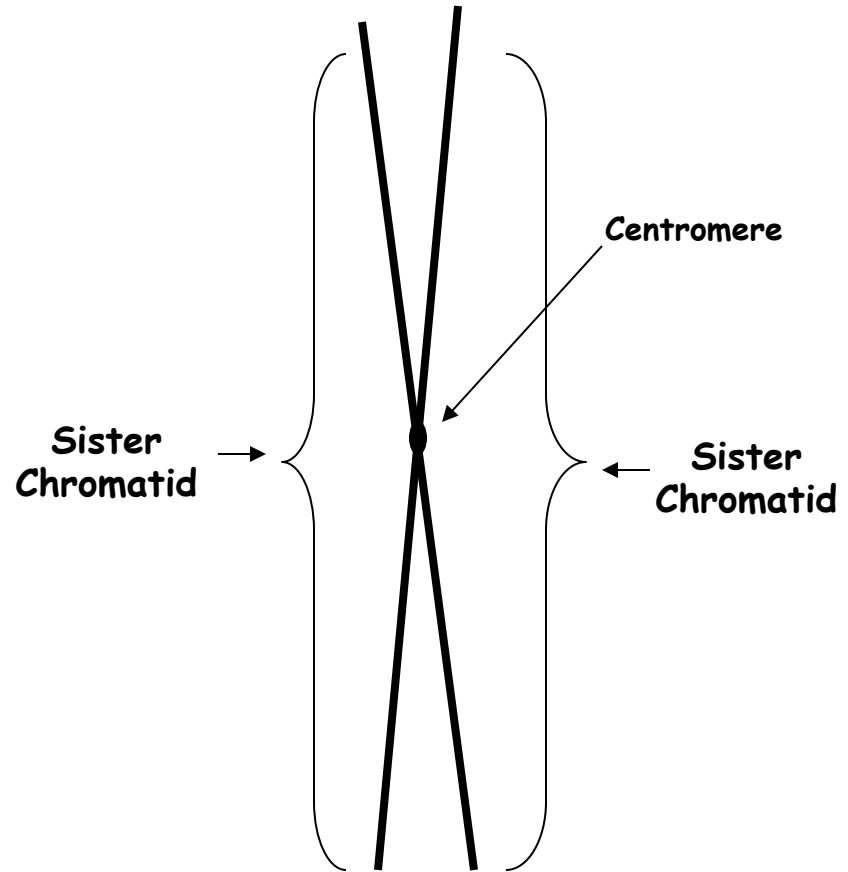
from McGraw-Hill



Drawing and Labeling Chromosomes

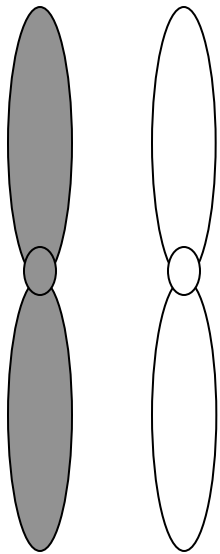


**Unreplicated
Uncondensed
Chromosome
(chromatin)**

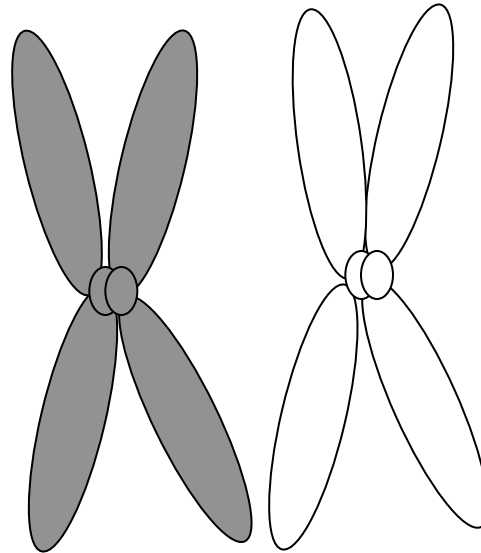


**Replicated
Uncondensed
Chromosome
(chromatin)**

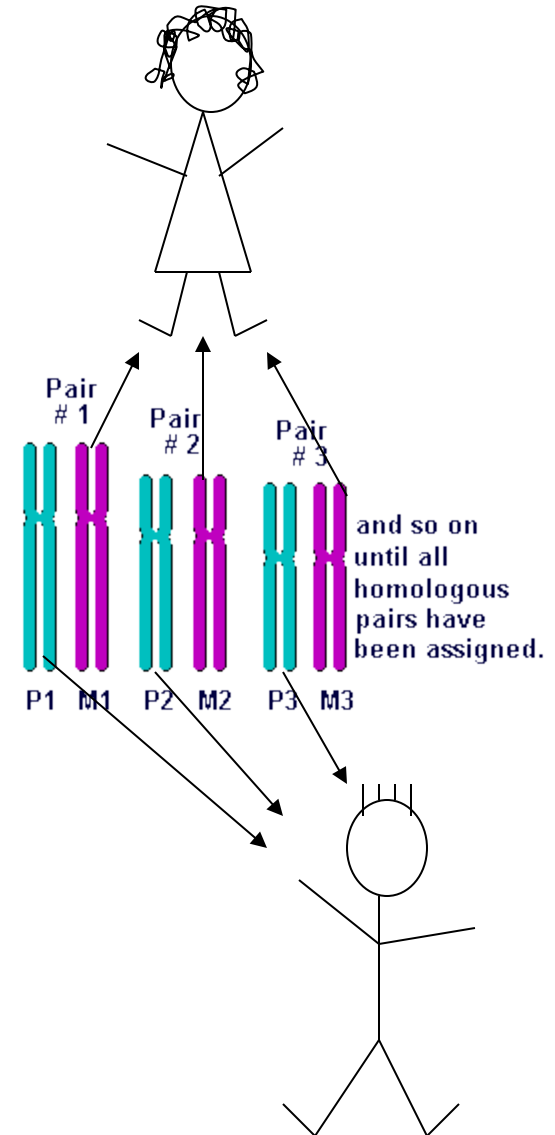
Drawing & Labeling Homologous Chromosomes



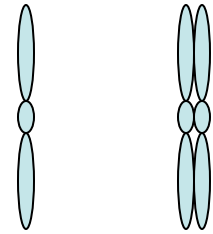
Unreplicated,
Condensed,
Homologous
Chromosomes



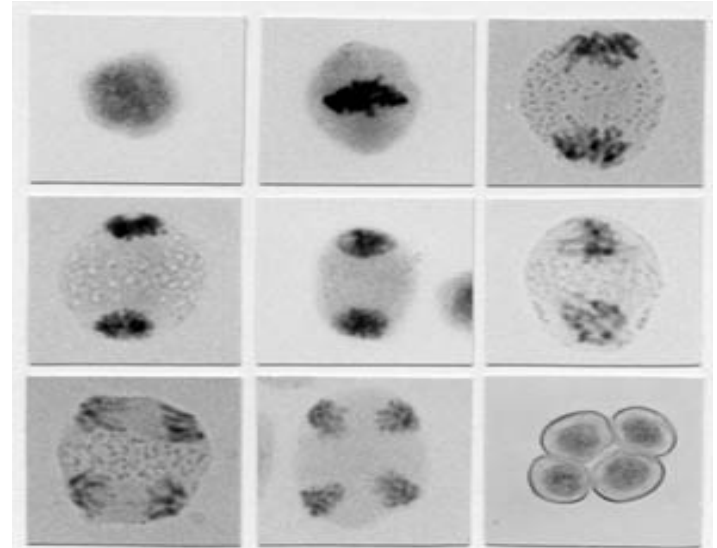
Replicated,
Condensed,
Homologous
Chromosomes



Meiosis Demo & Practice



- Break up into groups & get kit.
- Each kit should have:
 - 6 duplicated chromosomes (3 sets of homologues).
 - 4 pieces of string
 - plastic centromere pieces
- Use chromosome kits to work through the stages of meiosis.
- **BEFORE** you start writing on your *Meiosis Worksheet*, make sure that you have modeled the stages of *Meiosis* with the chromosome kits. (If your group needs help, raise your hand & I will come over assist.)
- Do not depict cross-over in your diagrams. You need to be able to track the journey of each individual chromosome from start to finish.



See the [ScienceProfOnline](https://www.scienceprofonline.com) Virtual Cell Biology Classroom **Genetics: Cell Division - Meiosis & Sexual Reproduction** for a printable Word .doc of this assignment.

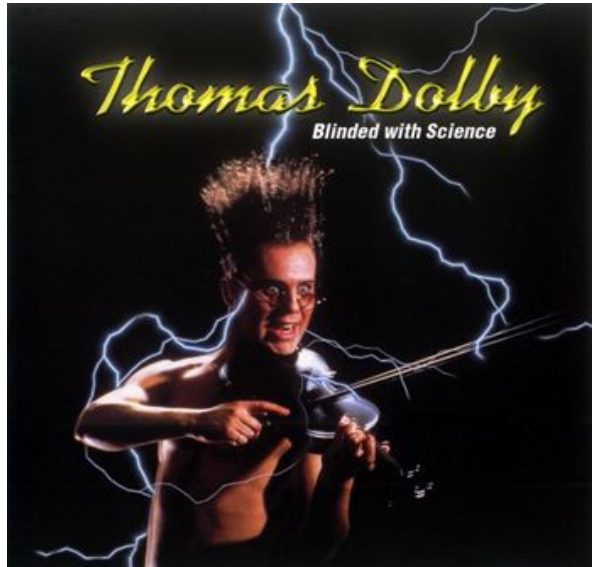
Confused?

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.
- "[X & Y](#)" song by Coldplay
- [Meiosis](#) animation from McGraw-Hill.
- [Independent Assortment](#) animation from Sinauer Associates.
- "[Let's Talk About Sex](#)" music video by Salt 'n' Pepa.

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