

Cellular Division

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Cell Division

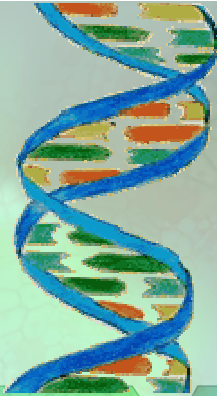
- ✓ All cells are derived from **pre-existing cells**
- ✓ New cells are produced for **growth** and to replace **damaged or old cells**
- ✓ Differs in **prokaryotes** (bacteria & some algae) and **eukaryotes** (protists, fungi, plants, animals, and most algae)

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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**

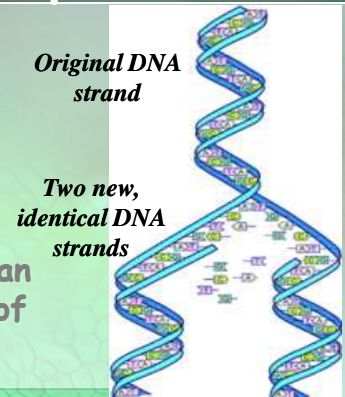


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DNA Replication

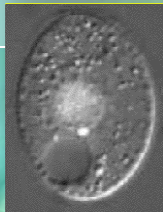
- ✓ DNA must be copied or **replicated** before cell division
- ✓ Each new cell will then have an **identical copy** of the DNA



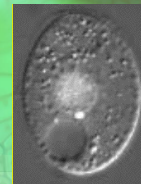
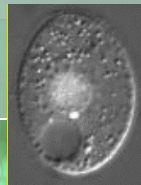
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Identical Daughter Cells



Parent Cell

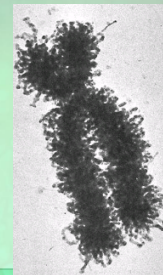


Two identical daughter cells

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Chromosomes

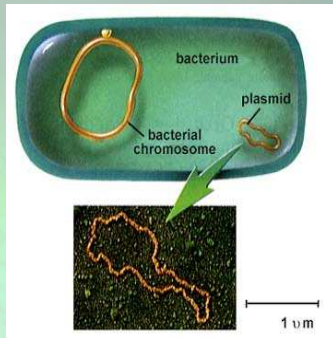


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Prokaryotic Chromosome

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



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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

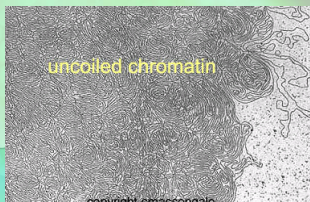


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Eukaryotic Chromosomes

- ✓ 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**

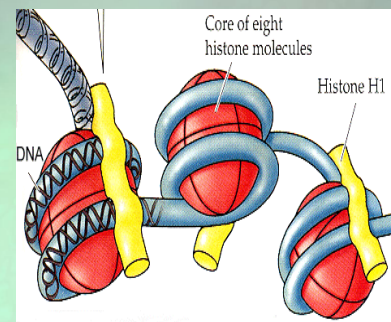


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Compacting DNA into Chromosomes

- ✓ DNA is tightly coiled around **proteins called histones**

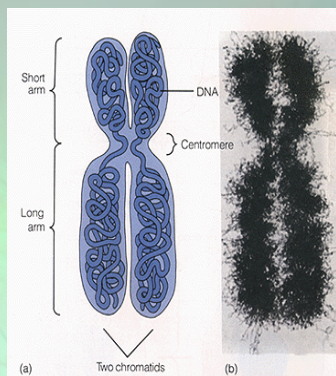


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Chromosomes in Dividing Cells

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



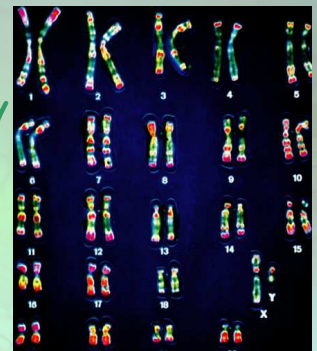
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Called Sister Chromatids

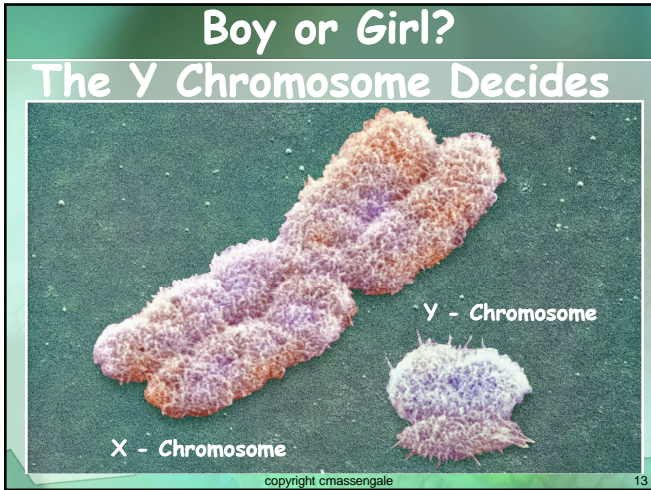
Karyotype

- ✓ 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**



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Types of Cell Reproduction

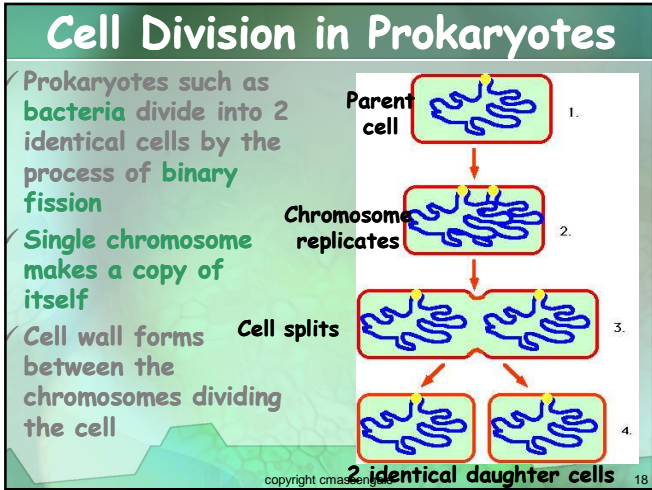
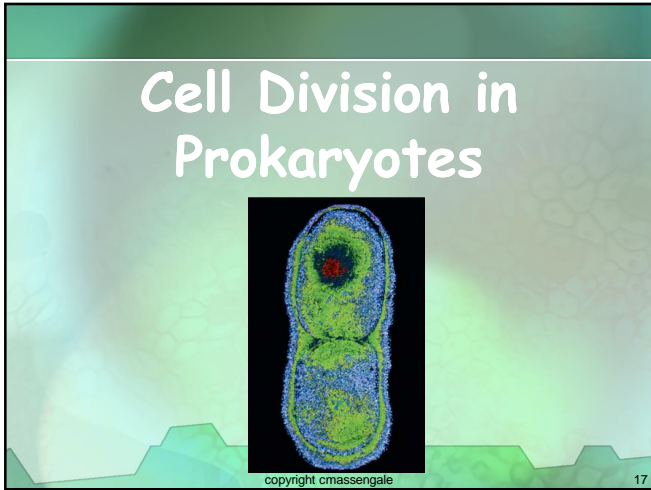
- ✓ **Asexual reproduction** involves a single cell dividing to make 2 new, identical daughter cells
 - Mitosis & binary fission are examples of asexual reproduction
 - Binary fission -> Prokaryotes
 - Mitosis -> Eukaryotes

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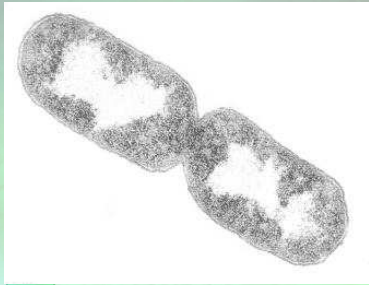
Types of Cell Reproduction

- ✓ **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

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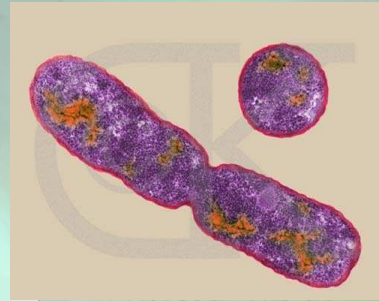
Prokaryotic Cell Undergoing Binary Fission



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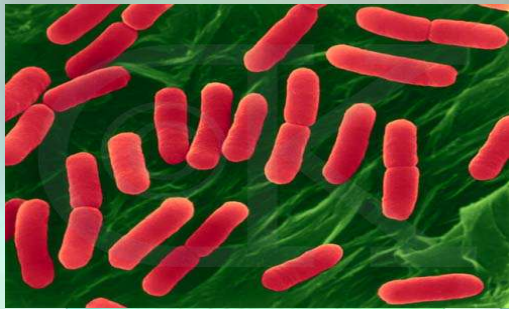
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Binary Fission of Bacterial Cell



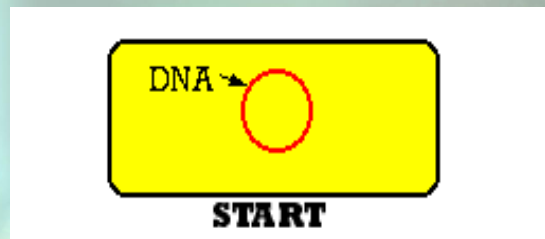
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E. Coli Dividing by Binary Fission



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Animation of Binary Fission



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The Cell Cycle

Asexual cell reproduction of an
eukaryotic cell

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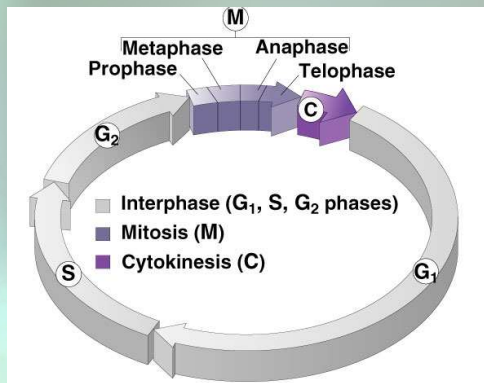
Five Phases of the Cell Cycle

- ✓ 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

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Cell Cycle



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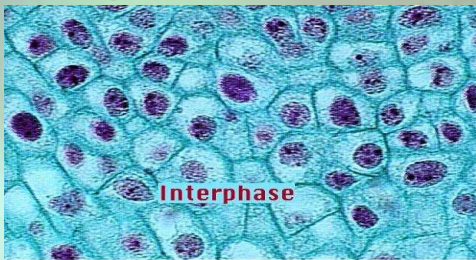
Interphase - "Resting" Stage

- Cells carrying on normal activities
- Chromosomes aren't visible
- Cell metabolism is occurring
- Occurs before mitosis

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Interphase

- Growth Stage 1 (G_1)
- Synthesis Stage (S)
- Growth Stage 2 (G_2)



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Interphase: 1st Growth Stage (G_1)

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

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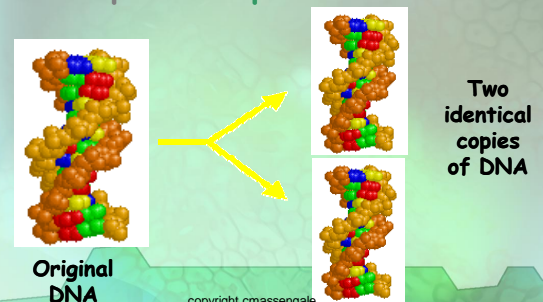
Interphase: 1st Growth Stage (G_1)

- Cytoplasm: Normal Metabolism
 - Protein Synthesis
 - Maintenance of Homeostasis
 - Membrane Transport
 - Intracellular Digestion
 - Photosynthesis & Respiration
 - Etc.
- First growth stage
- Cell increases in size
- Cell prepares to copy its DNA
 - Protein making
 - Energy storage

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Interphase - S Stage

- ✓ Cellular Metabolism continues
- ✓ Synthesis stage
- ✓ DNA is copied or replicated



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Interphase - 2nd Growth Stage (G₂)

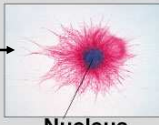
- ✓ 2nd Growth Stage
- ✓ Normal cellular metabolism continues
- ✓ Cell continues to grow
- ✓ Occurs after DNA has been copied but before mitosis
- ✓ All cell structures needed for division are made (e.g. centrioles)
- ✓ Both organelles & proteins are synthesized

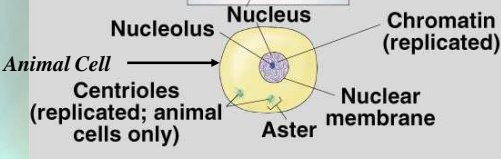
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What's Happening in Interphase?

INTERPHASE (G₂)

What the cell looks like → 

Animal Cell → 

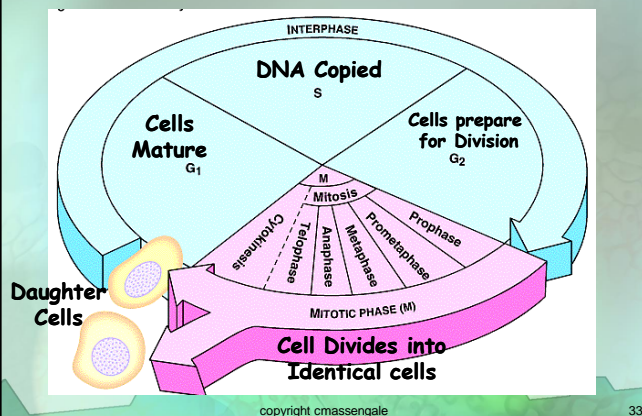
What's occurring →

- DNA replicates
- Centrioles, if present, replicate
- Cell prepares for division

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Sketch the Cell Cycle



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Mitosis

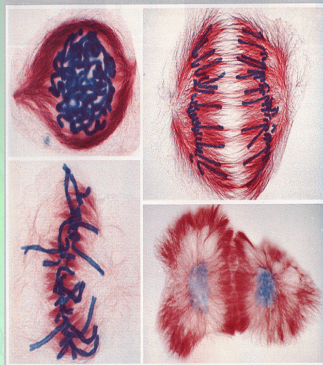


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Mitosis

- ✓ Division of the nucleus
- ✓ Also called karyokinesis
- ✓ Only occurs in eukaryotes
- ✓ Has four stages



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Mitosis Facts

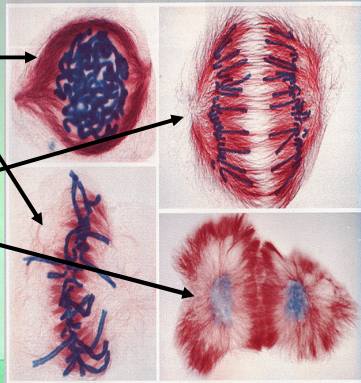
- ✓ Cell growth and protein production stop
 - ✓ Cell energy dedicated to production of 2 daughter cells
 - ✓ Happens in all cells except some that are programmed never to divide such as brain cells
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Four Mitotic Stages

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

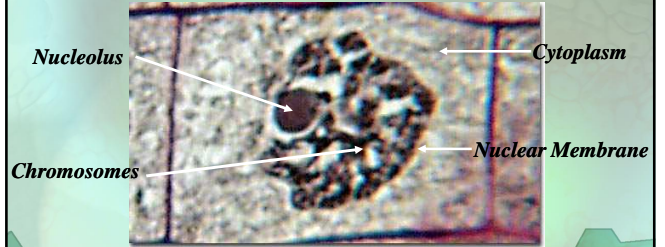


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Early Prophase

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



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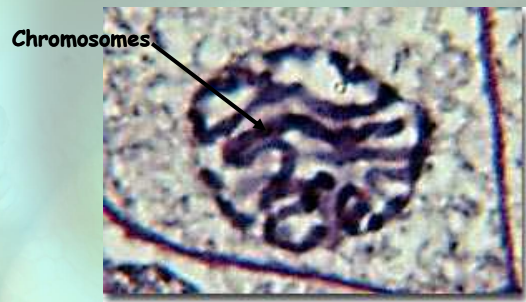
Late Prophase

- ✓ 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

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Late Prophase



Nucleus & Nucleolus have disintegrated

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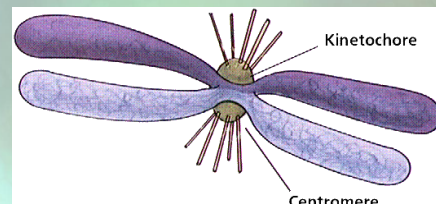
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Prophase

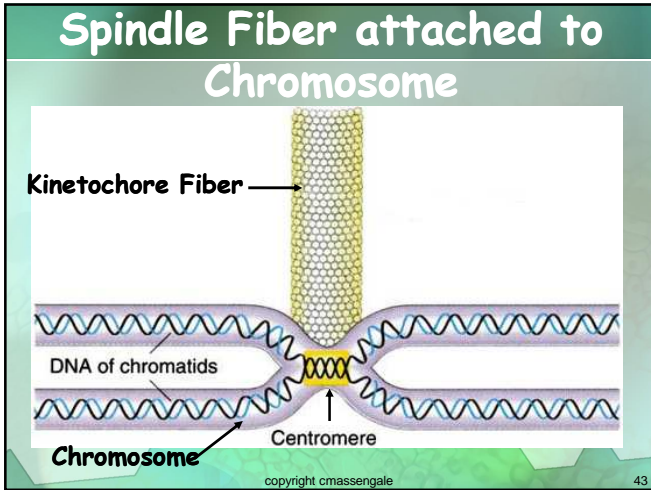


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Eukaryotic Chromosome



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Review of Prophase

Prophase

What the cell looks like

Condensed chromosomes

Mitotic spindle beginning to form

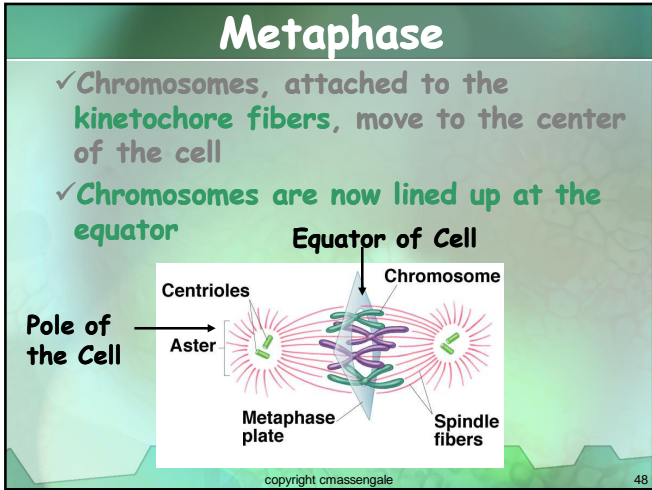
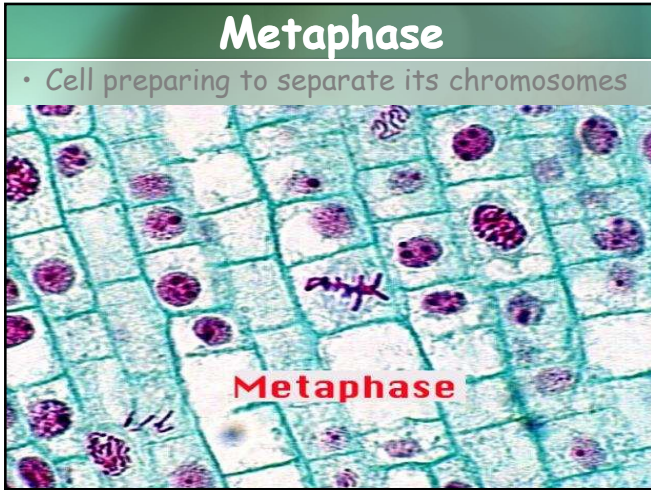
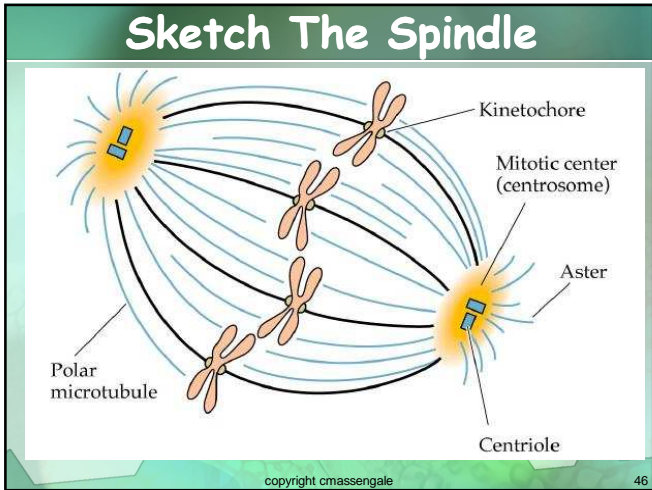
Centromere and kinetochore

- 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

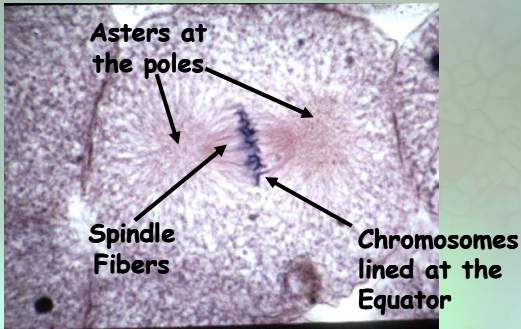
What's happening

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- ### 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
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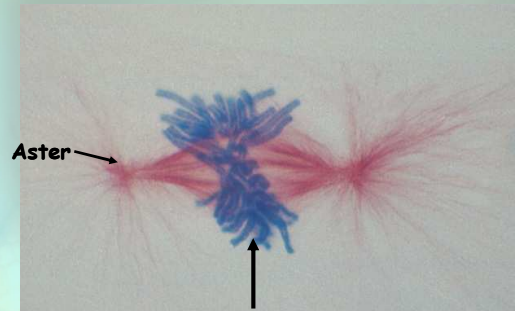
Metaphase



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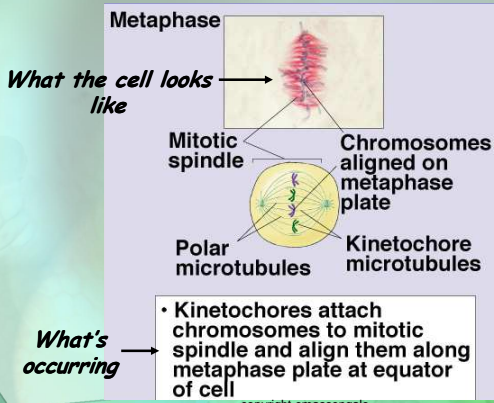
Metaphase



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Review of Metaphase

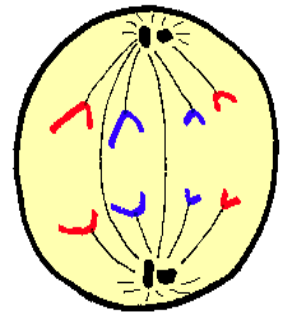


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Anaphase

- ✓ Occurs rapidly
- ✓ Sister chromatids are pulled apart to opposite poles of the cell by shortening kinetochore fibers (chromosomes split)



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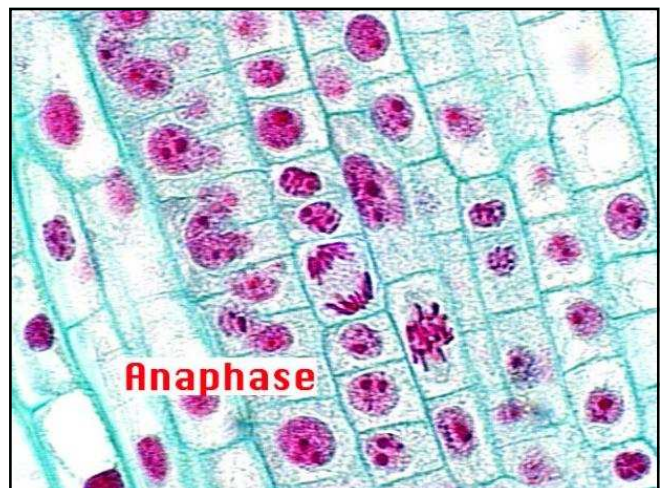
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Anaphase



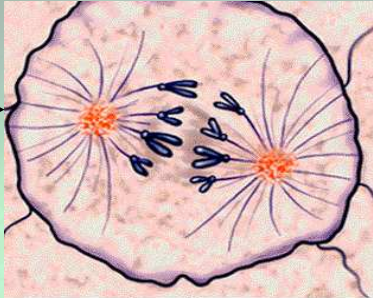
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Anaphase Review

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.

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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

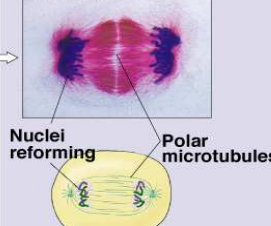
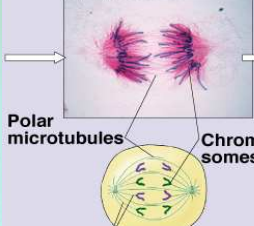
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Comparison of Anaphase & Telophase

Anaphase

Telophase



- Kinetocho microtubules**
- Kinetocho microtubules shorten, separating chromosomes to opposite poles
 - Polar microtubules elongate, preparing cell for cytokinesis

- Chromosomes reach poles of cell
- Kinetochores disappear
- Polar microtubules continue to elongate, preparing cell for cytokinesis
- Nuclear membrane re-forms
- Nucleolus reappears
- Chromosomes decondense

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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

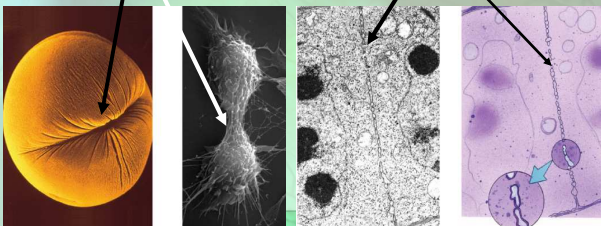
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Cytokinesis

Cleavage furrow in animal cell

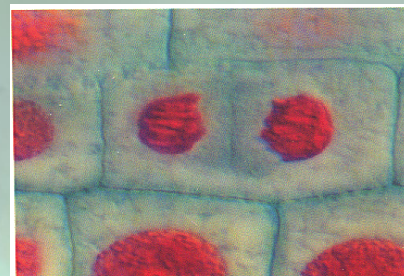
Cell plate in plant cell



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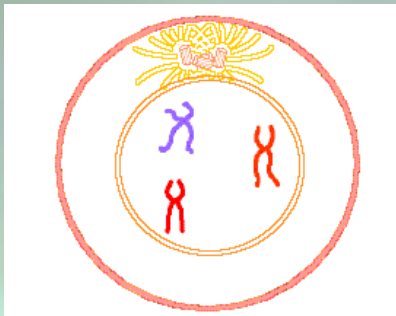
Cytokinesis



Cell Plate Forming in Plant Cells

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Mitotic Stages

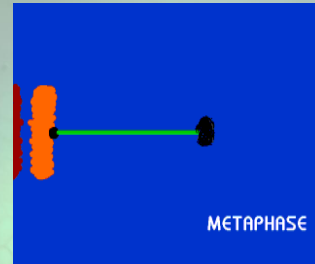


- Prophase:**
- condensation of chromosomes
 - disappearance of nucleoli and nuclear envelope

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Life Cycle of a Cell (Cell Stages)



Mitosis is a cycle with no beginning or end.

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The Cell Cycle

- The sequence of growth and division of a cell.
- 95% of cell cycle in Interphase
- 5% of cell cycle in mitosis

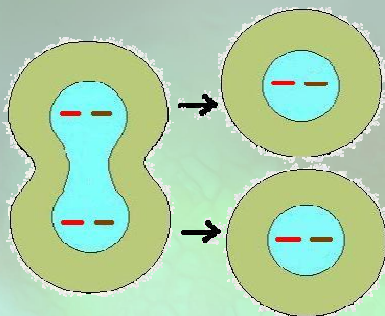
Daughter Cells of Mitosis

- ✓ 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)

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Identical Daughter Cells



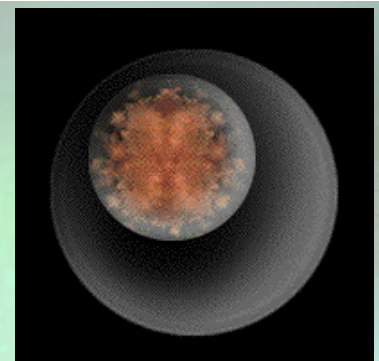
What is the $2n$ or diploid number?
2

Chromosome number the same, but cells smaller than parent cell

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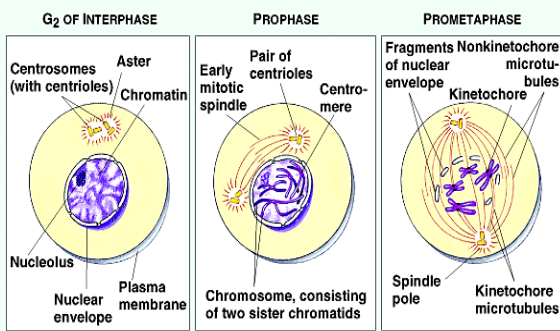
Review of Mitosis



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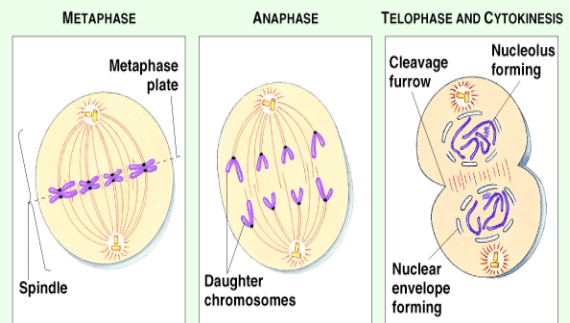
Draw & Learn these Stages



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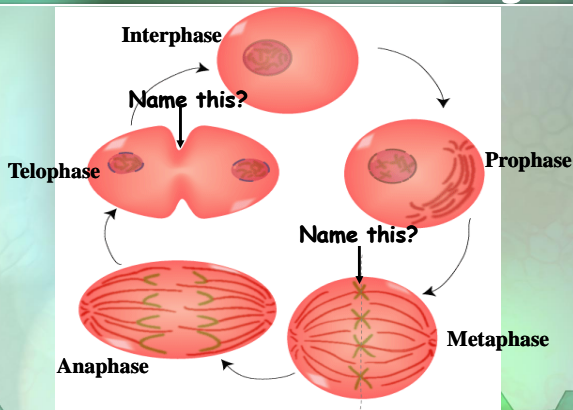
Draw & Learn these Stages



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Name the Mitotic Stages:

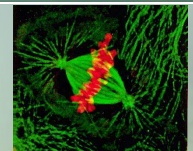


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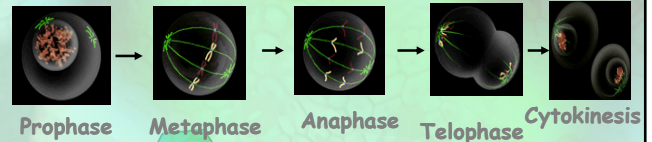
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Eukaryotic Cell Division

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



Chromosomes during Metaphase of mitosis

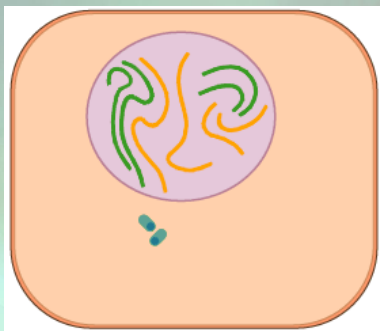


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Mitosis Animation

Name each stage as you see it occur?

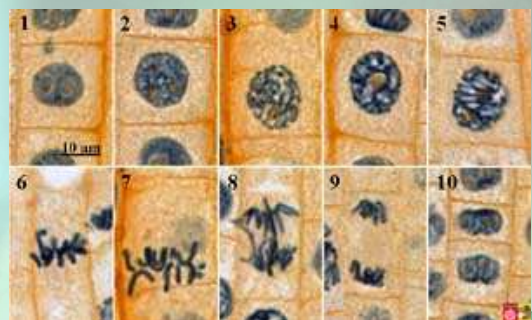


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Mitosis in Onion Root Tips

Do you see any stages of mitosis?



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Test Yourself over Mitosis

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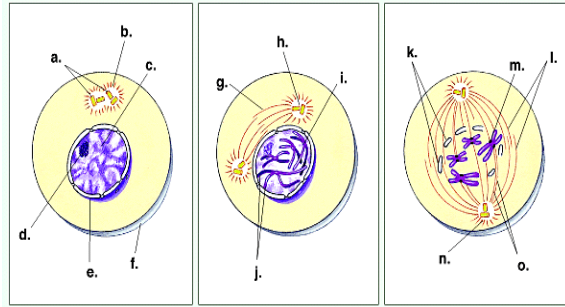
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Mitosis Quiz

G₂ OF INTERPHASE

PROPHASE

PROMETAPHASE



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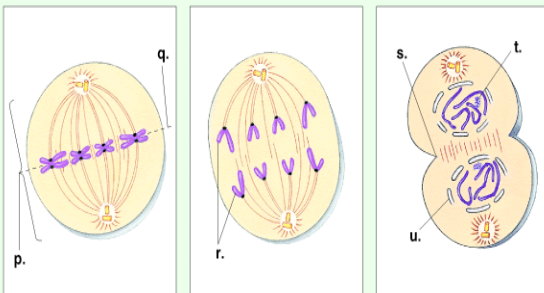
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Mitosis Quiz

METAPHASE

ANAPHASE

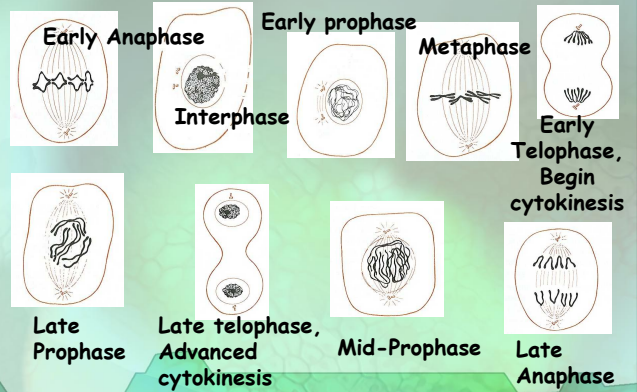
TELOPHASE AND CYTOKINESIS



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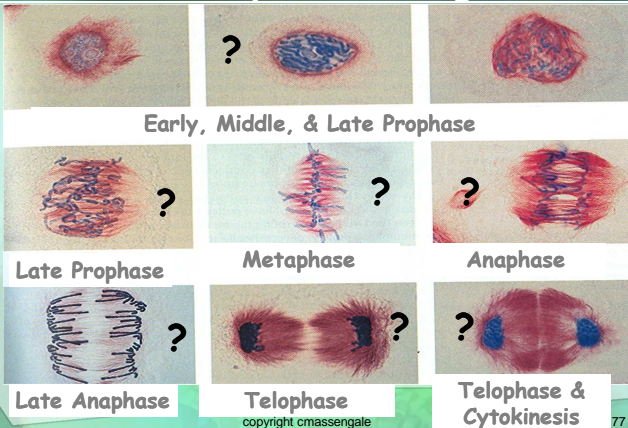
Name the Stages of Mitosis:



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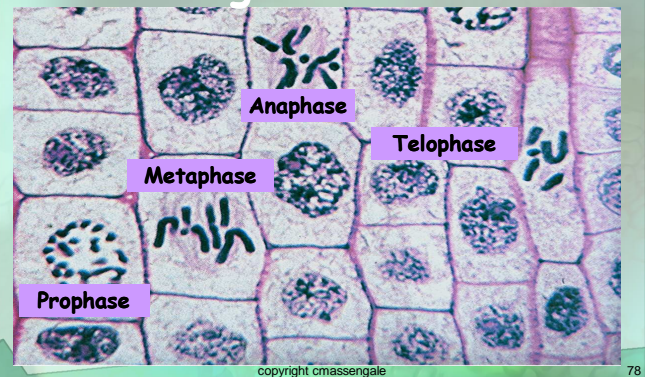
Identify the Stages



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Locate the Four Mitotic Stages in Plants

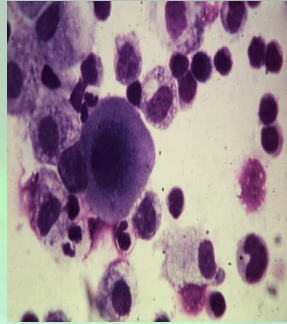


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Uncontrolled Mitosis

- ✓ 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**

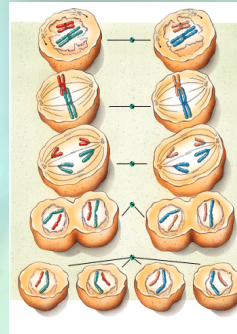


Cancer cells

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Meiosis



*Sexual Cellular
Reproduction*

*Formation of Gametes
(Eggs & Sperm)*

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Facts About Meiosis

- ✓ Preceded by interphase which includes **chromosome replication**
- ✓ Involves **Two** meiotic divisions --- **Meiosis I and Meiosis II**
- ✓ Called **Reduction- division**

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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

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Facts About Meiosis

- ✓ **Original cell is diploid (2n)** - Normal amount of genetic material; 2 copies of each chromosome type (pairs)
- ✓ **Four daughter cells** produced that are **haploid or monoploid (1n)** - $\frac{1}{2}$ of the genetic information of original cell; 1 copy of each chromosome type (no pairs)

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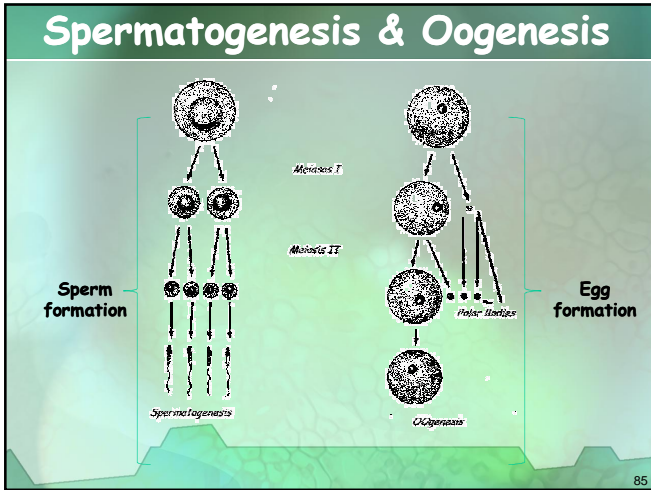
83

Facts About Meiosis

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

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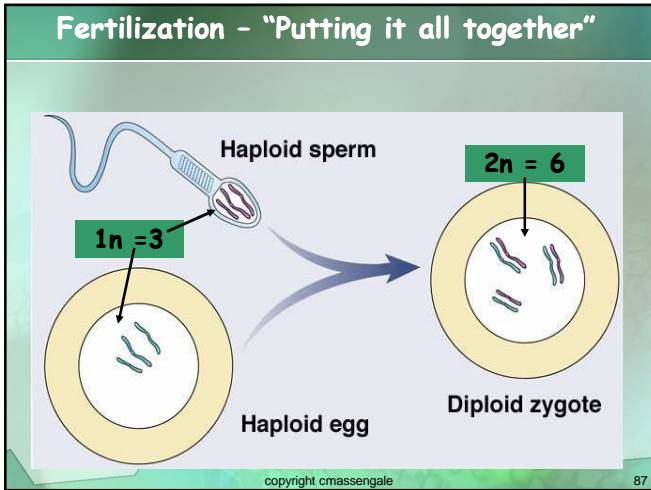
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Why Do we Need Meiosis?

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

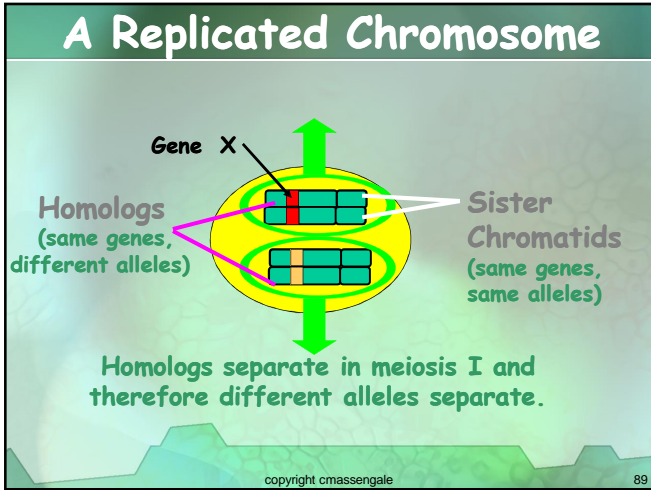
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Replication of Chromosomes

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

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Meiosis Forms Haploid Gametes

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

from mom + from dad = child (too much!)

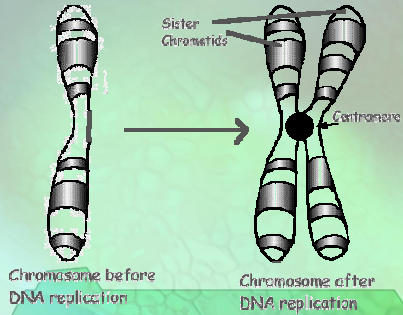
meiosis reduces genetic content

from mom + from dad = child (The right number!)

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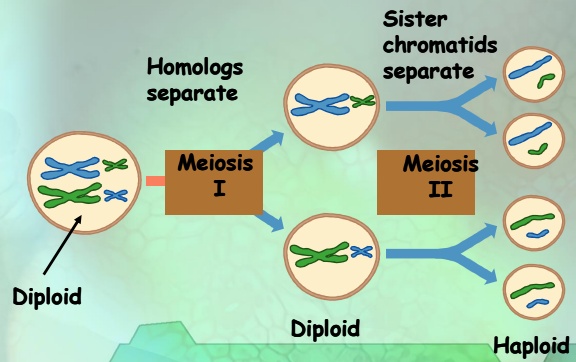
Getting Ready for Meiosis

- Prior to division (**S phase**), amount of **DNA doubles**



91

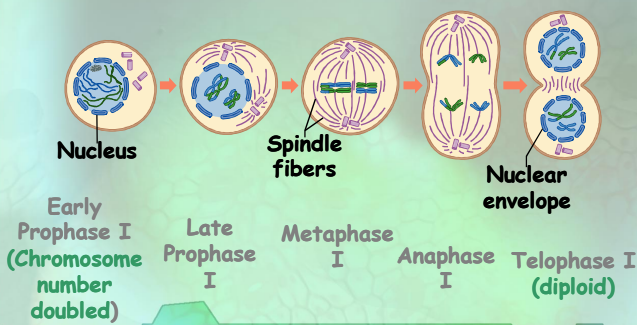
Meiosis: Two Part Cell Division



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Meiosis I: Reduction Division



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Prophase I



Early prophase
 ✓ Homologs pair.
 ✓ Crossing over occurs.

Late prophase
 ✓ Chromosomes condense.
 ✓ Spindle forms.
 ✓ Nuclear envelope fragments.

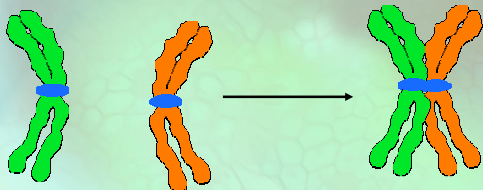
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Tetrads Form in Prophase I

Homologous chromosomes (each with sister chromatids)

Join to form a **TETRAD**

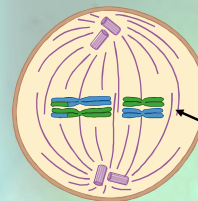


Called **Synapsis**

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Metaphase I



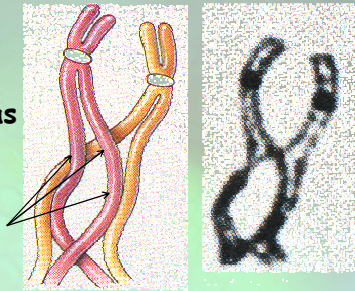
Homologous pairs of chromosomes align along the **equator** of the cell

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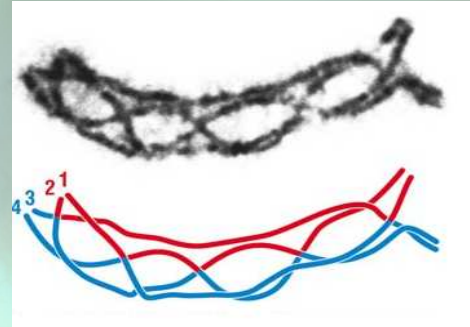
Metaphase I

- Areas of homologous chromosomes connect at areas called **CHIASMATA**
- **Genes are exchanged at these connections**



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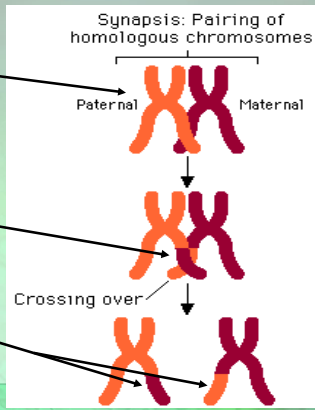
Chiasmata



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Crossing-Over

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



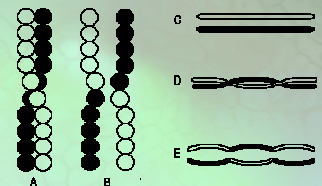
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Crossing Over

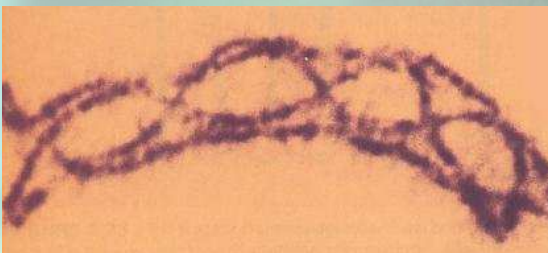
- Segments of homologous chromosomes break and reattach at similar locations.
- Results in **new genetic combinations** of offspring.
- This is the main advantage of sexual reproduction

Chromosome Crossing-over



100

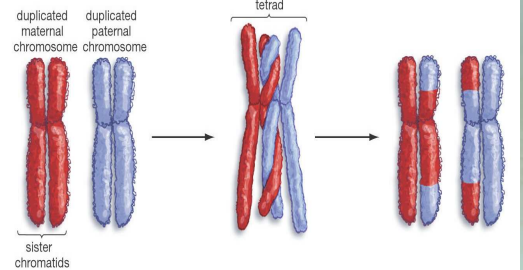
Homologous Chromosomes During Crossing-Over



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Crossing-Over



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

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Anaphase I

Homologs separate and move to opposite poles.

Sister chromatids remain attached at their centromeres.

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Anaphase I

- During Anaphase I, each **HOMOLOGOUS CHROMOSOME** is pulled to opposite sides of the cell.
- Unlike mitosis, the **CENTROMERES DO NOT BREAK.**

← Chromosome movement →

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Telophase I

Nuclear envelopes reassemble.

Spindle disappears.

Cytokinesis divides cell into two.

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Meiosis II

Gene X

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.

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Meiosis II: Reducing Chromosome Number

Prophase II Metaphase II Anaphase II Telophase II

4 Genetically Different haploid cells

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Prophase II

Nuclear envelope fragments.

Spindle forms.

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Metaphase II

Chromosomes align along equator of cell.

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Anaphase II

Equator

Pole

Sister chromatids separate and move to opposite poles.

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Telophase II

Nuclear envelope assembles.

Chromosomes decondense.

Spindle disappears.

Cytokinesis divides cell into two.

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Meiosis II

- DNA **DOES NOT** double
- Chromosomes randomly line-up along metaphase plate like regular mitosis.
- During **Anaphase II**, **CENTROMERES BREAK** and each **SISTER CHROMATID** is pulled to opposite sides of the cell.
- **Nuclei reform** and **cytokinesis** usually occurs (although it is often unequal).

Sister chromatids

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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

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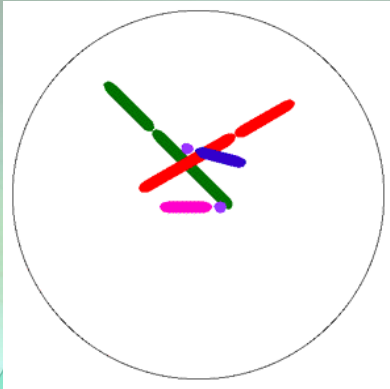
Overview of Meiosis

Prophase I, Metaphase I, Anaphase I, Telophase I (early), Telophase I (late)

Prophase II, Metaphase II, Anaphase II, Telophase II (early), Telophase II (late)

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Meiosis Animation



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Gametogenesis

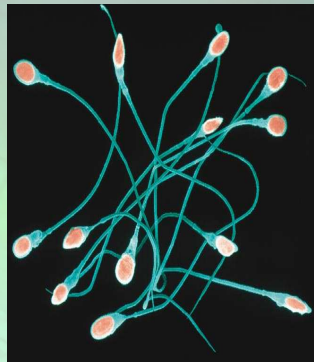
Oogenesis or Spermatogenesis

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Spermatogenesis

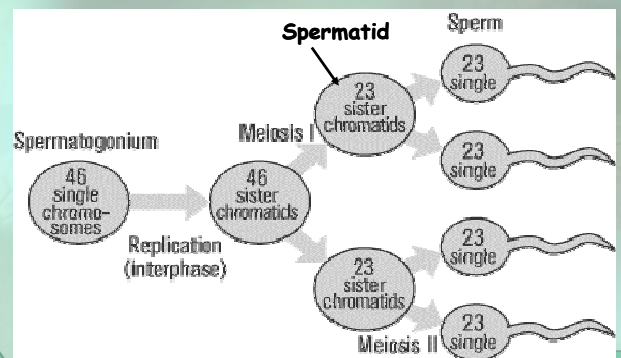
- ✓ Occurs in the **testes**
- ✓ Two divisions produce 4 spermatids
- ✓ Spermatids mature into sperm
- ✓ Men produce about **250,000,000 sperm per day**



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Spermatogenesis in the Testes

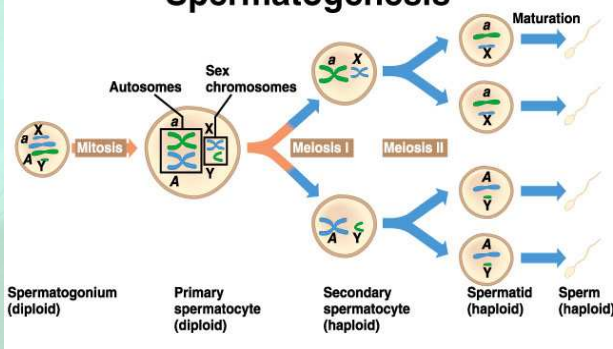


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Spermatogenesis

Spermatogenesis



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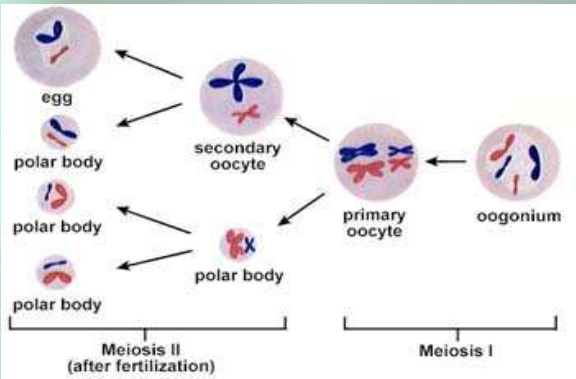
Oogenesis

- ✓ 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**

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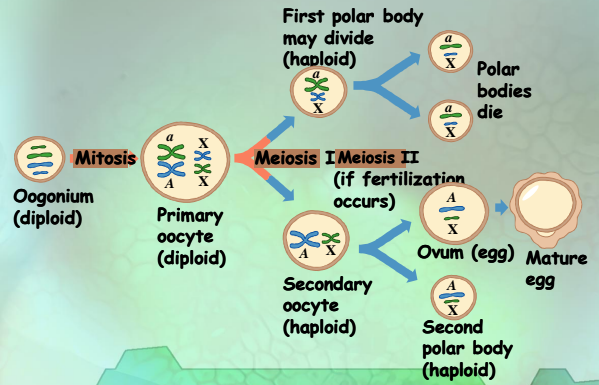
Oogenesis in the Ovaries



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Oogenesis



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Comparing Mitosis and Meiosis

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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

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Some Important Definitions

- Somatic Cells – body cells
 - Produced through mitosis
 - Has 46 chromosomes (23 pairs)
- Homolog – each member of a chromosome pair
- Diploid (2n) – total of 46 chromosomes in people – zygote & somatic cells
- Haploid (n) – total of 23 chromosomes in people, gametes (sperm & egg)