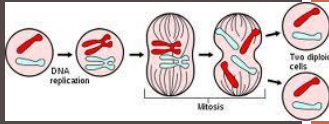
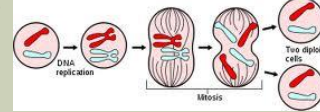


MITOSIS AND THE CELL CYCLE



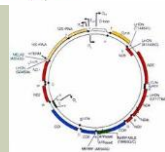
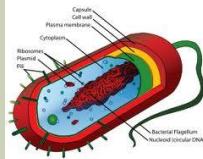
PURPOSE OF MITOSIS

- Growth (of body, tissues)
 - Increase number of cells (cells grow in interphase)
- Repair damaged tissue or replace damaged or dead cells (not repair cells)
- Cell division between prokaryotes and eukaryotes is very different due to cell structures



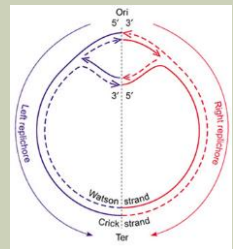
PROKARYOTIC CELL DIVISION

- Far more simple than in Eukaryotes
- Most prokaryotes have a genome made up of a single, circular DNA molecule
- Replicate via binary fission.



BINARY FISSION

- Begins with DNA replication
 - Starts at the origin site
 - Proceeds bidirectionally around the circular DNA to a specific site of termination.
- The evolution of eukaryotic cells = much more complex genomes
 - New and different ways to replicate and segregate the genome during cell division



CHROMOSOMES

- Chromosomes were first discovered in 1882 by Walther Fleming.
- The number of chromosomes varies from one species to another.
 - Humans have 23 nearly identical pairs for a total of 46 chromosomes.



CHROMOSOME STRUCTURE

- DNA extends unbroken through the entire length of the chromosome.
 - A typical human chromosome contains about 140 million nucleotides.
 - Every 200 nucleotides, the DNA duplex is coiled around a core of eight histone proteins, forming a nucleosome.
- The particular array of chromosomes an individual possesses is its **karyotype**

Human chromosomes!

The diagram illustrates human chromosomes. On the left, a single chromosome is shown with its two sister chromatids joined at a central point labeled 'centromere'. Each of the two strands is labeled 'chromatid'. On the right, a karyotype shows 22 pairs of autosomes and the sex chromosomes (X and Y), numbered 1 through 22. The pairs are arranged in rows, with the first row containing pairs 1-5, the second row 6-12, the third row 13-18, and the fourth row 19-22. The sex chromosomes are labeled 'X' and 'Y'.

CHROMOSOME STRUCTURE

- Sister chromatids: identical chromosome halves that will be separated in mitosis
- Centromere: band that holds sister chromatids together
- Telomere: end section of a chromosome that repeats genetic code and prevents the chromosome from deteriorating
 - Important because they prevent DNA from being lost with each replication (DNA replication enzymes can't quite go all the way to the end of each strand)

The diagram shows a single chromosome with two sister chromatids. The ends of the chromatids are labeled 'telomere'. The central point where the chromatids meet is labeled 'centromere'. The shorter arms are labeled 'p arm' and the longer arms are labeled 'q arm'.

HAPLOID VS. DIPLOID

- Haploid (n) number:** The number of different chromosomes a species contains
 - one complete set of chromosomes
- Humans are diploid, with **homologues** (corresponding chromosomes) coming from both the maternal and paternal lineages.

The diagram shows two sets of chromosomes. The top set consists of two chromosomes, one red and one purple. The bottom set consists of four chromosomes, two red and two purple, representing a diploid state.

THE CELL CYCLE

- Five phases:
 - G₁ = growth or gap 1
 - S = DNA replication (synthesis)
 - G₂ = growth or gap 2
 - M = mitosis
 - C = cytokinesis
- Also divided into phases
 - Interphase (G₁ + S + G₂)
 - Prophase
 - Metaphase
 - Anaphase
 - Telophase
 - Cytokinesis

The diagram shows a circular cell cycle. The main cycle is divided into Interphase (G₁, S, G₂) and Mitotic Phase (M). A smaller cycle below shows the stages of mitosis: Prophase, Metaphase, Anaphase, and Telophase, leading to Cytokinesis.

This diagram shows the cell cycle as a continuous loop. It includes a resting phase G₀ that branches off from G₁. The main cycle consists of G₁ (Growth), S (DNA Replication), G₂ (Preparation for Mitosis), and M (Mitosis). The M phase is further divided into Prophase, Anaphase, and Telophase. Arrows indicate the progression from G₁ to S, S to G₂, G₂ to M, and M back to G₁.

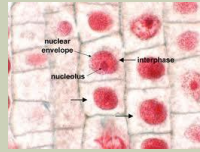
CELL CYCLE CONTINUED

- There is also a resting phase, sometimes called G₀ during which no growth or active division occurs
- Simply put:
 - Interphase: Cell is growing and storing nutrients to undergo mitosis
 - Mitosis: Cell is dividing itself into two identical daughter cells
- Organisms take different amounts of time to pass through the cell cycle, ranging from about 8 minutes to over a year

This diagram shows a cell entering the cell cycle from a G₀ state. It passes through G₁ (Growth), S (DNA Replication), and G₂ (Preparation for Mitosis) before entering the M phase (Mitosis). The M phase is divided into Prophase, Metaphase, Anaphase, and Telophase, which leads to Cytokinesis and the formation of two daughter cells. The diagram also shows a cell that has completed mitosis and returned to the G₀ state.

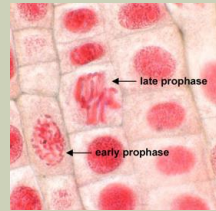
INTERPHASE

- Throughout the two growth phases:
 - Proteins synthesized
 - Cell gets larger
 - Organelles and extra membrane produced
- S phase:
 - DNA replication occurs so that half of what is created can go to each new daughter cell



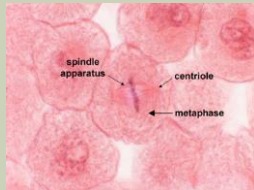
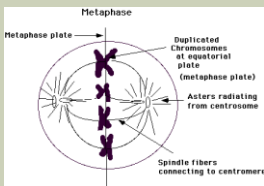
MITOSIS: PROPHASE

- Nucleolus disappears
- Chromatin condenses into chromosomes in early prophase
- The spindle apparatus is assembled—centrosomes (centrioles + protein) move to opposite ends of the cell
- Sister chromatids are linked to opposite poles of the cell by microtubules
- The nuclear envelope breaks down



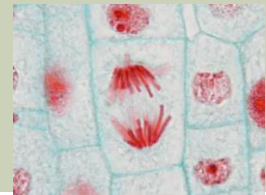
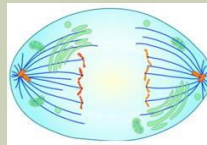
MITOSIS: METAPHASE

- Chromosomes align in the center of the cell along the metaphase plate
- Pulled by mitotic spindles



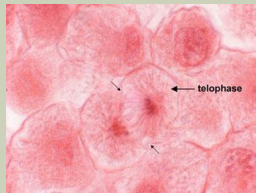
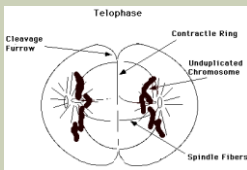
MITOSIS: ANAPHASE

- Centromeres divide, freeing the two sister chromatids from each other
- Sister chromatids are pulled to opposite poles of the large cell as the attached microtubules shorten.



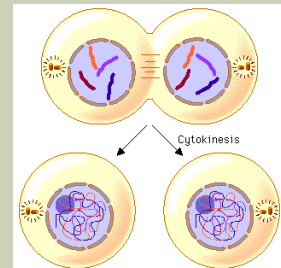
MITOSIS: TELOPHASE

- Spindle apparatus disassembles
- Nuclear membrane begins to re-form around each bundle of separated chromosomes



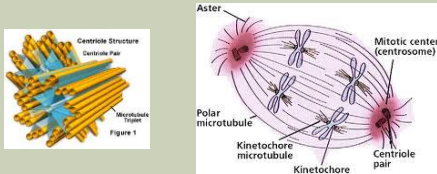
CYTOKINESIS

- Phase of the cell cycle when the cell actually divides
- Cytokinesis generally involves the cleavage of the cell into roughly equal halves, forming two daughter cells
- Each new daughter cell is a clone of the original parent with the same DNA



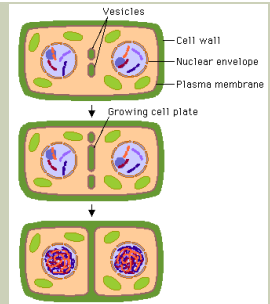
DIFFERENCE BETWEEN PLANTS AND ANIMALS

- Recall that plant cells don't have centrioles
 - Centrioles help direct mitotic spindles, but aren't necessary. Plants just rely on protein centrosomes to pull and direct chromosomes



DIFFERENCE BETWEEN PLANTS AND ANIMALS

- In cytokinesis...
 - Animal cell pinches in the middle
 - In plants "cell plate" forms between two layers of cell wall and the membranes divide after
 - Followed by elongation

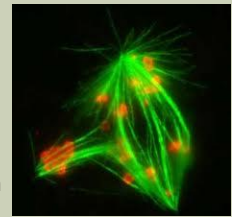


CELL CYCLE CONTROL

- The cell cycle is carefully controlled
- Three main checkpoints to both assess the internal state of the cell and integrate external signals.
 - G_1/S checkpoint = primary point at which the cell decides to divide
 - G_2/M checkpoint represents a commitment to mitosis
 - Spindle checkpoint (end of metaphase) ensures that all chromosomes are attached to the spindle in preparation for anaphase.

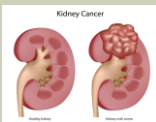
MOLECULAR MECHANISMS OF CELL CYCLE CONTROL

- Two groups of proteins, cyclins and Cyclin-dependent kinases, interact and regulate the cell cycle
 - Kinase: enzyme that transfers phosphates \rightarrow energy!
- Cells also receive protein signals (growth factors) that affect cell division.



CANCER AND THE CONTROL OF CELL PROLIFERATION

- Cancer is failure of cell division control
- It is believed that a malfunction in the p53 gene may allow cells to go through repeated cell division without being stopped at the appropriate checkpoints
- Proto-oncogenes are normal cell genes that become oncogenes when mutated.
 - can encode growth factors, protein relay switches, and kinase enzyme.
- Other tumor-suppressor genes can also lead to cancer when they are mutated.



Loss of Normal Growth Control

