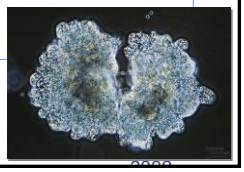
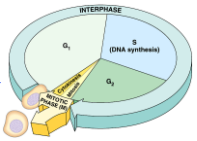
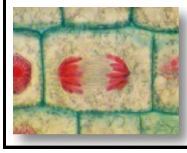
Biology is the only subject in which multiplication is the same thing as division…



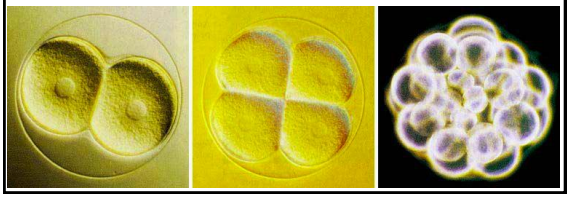


The Cell Cycle: Cell Growth, Cell Division



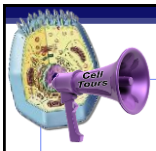
Getting from there to here…

- Going from egg to baby….
  - the original fertilized egg has to divide…
    - and divide…
      - and divide…
        - and divide…



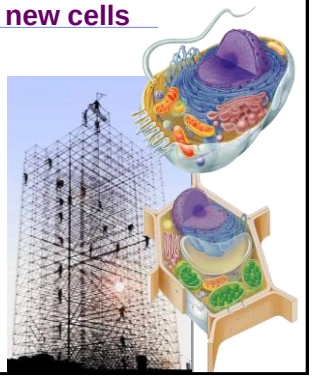
Why do cells divide?

- For reproduction
  - asexual reproduction
    - one-celled organisms
- For growth
  - from fertilized egg to multi-celled organism
- For repair & renewal
  - replace cells that die from normal wear & tear or from injury



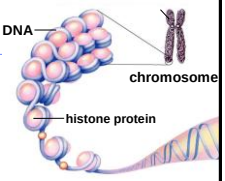
Making new cells

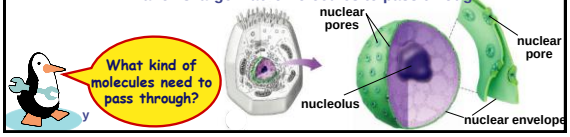
- Nucleus
  - chromosomes
  - DNA
- Cytoskeleton
  - centrioles
    - in animals
  - microtubule spindle fibers

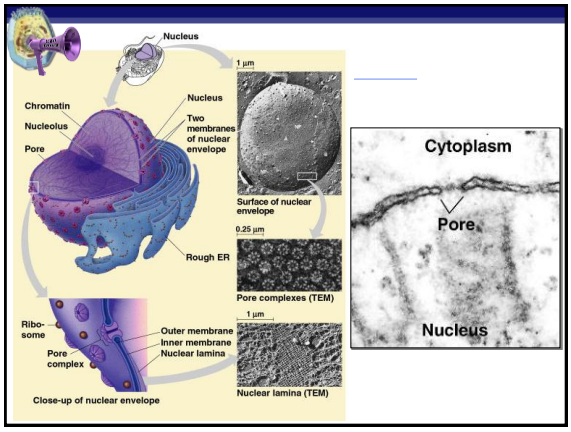


Nucleus

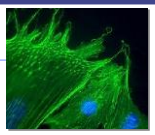
- Function
  - protects DNA
- Structure
  - nuclear envelope
    - double membrane
    - membrane fused in spots to create pores
      - allows large macromolecules to pass through



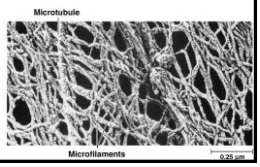




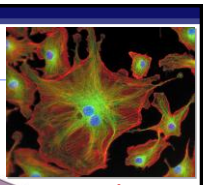
Cytoskeleton



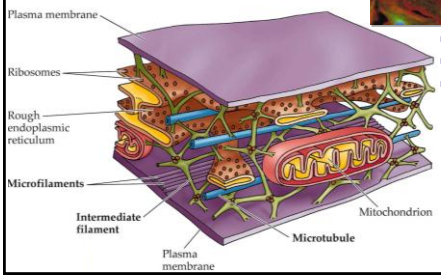
- Function
  - structural support
    - maintains shape of cell
    - provides anchorage for organelles
      - protein fibers
        - microfilaments, intermediate filaments, microtubules
  - motility
    - cell locomotion
    - cilia, flagella, etc.
  - regulation
    - organizes structures & activities of cell



Cytoskeleton

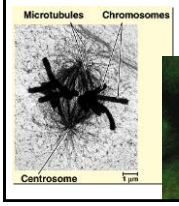


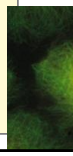
- actin
- microtubule
- nuclei

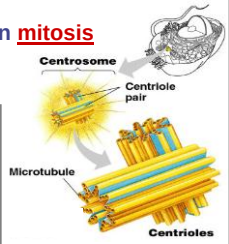


Centrioles

- Cell division
  - in animal cells, pair of centrioles organize microtubules
    - spindle fibers
  - guide chromosomes in mitosis



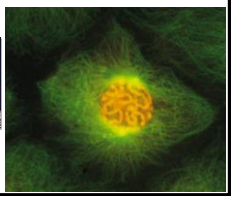




End of the Tour

Getting the right stuff

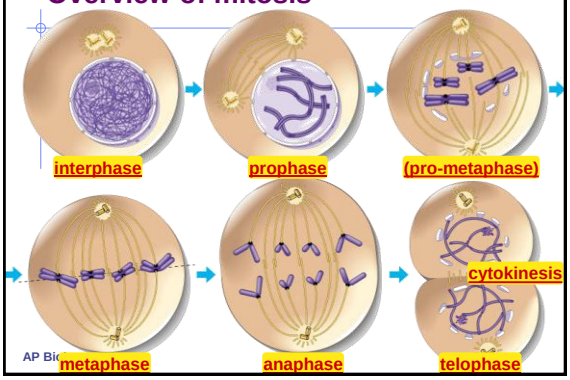
- What is passed on to daughter cells?
  - exact copy of genetic material = DNA
    - mitosis
  - organelles, cytoplasm, cell membrane, enzymes
    - cytokinesis



chromosomes (stained orange) in kangaroo rat epithelial cell
→notice cytoskeleton fibers

Overview of mitosis

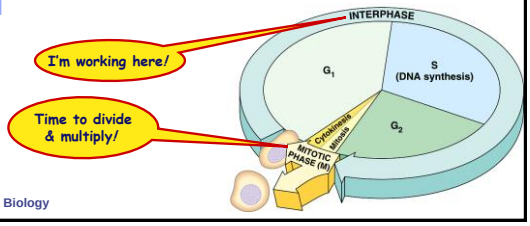
I.P.M.A.T.



AP Bi

Interphase

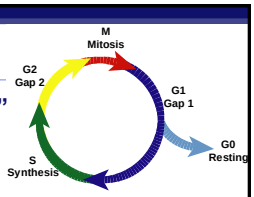
- 90% of cell life cycle
  - cell doing its "everyday job"
    - produce RNA, synthesize proteins/enzymes
  - prepares for duplication if triggered



AP Biology

Cell cycle

- Cell has a "life cycle"



cell is formed from a mitotic division

cell grows & matures to divide again

cell grows & matures to never divide again

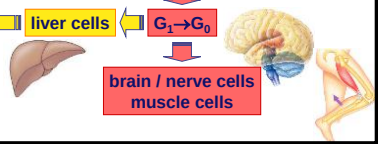
G_1, S, G_2, M

liver cells

$G_1 \rightarrow G_0$

epithelial cells, blood cells, stem cells

brain / nerve cells muscle cells



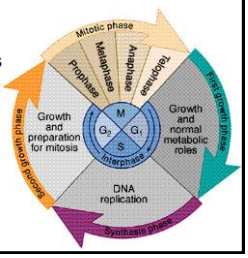
AP B

Interphase

- Divided into 3 phases:
  - G_1 = 1st Gap (Growth)
    - cell doing its "everyday job"
    - cell grows
  - S = DNA Synthesis
    - copies chromosomes
  - G_2 = 2nd Gap (Growth)
    - prepares for division
    - cell grows (more)
    - produces organelles, proteins, membranes

G_0

signal to divide

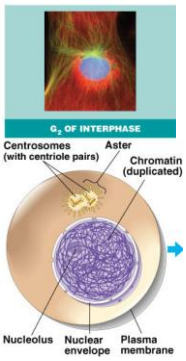


AP Biology

green = key features

Interphase

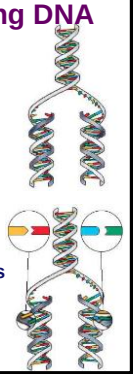
- Nucleus well-defined
  - DNA loosely packed in long chromatin fibers
- Prepares for mitosis
  - replicates chromosome
    - DNA & proteins
  - produces proteins & organelles



AP Biology

S phase: Copying / Replicating DNA

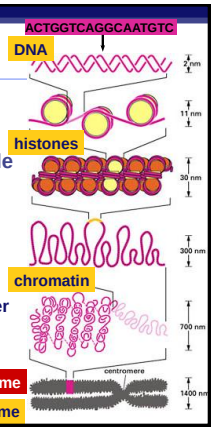
- Synthesis phase of Interphase
  - dividing cell replicates DNA
  - must separate DNA copies correctly to 2 daughter cells
    - human cell duplicates ~1-2 meters DNA
    - each daughter cell gets complete identical copy
    - error rate = ~1 per 100 million bases
      - 3 billion base pairs in mammalian genome
      - ~30 errors per cell cycle
        - mutations (to somatic (body) cells)



AP Biology

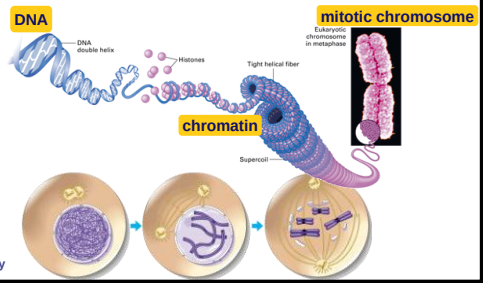
Organizing DNA

- DNA is organized in chromosomes
  - double helix DNA molecule
  - wrapped around histone proteins
    - like thread on spools
  - DNA-protein complex = chromatin
    - organized into long thin fiber
  - condensed further during mitosis



Copying DNA & packaging it…

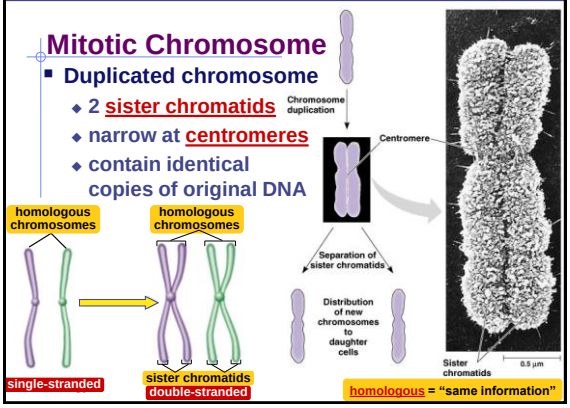
- After DNA duplication, chromatin condenses
  - coiling & folding to make a smaller package



double-stranded mitotic human chromosomes

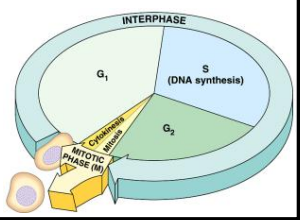
Mitotic Chromosome

- Duplicated chromosome
  - 2 sister chromatids
  - narrow at centromeres
  - contain identical copies of original DNA



Mitosis

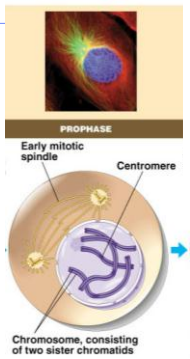
- Dividing cell's DNA between 2 daughter nuclei
  - "dance of the chromosomes"
- 4 phases
  - prophase
  - metaphase
  - anaphase
  - telophase



green = key features

Prophase

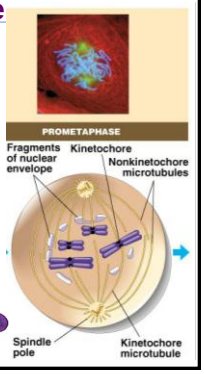
- Chromatin condenses
  - visible chromosomes
    - chromatids
- Centrioles move to opposite poles of cell
  - animal cell
- Protein fibers cross cell to form mitotic spindle
  - microtubules
    - actin, myosin
  - coordinates movement of chromosomes
- Nucleolus disappears
- Nuclear membrane breaks down

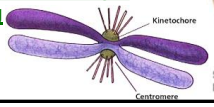


green = key features

Transition to Metaphase

- Prometaphase
  - spindle fibers attach to centromeres
    - creating kinetochores
  - microtubules attach at kinetochores
    - connect centromeres to centrioles
  - chromosomes begin moving

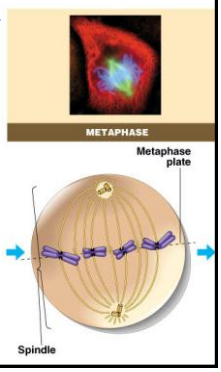


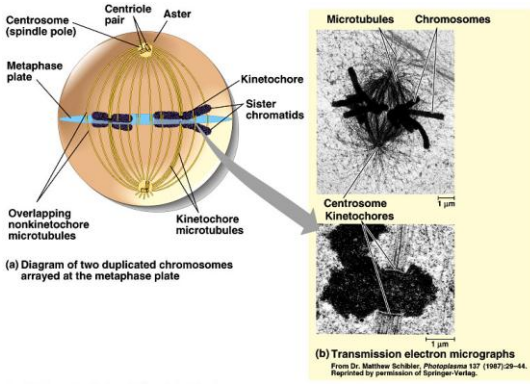


green = key features

Metaphase

- Chromosomes align along middle of cell
  - metaphase plate
    - meta = middle
  - spindle fibers coordinate movement
  - helps to ensure chromosomes separate properly
    - so each new nucleus receives only 1 copy of each chromosome

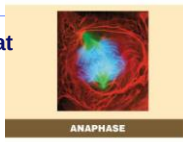


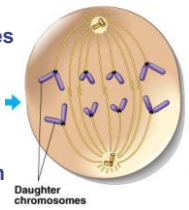


green = key features

Anaphase

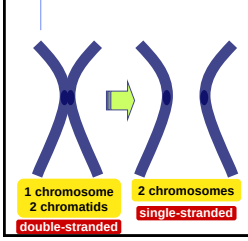
- Sister chromatids separate at kinetochores
  - move to opposite poles
  - pulled at centromeres
  - pulled by motor proteins "walking"along microtubules
    - actin, myosin
    - increased production of ATP by mitochondria
- Poles move farther apart
  - polar microtubules lengthen

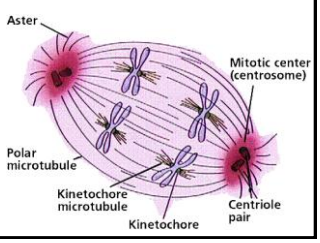




Separation of chromatids

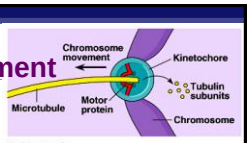
- In anaphase, proteins holding together sister chromatids are inactivated
  - separate to become individual chromosomes

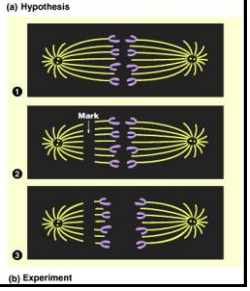




Chromosome movement

- Kinetochores use motor proteins that "walk" chromosome along attached microtubule
  - microtubule shortens by dismantling at kinetochore (chromosome) end

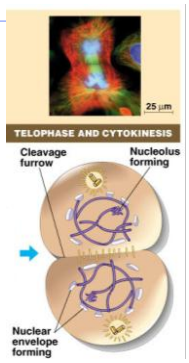




green = key features

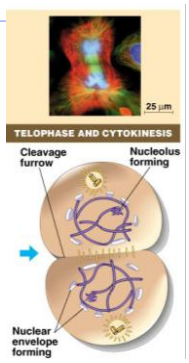
Telophase

- Chromosomes arrive at opposite poles
  - daughter nuclei form
  - nucleoli form
  - chromosomes disperse
    - no longer visible under light microscope
- Spindle fibers disperse
- Cytokinesis begins
  - cell division

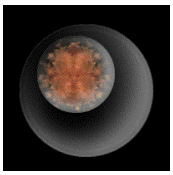


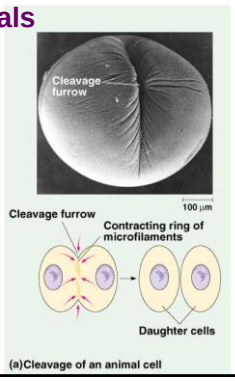
Cytokinesis

- Animals
  - constriction belt of actin microfilaments around equator of cell
    - cleavage furrow forms
    - splits cell in two
    - like tightening a draw string

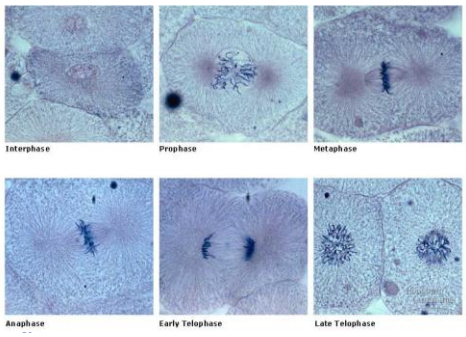


Cytokinesis in Animals

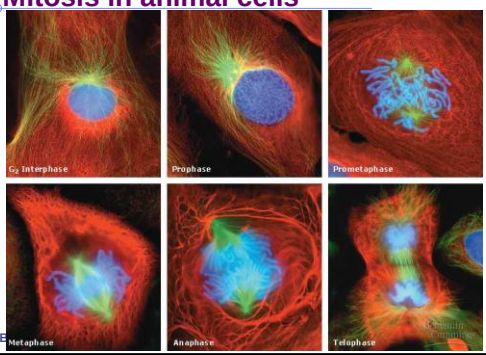




Mitosis in whitefish blastula

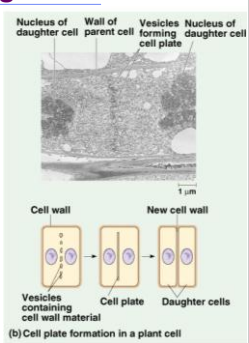


Mitosis in animal cells



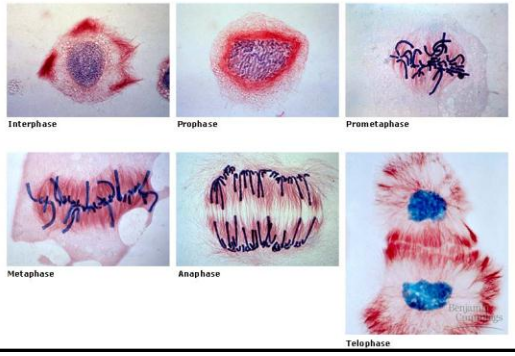
Cytokinesis in Plants

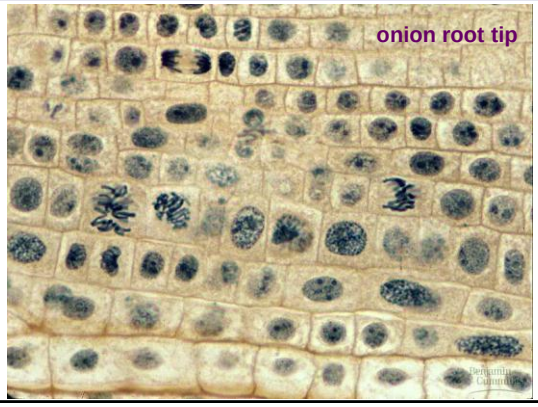
- Plants
  - cell plate forms
    - vesicles line up at equator
      - derived from Golgi
    - vesicles fuse to form 2 cell membranes
  - new cell wall laid down between membranes
    - new cell wall fuses with existing cell wall



Cytokinesis in plant cell

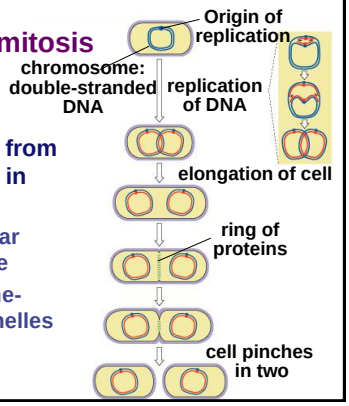
Mitosis in plant cell





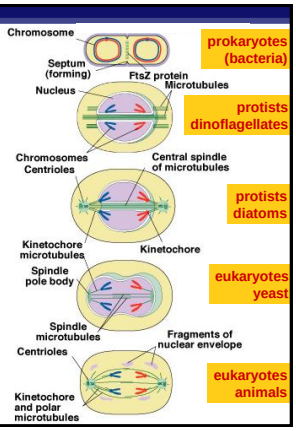
Evolution of mitosis

- Mitosis in eukaryotes likely evolved from binary fission in bacteria
  - single circular chromosome
  - no membrane-bound organelles

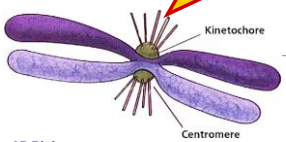


Evolution of mitosis

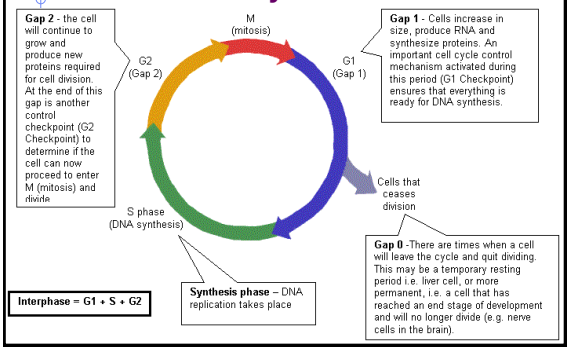
- A possible progression of mechanisms intermediate between binary fission & mitosis seen in modern organisms



Any Questions??



Control of Cell Cycle



Gap 2 - the cell will continue to grow and produce new proteins required for cell division. At the end of this gap is another control checkpoint (G2 Checkpoint) to determine if the cell can now proceed to enter M (mitosis) and divide.

Gap 1 - Cells increase in size, produce RNA and synthesize proteins. An important cell cycle control mechanism activated during this period (G1 Checkpoint) ensures that everything is ready for DNA synthesis.

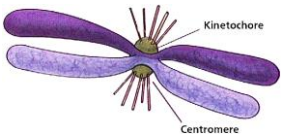
Gap 0 -There are times when a cell will leave the cycle and quit dividing. This may be a temporary resting period i.e. liver cell, or more permanent, i.e. a cell that has reached an end stage of development and will no longer divide (e.g. nerve cells in the brain).

Synthesis phase – DNA replication takes place

Interphase = G1 + S + G2

Kinetochore

- **Each chromatid has own kinetochore proteins**
  - **microtubules attach to kinetochore proteins**



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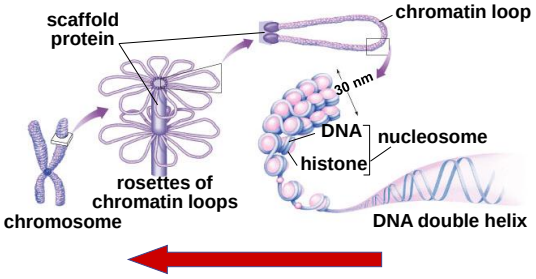
Chromosome structure



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