Biology

Unit 1:

Cell Structure and Function

Cell Metabolism

Lecture 1

Cell Structure and Function

Plasma Membrane

Cell General Information

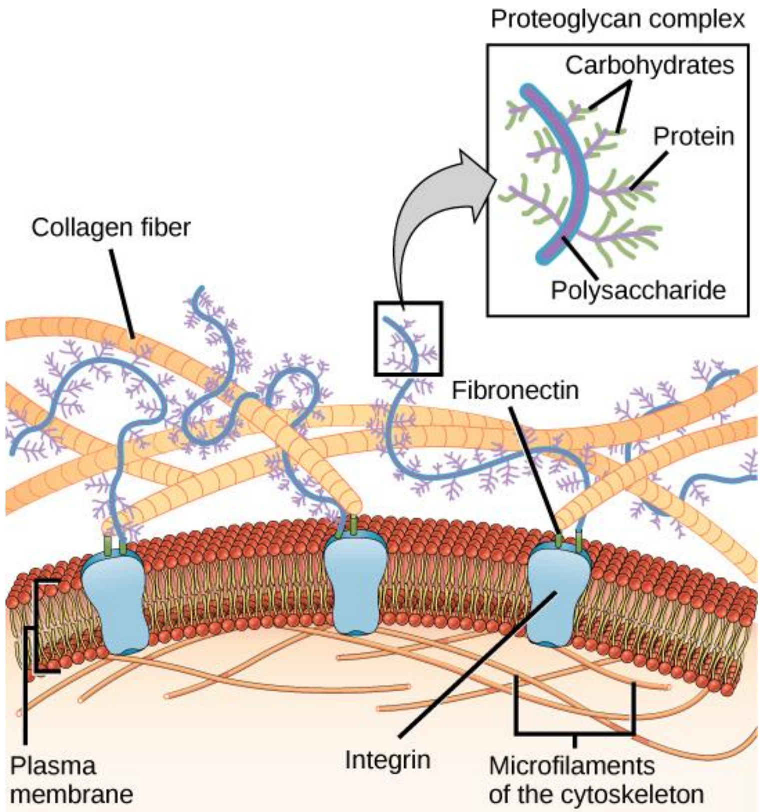
- The human body contains trillions of cells
- Cells are the building blocks of all plants and animals
- All cells come from the division of preexisting cells
- Cells are the smallest units that perform all vital physiological functions
- Each cell maintains homeostasis at the cellular level
- Homeostasis at higher levels reflects the combined and coordinated actions of many cells

Cell Structure

- Cells consist of
  - Plasma membrane
  - Cytoplasm
    - Cytosol
    - Organelles
    - Nucleus

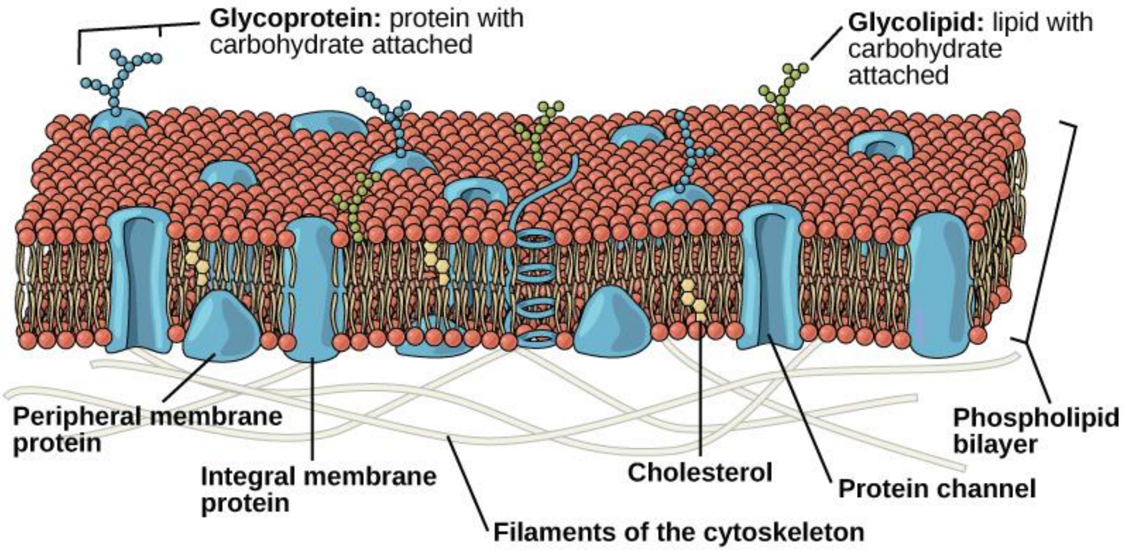
Plasma Membrane

- The plasma membrane consists of the following:
  - Phospholipid bilayer
  - Proteins
  - Carbohydrates
  - Steroids
- We will primarily discuss the structure and role of the phospholipid bilayer and the proteins



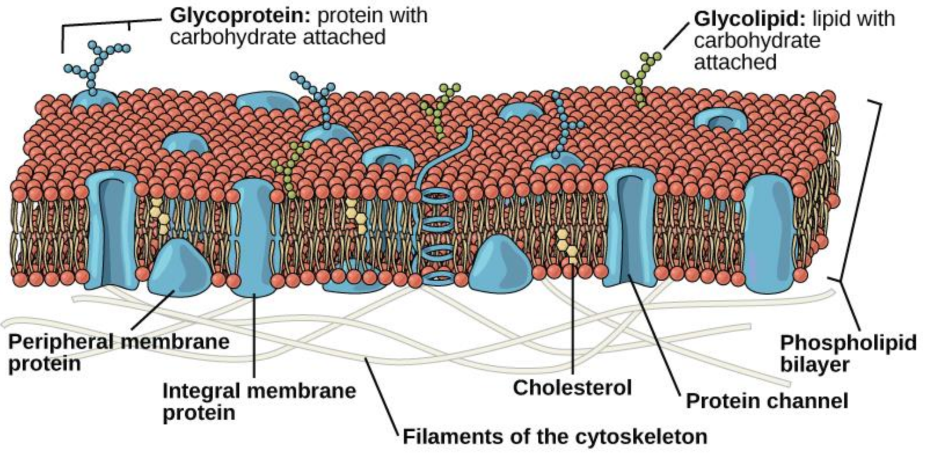
Phospholipids Bilayer

- Forms most of surface area of the cell membrane (though only 42 percent of weight)
- Contains a diglyceride (two fatty acids bonded to a glycerol backbone) and a phosphate group
- Have hydrophilic end (phosphate portion) and hydrophobic end (lipid portion)
- Large molecules and water soluble solutes cannot pass through the lipid bilayer so it serves as the primary barrier



Proteins of the Plasma Membrane

- Proteins serve many roles on the plasma membrane. They can be one or more of the following:
  - Anchoring proteins - Attach cell membrane to other structures and stabilize its position
  - Recognition proteins - Recognized by the immune system as either self or not self
  - Receptor proteins - Sensitive to extracellular molecules such as neurotransmitters or hormones
  - Carrier proteins - Binds solutes and transports them across the membrane
  - Channels - Permits movement of ions across plasma membrane
  - Ions and water soluble material do not dissolve in lipids and can not cross the lipid bilayer, they use these channels to cross

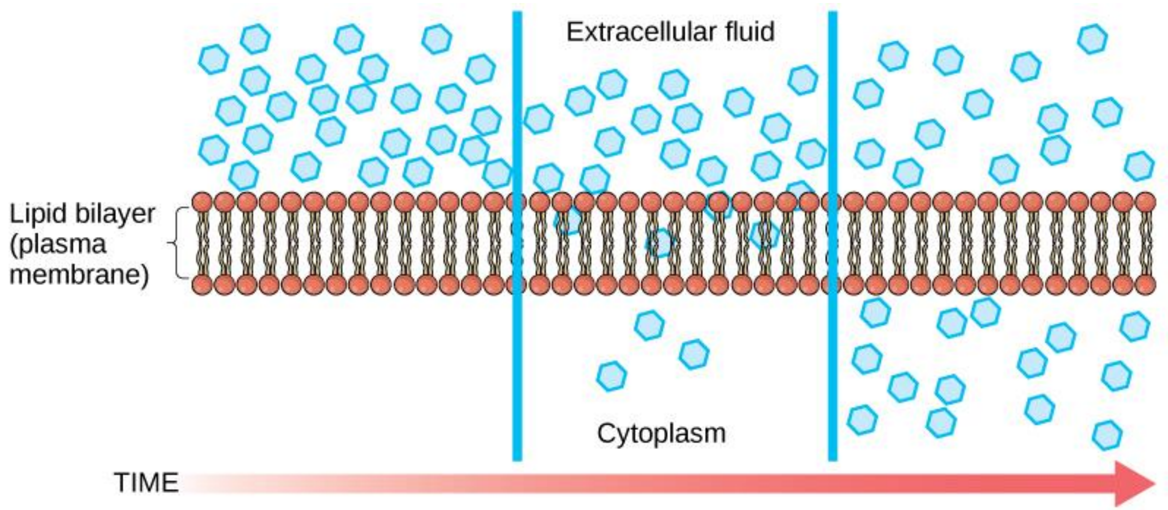


Plasma Membrane Function

- The plasma membrane performs the following functions:
  - Acts as a physical barrier between the inside and outside of the cell
  - Regulates exchange between the inside and outside of the cell
  - Sensitivity – responds to chemical, pH and mechanical changes in the extracellular environment
  - Provides structural support

Movement of Substances Across the Plasma Membrane

- The plasma membrane is selectively permeable
- Certain substances can move freely across, others can not
- The movement of these substances is regulated by the proteins structures on the membrane
- The movement is either passive (no ATP required) or active (requires ATP)



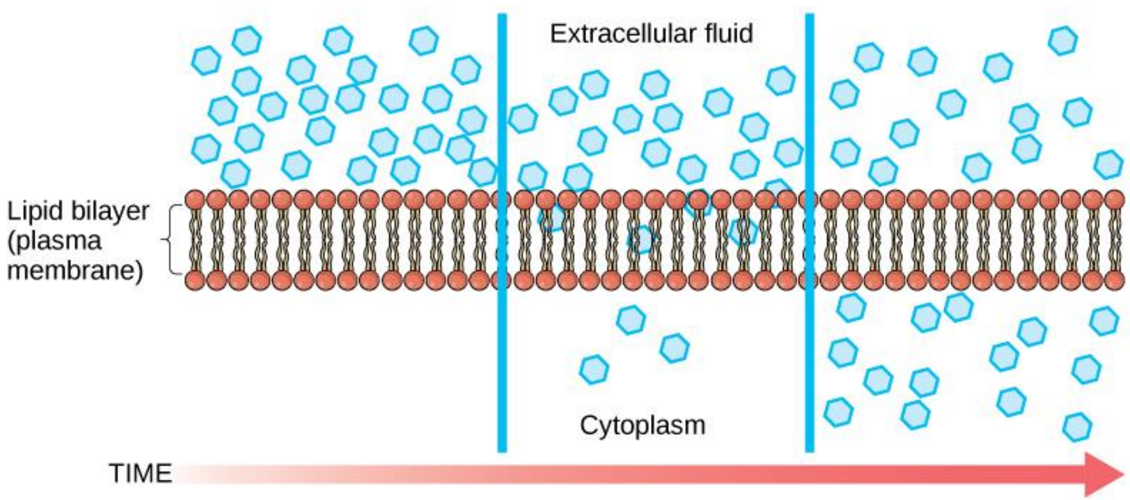
Passive Transport Mechanisms

- Passive Transport requires no energy
- Substances move from high to low concentrations.
- The energy is inherent in the concentration gradient.
- Passive transport involve

- These types of diffusion are:
  - Simple diffusion
  - Osmosis
  - Channel-mediated diffusion
  - Facilitated diffusion

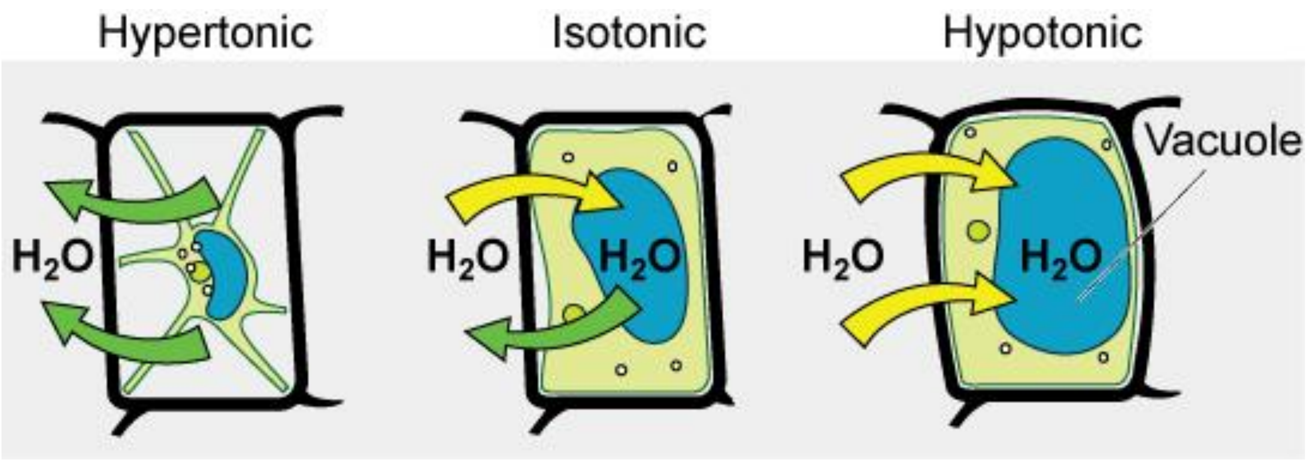
Simple Diffusion

- Substances move from an area of higher concentration to an area of lower concentration
- Therefore substances move down there concentration gradient
- Some substances can diffuse through the lipid portion of the cell membrane (alcohol, fatty acids, steroids, dissolved gases, lipid soluble drugs)
    - Example) Carbon Dioxide, plasma membrane is freely permeable to CO_2
    - Concentrations build up within the cell, CO_2 diffuses down its concentration gradient to the interstitial fluid



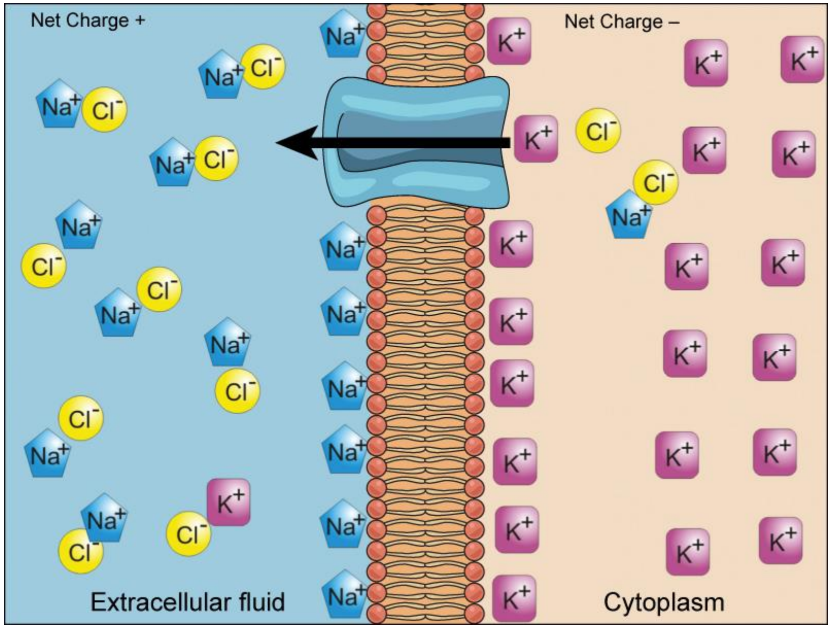
Simple Diffusion and Osmosis

- The movement of water across a selectively permeable membrane (permeable to water and not to the solutes)
- Water moves in the direction of the higher concentration of solutes
- Movement occurs between two solutions which have either the same, more, or less solutes
  - Isotonic – the two solutions have the same concentration of solutes, no net movement occurs
  - Hypertonic – this solution has a higher concentration of solutes
  - Hypotonic – this solution has a lower concentration of solutes



Channel Mediated Diffusion

- Channel Mediated Diffusion
  - Some substances such as many ions cannot freely move across the plasma membrane and require specific protein channels on the membrane
  - When these channels are open, the ions still move down their concentration gradients (still no energy required)
  - Size is an issue, very small ions can pass, but larger molecules such as glucose requires other means



Facilitated Diffusion

- Facilitated Diffusion
  - Larger substances such as glucose requires a carrier protein
  - The molecule to be transported first bonds to the carrier protein
  - The protein changes shape and moves the substance across the membrane
  - Still no energy is required, because the substances is moving down its concentration gradient

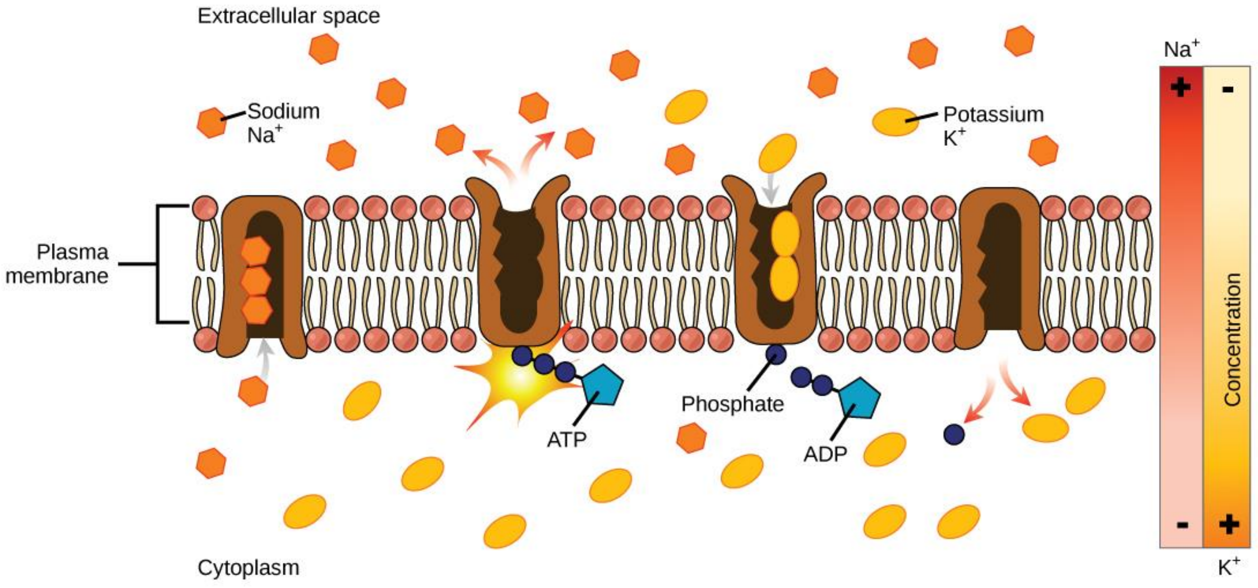
Active Transport Mechanisms

- Active transport requires energy in the form of ATP to move substances up their concentration gradient
- These move substance from low concentration to high concentration

- Active transport mechanism include:
  - Protein (ion) pumps
  - Vesicular transport
    - Endocytosis
      - Phagocytosis
      - Pinocytosis
    - Exocytosis

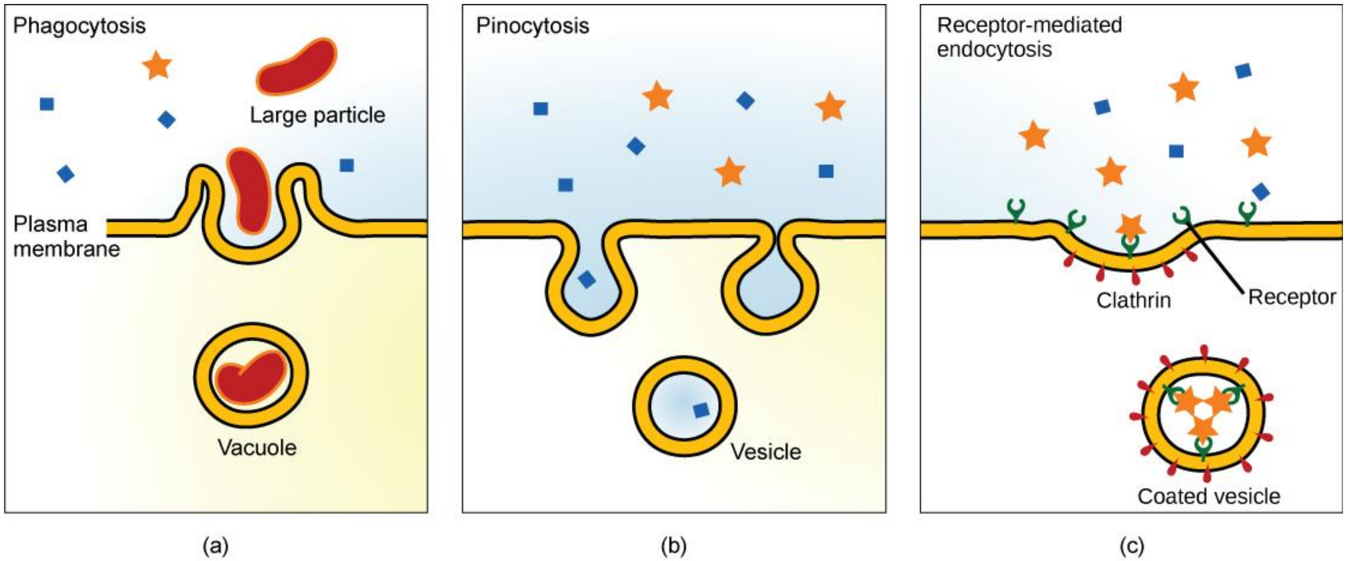
Protein (ion) Pumps

- Moved across membrane by protein pumps
  - Example) Sodium-potassium pump
  - Na^+ – Sodium ion, K^+ –Potassium ion
  - ATP is used to pump 3 Na^+ into the extracellular fluid and 2 K^+ into the intracellular fluid



Vesicular Transport

- Materials are moved into or out of a cell by means of membranous sac (vesicles)
- Includes:
  - Endocytosis which moves substances into the cell
    - Endocytosis includes phagocytosis (brings solid substances in) and pinocytosis (brings liquid solutions in)
  - Exocytosis which moves substances out of the cell



Lecture 2

Cell Structure and Function

Nucleus and Cell Organelles

Cell Structure and Function

- Cells are composed of
  - The Plasma membrane
    - Composed of:
      - Phospholipid bilayer
      - Proteins
      - Carbohydrates, steroids and other molecular structures
  - The Cytoplasm
    - Composed of:
      - Cytosol
      - Cell organelles
      - Nucleus

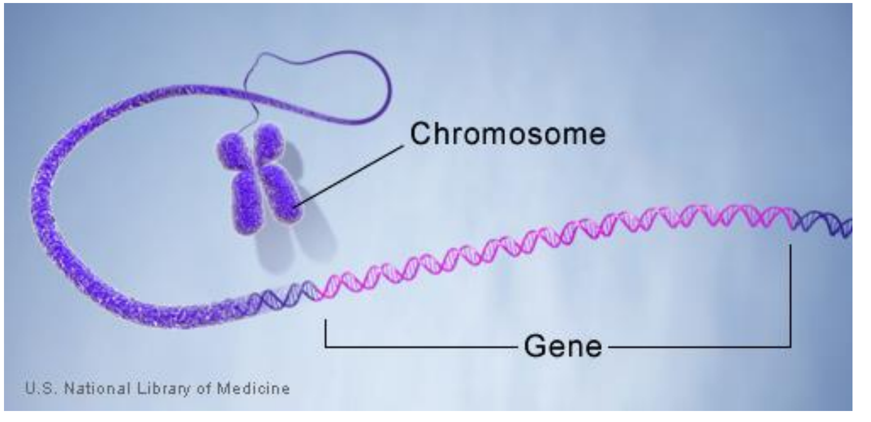
Cytoplasm

Nucleus

- The nucleus contains the genetic information
- This information contains the blueprints for protein production
- The DNA stored in the nucleus is the molecular structure which contains this information. This molecule is too large to leave the nucleus where protein production occurs.
- RNA is required to transcribe a small portions of the information contained in the DNA and interact with structures outside of the cell to manufacture proteins

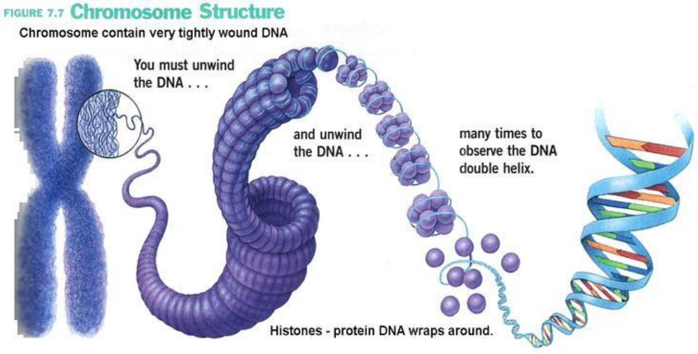
Nucleic Acid and Genes

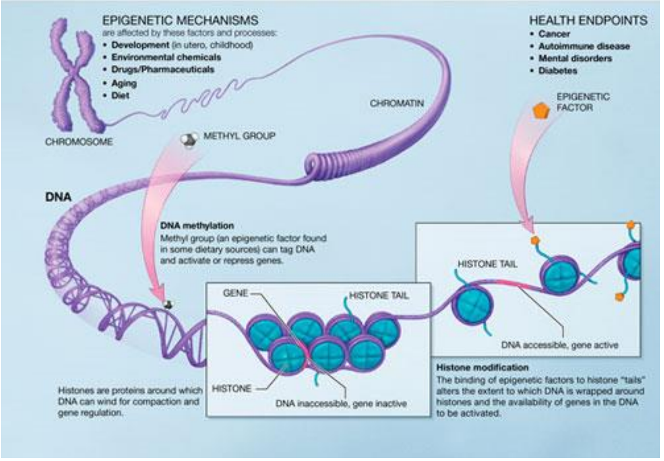
- The nucleus of a cell controls cell structure and function due to the DNA coding for protein synthesis
- Three steps are involved in protein synthesis
  - –Gene activation
  - –Transcription
  - –Translation



Gene Activation

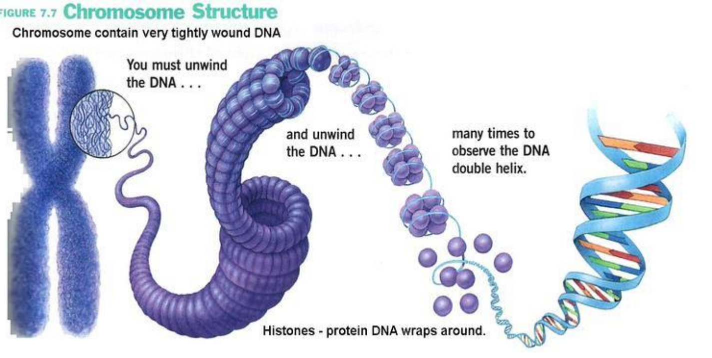
- DNA molecules contain thousands of segments called genes. These code for specific proteins.
  - –DNA molecules are estimated to contain between 20,000-25,000 genes.
- –DNA is packaged into thread-like structures called chromosomes.
  - –The DNA molecules are nearly 2 meters in length, but are usually tightly coiled. This keeps the genes inactive.

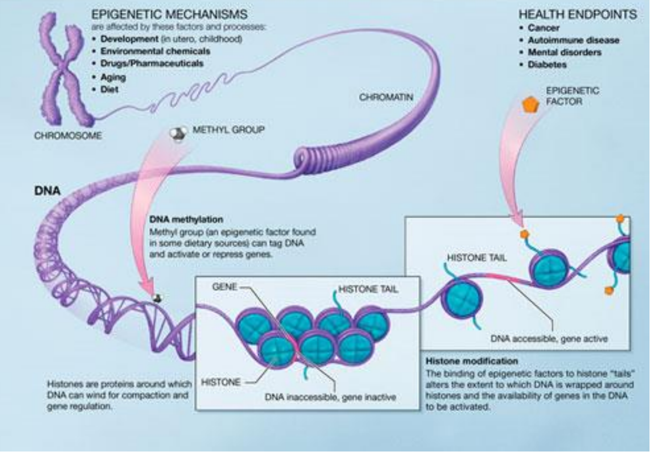




Gene Activation

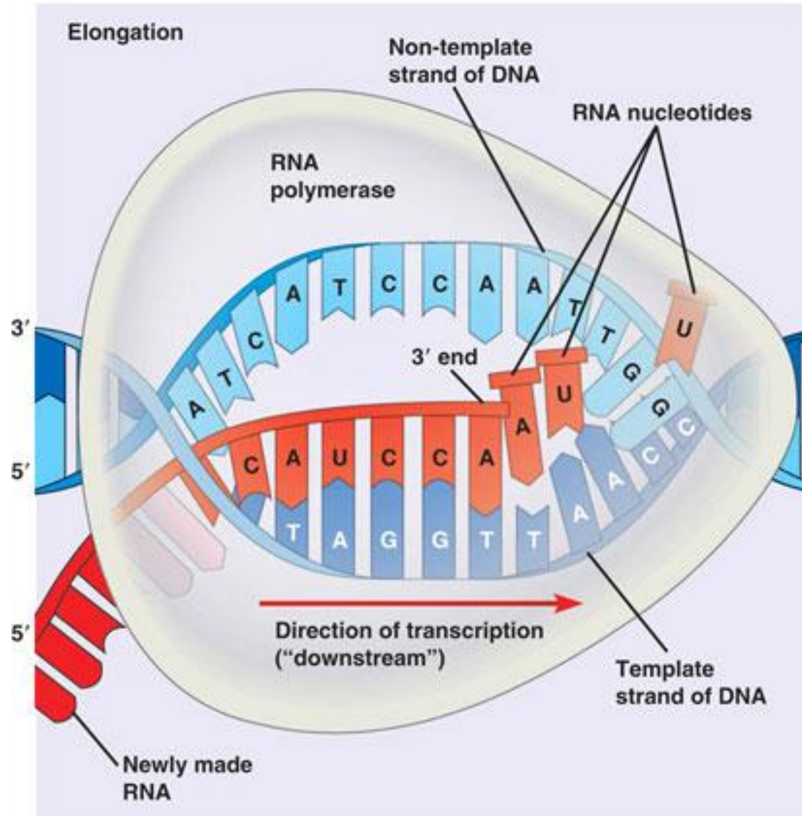
- During gene activation, enzymes cause portions of the DNA molecule to uncoil which allows gene expression to occur. This is referred to as gene activation.
- This uncoiling prepares the DNA for the next step - Transcription





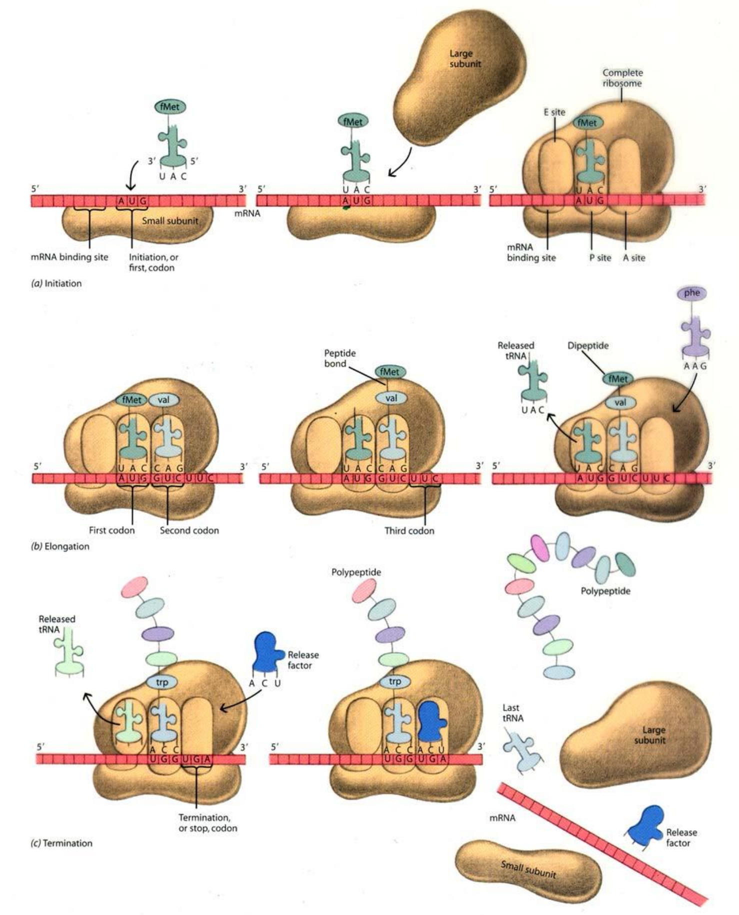
Transcription

- Transcription is the process in which an RNA strand is synthesized from a section of a DNA molecule
  - The specific type of RNA that is synthesized is messenger RNA or mRNA
- The resulting mRNA exits through nuclear pores into the cytoplasm
  - The cytoplasm is where proteins are produced
  - mRNA takes the information from the DNA in the nucleus out to the ribosomes in the cyoplasm to make the appropriate protein

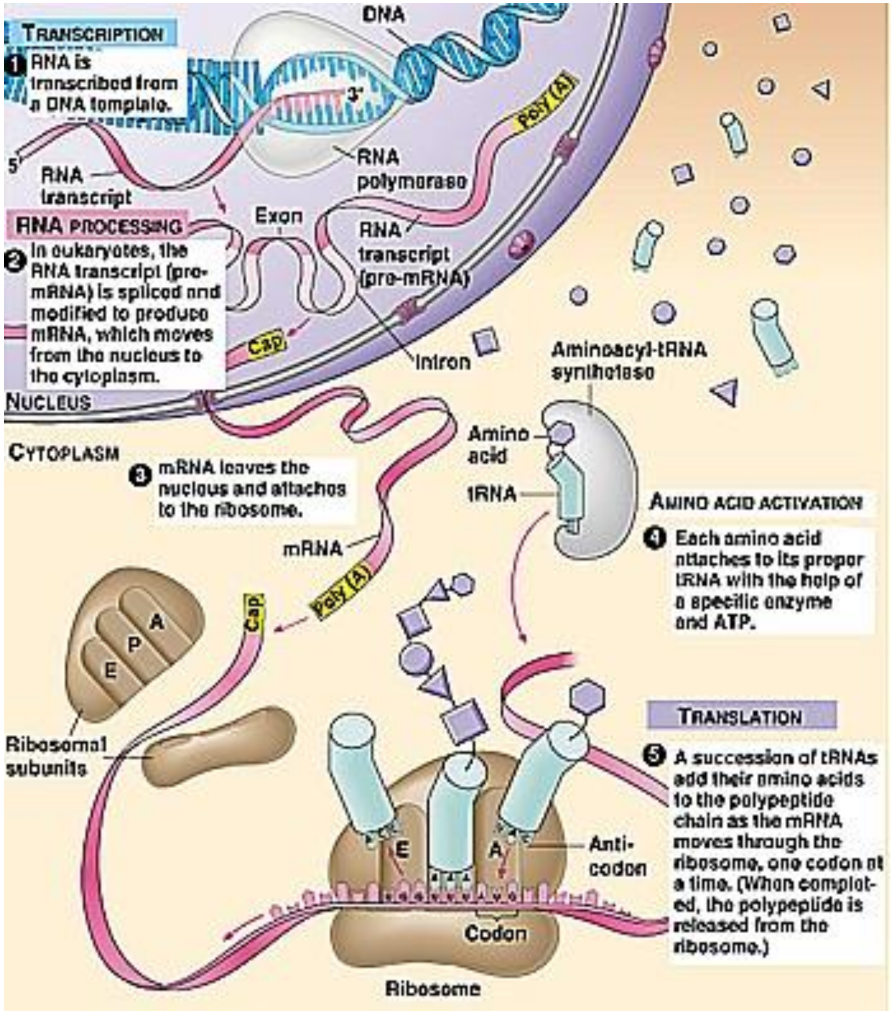


Translation

- •Translation is the process of protein synthesis and involves assembling a functional polypeptide which is multiple amino acids bonded together
- •This process converts the ‘language’ of nucleotide bases carried by the mRNA to the ‘language’ of amino acids
- •This process occurs in an organelle called ribosomes
- •Ribosomes are either free in they cytoplasm or fixed as part of the endoplasmmic reticulum



Final Process



Mutations

- Although the process described is very straightforward, mistakes occur
- A mutation is a mistake made during DNA replication where a nucleotide is incorrectly replaced, added or omitted
- These mistakes do not happen very often and when they do, often have no discernable effect on the organism, but occasionally have devastating effects
- There are many different types of mutations
  - Insertions (the addition of an extra nucleotide)
  - Deletion (the deletion of a nucleotide)
  - Substitution (the incorrect placement of a nucleotide)
- Any of these mistakes can result in an incorrect mRNA strand and more importantly, an incorrect polypeptide chain
- If the polypeptide chain is changed enough then the resulting protein may not function correctly
  - Ex) Sickle cell anemia, a devastating blood disease is a result of one base pair substitution. This small mutation has a large scale effect

Cell Organelles

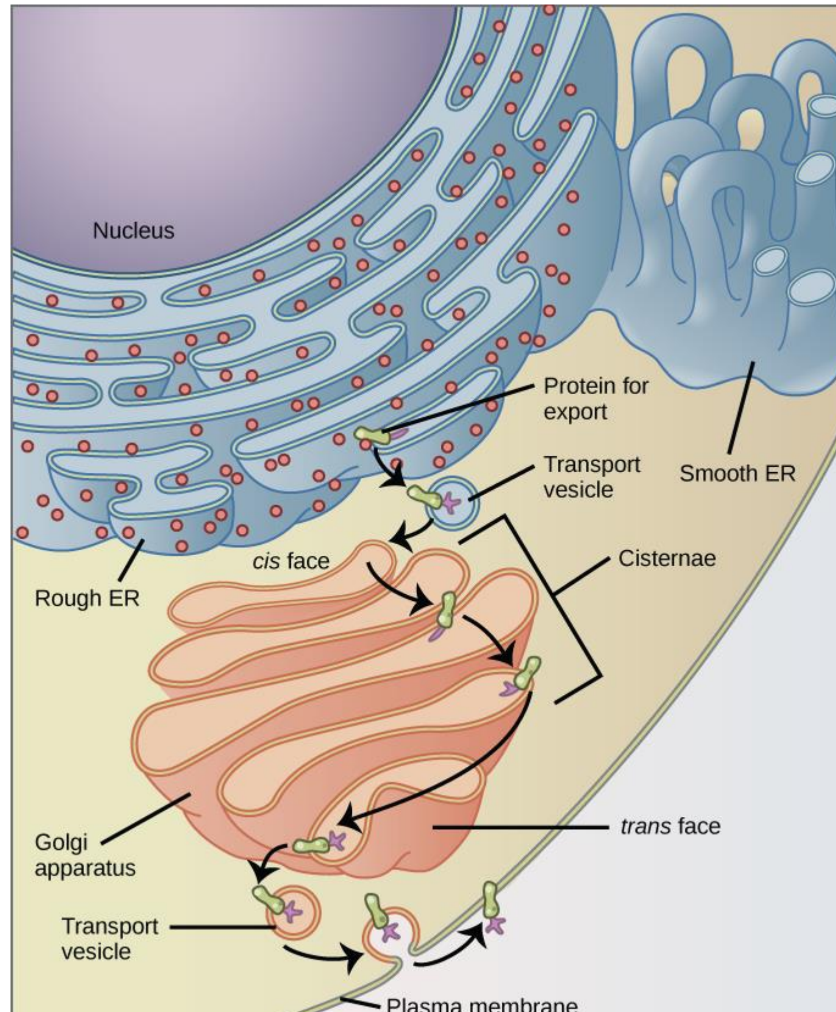
Organelles of the Cell

- Ribosomes
- Endoplasmic Reticulum
- Golgi Apparatus
    - These are all involved with protein production and transfer through the cell

- Mitochondria
- Lysosomes
- Other Specialized Structures
    - Ex) Microvilli, Cilia

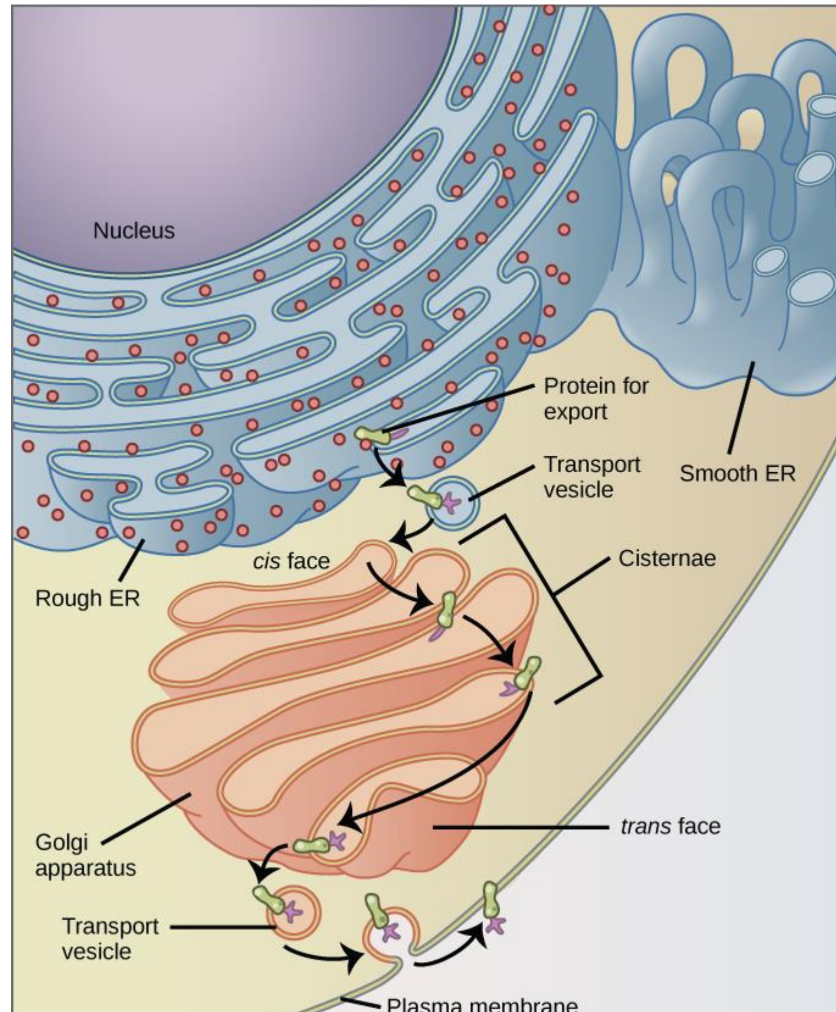
Ribosomes, Endoplasmic Reticulum, Golgi Apparatus

- These three organelles are responsible for protein synthesis, transfer through the cell and packaging in membrane bound vesicles for transfer within or out of the cell
- Ribosomes can be free or fixed ribosomes
  - Ribosomes are the manual laborers employed by the nucleus, they synthesize proteins from amino acids with the blueprints provided by the DNA
  - Proteins are the machinery 'gears and mechanism' used for cell functions, they also serve many other important biological roles



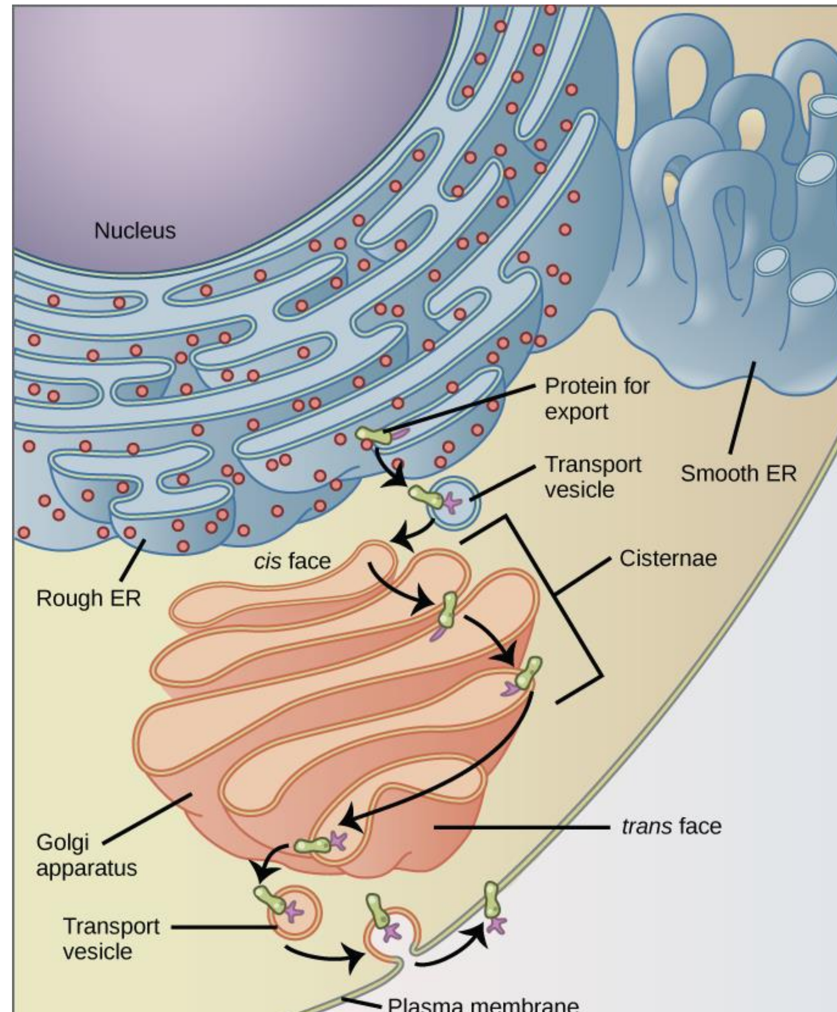
Ribosomes, Endoplasmic Reticulum, Golgi Apparatus

- Free ribosomes are scattered throughout the cytosol
- Fixed ribosomes are attached to another organelle called the Endoplasmic Reticulum



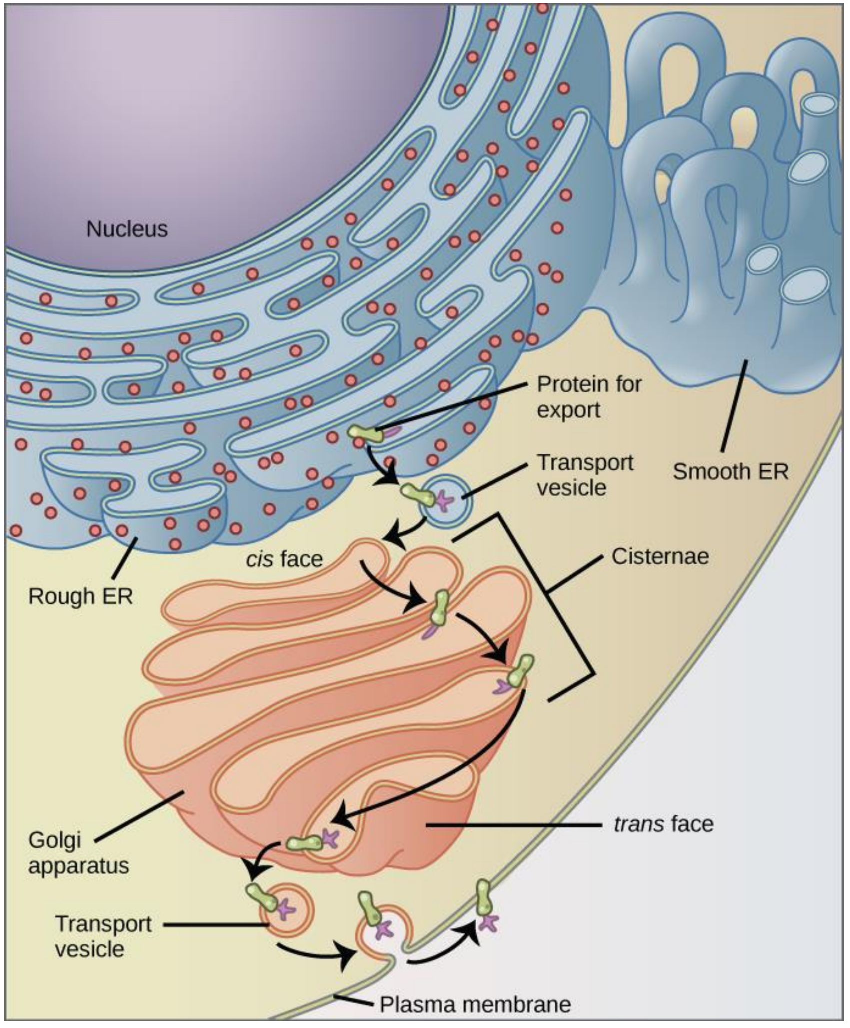
Ribosomes, Endoplasmic Reticulum, Golgi Apparatus

- The ER is the highway and road system, along the way goods (proteins and membrane) are manufactured and sent along the way
- There is smooth or rough ER, rough contains ribosomes (protein production), smooth does not (membrane productions - also drug and toxin detoxification, ex. CYP enzymes)



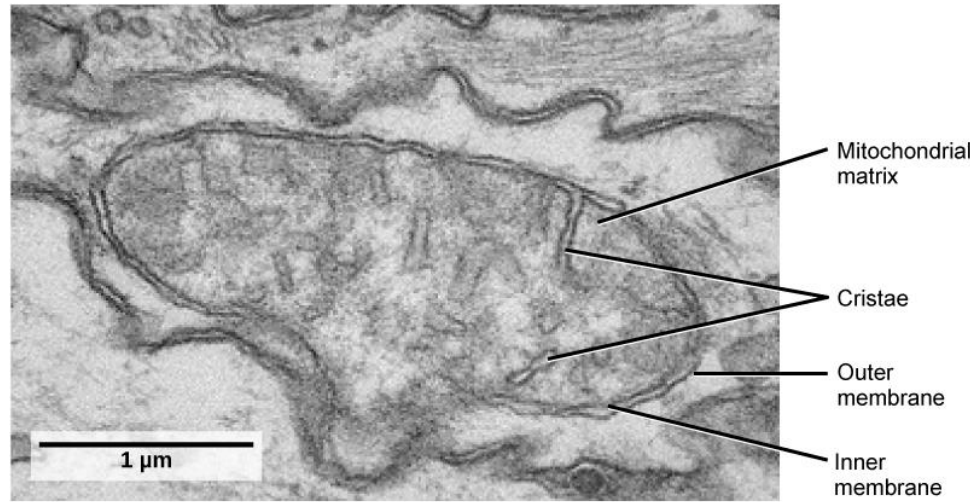
Ribosomes, Endoplasmic Reticulum, Golgi Apparatus

- Proteins enter the ER where they are modified and packaged for secretion to golgi apparatus
- Golgi apparatus sorts and packages proteins and lipids for vesicular transport within or out of the cell
  - GA like the post office - prepares packages created by Ribosomes and ER for shipment to rest of the cell



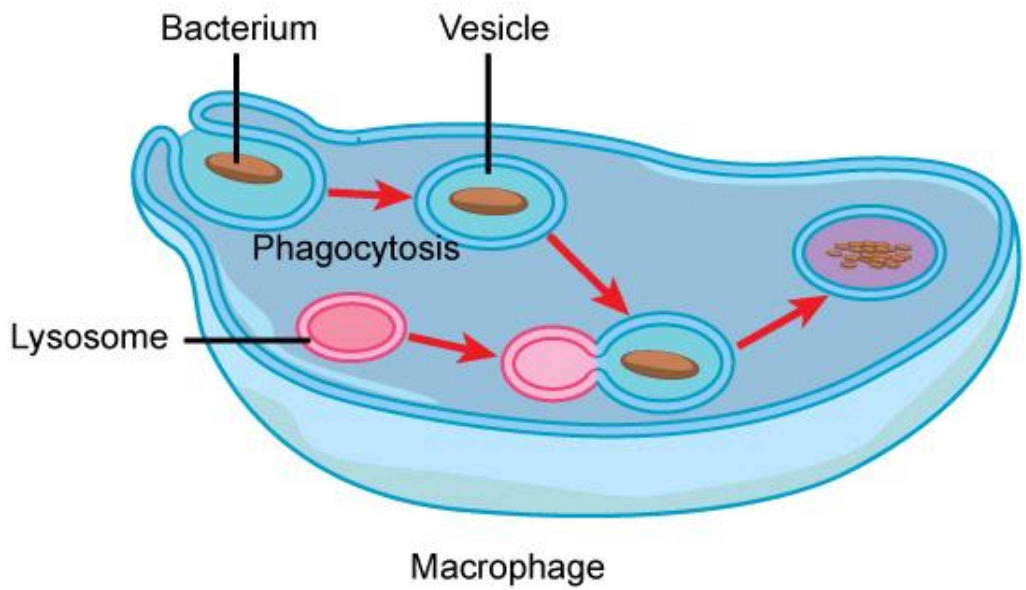
Mitochondria

- Energy production center of the cell (energy plant)
- Uses the breakdown of nutrients to fuel ATP production from ADP
- ATP (adenosine triphosphate) is the fuel that powers cell functions
- ATP production involves several energy producing pathways which will be discussed next lecture



Lysosomes

- Waste disposal and recycling centers
- The lysosomes are digestive sacs that can break down macromolecules in the cell using the process of hydrolysis. The digestion is carried out with lysosomal enzymes found in the lysosome. Like waste disposal in a city, lysosomes help keep excessive or bulky macromolecules from building up in the cell



Lecture 3

Cellular Metabolism, Metabolic Pathways, Enzyme, Cofactors and Coenzymes

Review

Cell Organelles, Nucleus, Gene Expression

DNA, RNA and Gene Expression

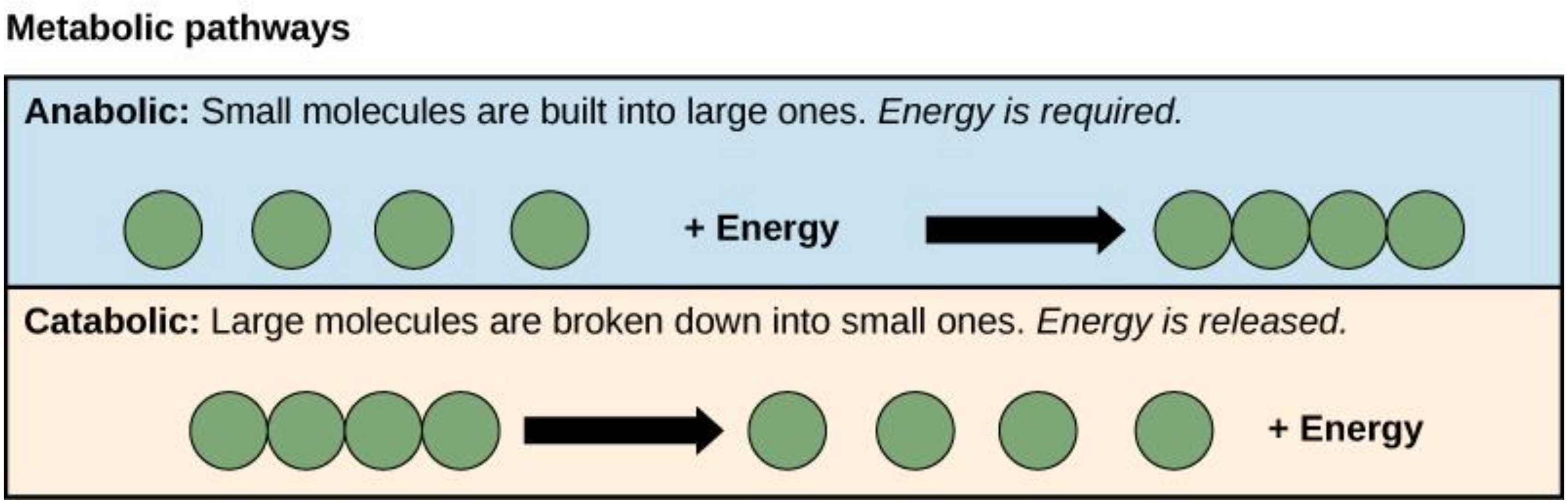
- What is the role of DNA? Where in the cell is it?
  - DNA contains the code or blueprint for protein production
  - DNA resides in the nucleus of the cells
- What is the role of RNA?
  - RNA actively participates in protein synthesis
- Where does protein synthesis occur?
  - Outside the nucleus in ribosomes (may be in endoplasmic reticulum)
- Why does DNA need RNA?
  - DNA is to large to exit the nucleus, mRNA makes a transcription of the sequences of bases that are part of a gene and takes this out of the nucleus

Cellular Metabolism

- Recall that cells are the simplest units of life
- Our lives depend on the metabolic processes that occur in the trillions of cells present in the body
- Metabolism is the sum of all the biochemical processes underway within the body at any moment

Cellular Metabolism

- Cellular metabolism include:
  - Anabolism – the synthesis of organic compounds from simpler precursors (adds), requires energy
  - Catabolism – the breakdown of organic molecules into simpler components (cuts), releases energy

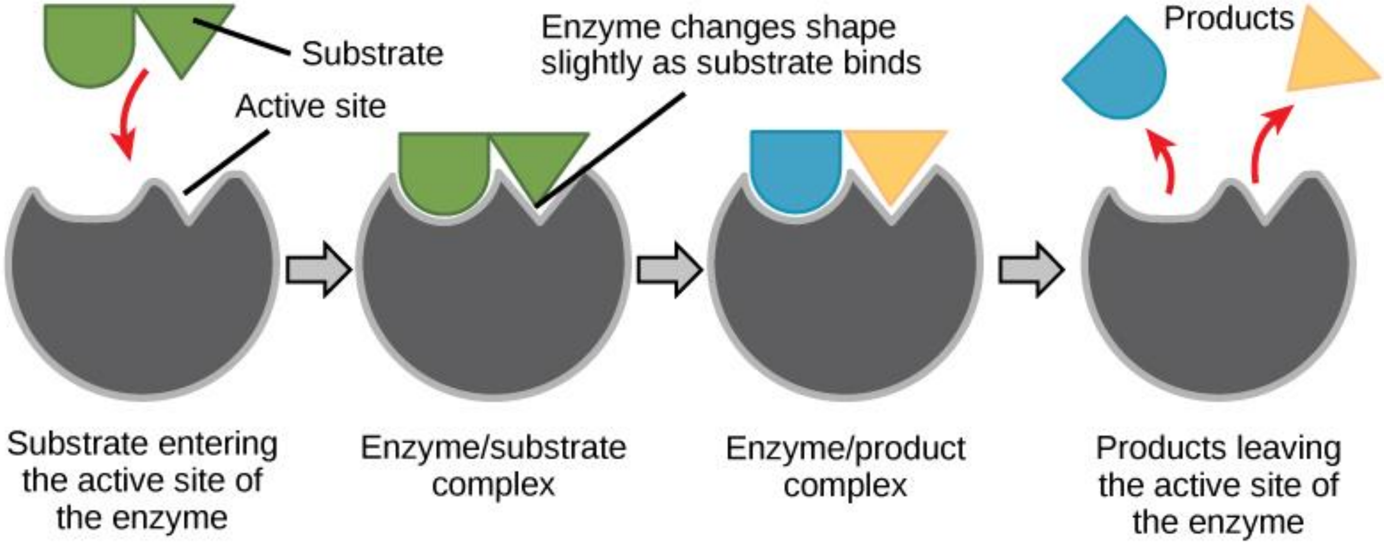


Metabolic Pathways

- Cells perform many complex reactions that occur in multiple steps
- In each step along the way, enzymes are necessary to catalyze this particular step of the reaction
- These multi-step reactions are referred to as metabolic pathways
- Definition of metabolic pathways - A series of chemical reactions catalyzed by enzymes and are connected by their intermediates, i.e. the reactants of one reaction are the products of the previous one, and so on
- We will look at the following metabolic pathways related to energy production (ATP) in the body
  - Glycolysis
  - Citric Acid (Kreb) Cycle
  - Oxidative Phosphorylation
- First we will look at how enzymes work

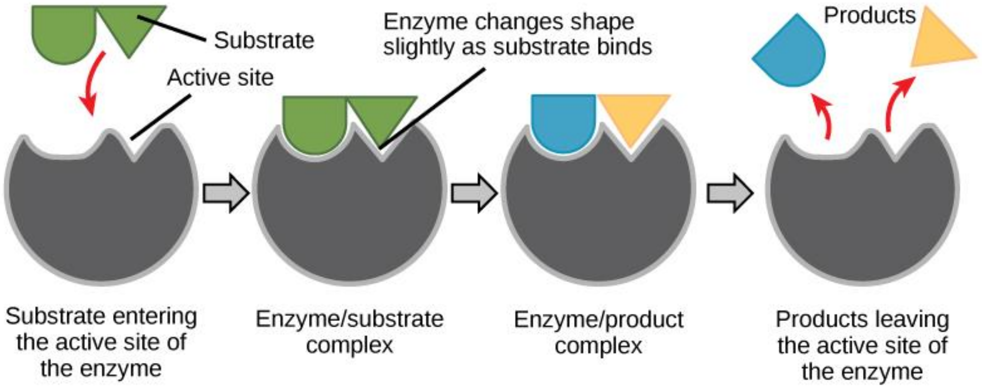
Enzymes

- A substance that helps a chemical reaction to occur is called a catalyst, and the molecules that catalyze biochemical reactions are called enzymes
- Enzymes mediate most of the metabolic processes in our body
  - This includes both anabolic and catabolic reactions
  - They increase the rates of these reactions without being consumed themselves



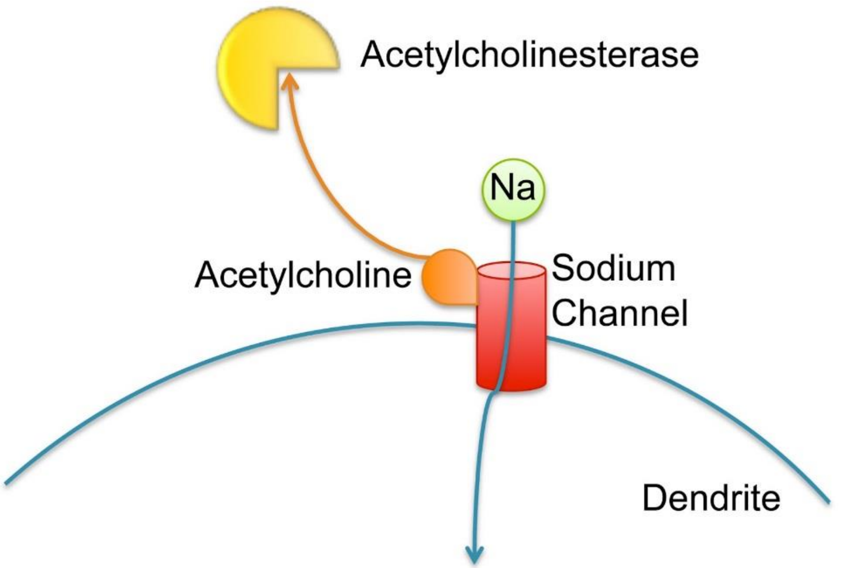
Enzymes

- Enzymes (which are almost always proteins) interact with reactants to form final products
  - The reactants are called substrates
  - Substrates bind to specific regions of enzymes called active sites
    - The substrate and active site fit lock and key
    - Substrates can be any organic or inorganic compound, however due to the specific shape of enzyme active sites, they are specific to a precise substrate
  - The enzyme then initiates a reaction and produces a product
  - The enzyme is not permanently changed or consumed in this reaction and is able to be used again to produce the same reaction



Enzymes

- Although there exists a more systematic nomenclature, enzymes can often be recognized by the suffix –ase added to the name of the substrate they act on
  - Ex) acetylcholinesterase is an important enzyme which breaks down acetylcholine

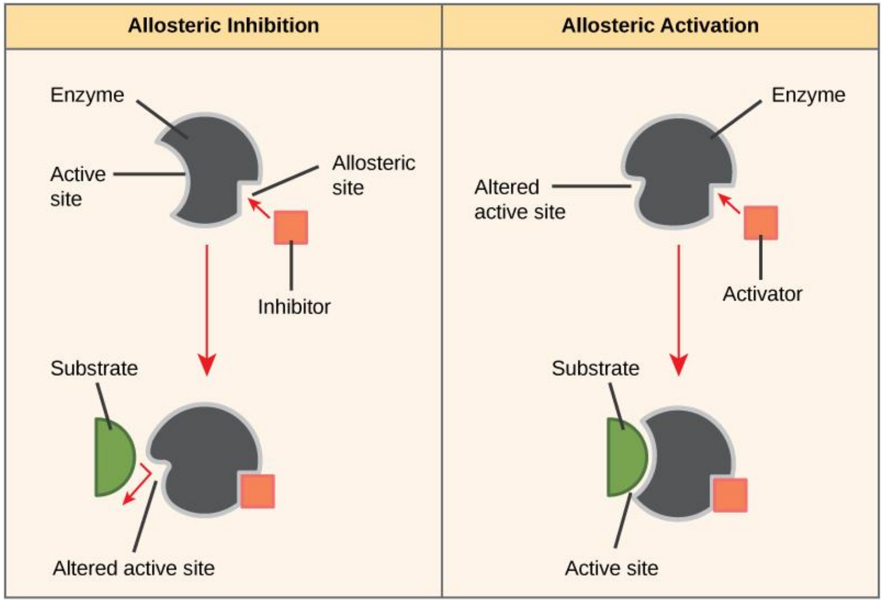


Regulation of Enzymatic Function

- Enzymes are regulated by other molecules
- These other molecules can activate or inhibit enzymes
- There are two ways they inhibit enzymes
  - Competitive inhibition – the substance binds and blocks the active site
  - Noncompetitive inhibition – the substance binds elsewhere on the enzyme, but still alters the ability for substrates to bind with active sites
    - Some inhibitor molecules bind to enzymes in a location where their binding induces a conformational change that reduces the affinity of the enzyme for its substrate. This type of inhibition is called allosteric inhibition

Regulation of Enzymatic Function

- Some inhibitor and activator molecules bind to enzymes in a location where their binding induces a conformational change that reduces the affinity of the enzyme for its substrate.
- This type of inhibition is called allosteric inhibition
- This type of activation is called allosteric activation



Allosteric Modulators in Pharmocology

- Certain drugs inhibit the action of enzymes
- For example, statins are inhibitors of the enzyme HMG-CoA reductase, which is the enzyme that synthesizes cholesterol from lipids in the body
- COX-2 inhibitors such as Celebrex inhibit the enzyme cyclooxygenase-2 which is necessary to convert omega-6 fatty acids to prostaglandin, an inflammatory modulator

Cofactors and Coenzymes

- Many enzymes do not work optimally, or even at all, unless bound to other specific non-protein helper molecules
- Binding to these molecules promotes optimal shape and function of their respective enzymes
- Two examples of these types of helper molecules are cofactors and coenzymes

Cofactors and Coenzymes

- A cofactor is an inorganic ion or molecule that must first bind to an enzyme before a substrate is able to bind to the active site
    - They either bind to the active site or somewhere else on the enzyme, causing a change in shape and allowing a substrate to bind at the active site
    - Ca^{2+} and Mg^{2+} are example of ions that are cofactors
- Nonprotein organic molecules that function as cofactors are called coenzymes
    - Many coenzymes are derived from vitamins (some vitamins are coenzymes, others are necessary components of coenzymes)
    - Vitamins are structurally related to carbohydrates or lipids and mostly cannot be created by the body, but instead must be obtained in the diet
    - For example, coenzymes derived from some B vitamins are necessary for amino acid, nucleic acid and lipid metabolism
    - Vitamin C is a direct coenzyme for multiple enzymes that take part in building the important connective tissue ingredient, collagen
- Like enzymes, cofactors and coenzymes are not part of the final product of the reaction

Temperature and pH Effects on Enzymes

- Changes in temperature or pH can alter protein/active site shape and therefore alter its function
- This alteration is called denaturation
  - Ex 1) cooking eggs denature the proteins in the otherwise soluble egg whites, creating a completely and irreversibly altered structure
  - Ex 2) Very high fevers can change the shape of structural proteins and enzymes. Some of this denaturation can be reversed if death does not occur
- Changes in pH can also alter the shape of proteins
  - Ex 3) Pancreatic enzymes such as trypsin are activated due to the alkaline nature in the duodenum
  - Ex 4) Ceviche uses the acidity of limes to ‘cook’ fish. This acidity denatures the proteins in the fish

- Animations
  - From McGraw Hill
    - http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter2/animation__how_enzymes_work.html
    - http://highered.mcgraw-hill.com/sites/0070960526/student_view0/chapter6/animations.html
  - Another good animation
    - http://www.lpscience.fatcow.com/jwanamaker/animations/Enzyme%20activity.html
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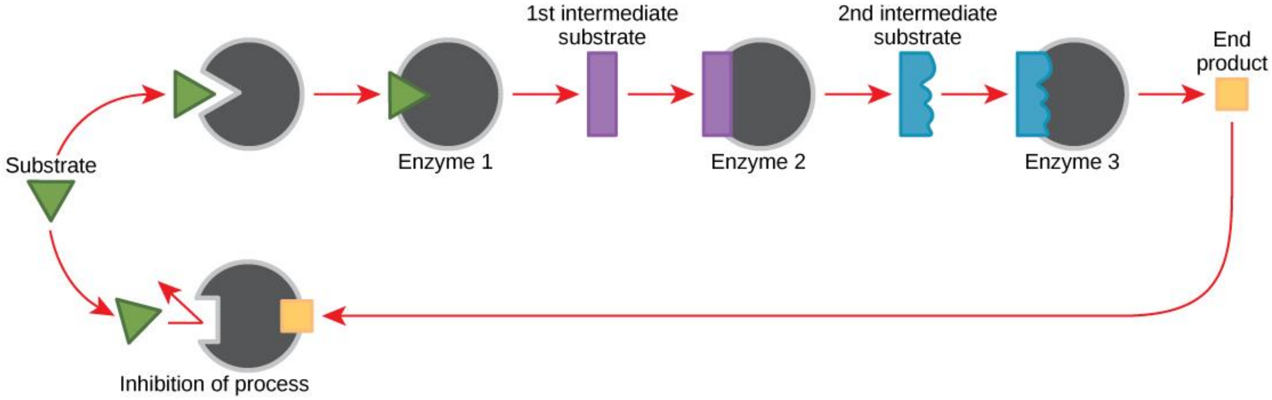
Feedback Inhibition in Metabolic Pathways

- Cells have evolved to use the products of their own reactions for feedback inhibition of enzyme activity
- Feedback inhibition involves the use of a reaction product to regulate its own further production



Feedback Inhibition in Metabolic Pathways

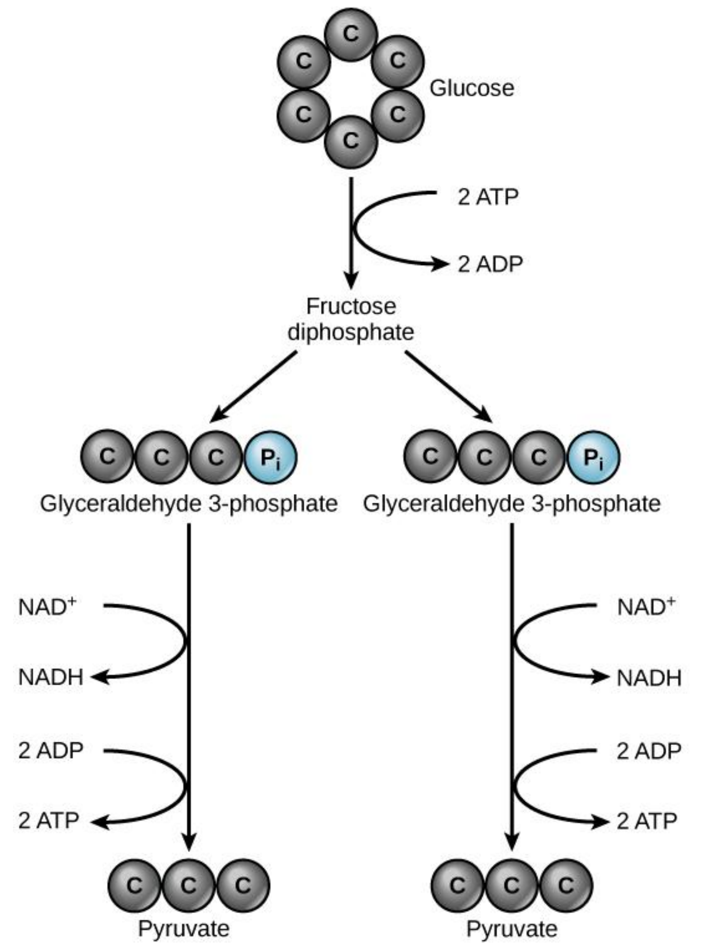
- ATP is an allosteric regulator of some of the enzymes involved in the catabolic breakdown of sugar, the process that creates ATP
  - When ATP is in abundant supply, the cell can prevent the production of ATP
- On the other hand, ADP serves as a positive allosteric regulator (an allosteric activator) for some of the same enzymes that are inhibited by ATP
  - When relative levels of ADP are high compared to ATP, the cell is triggered to produce more ATP through sugar catabolism

Energy Producing Metabolic Pathways

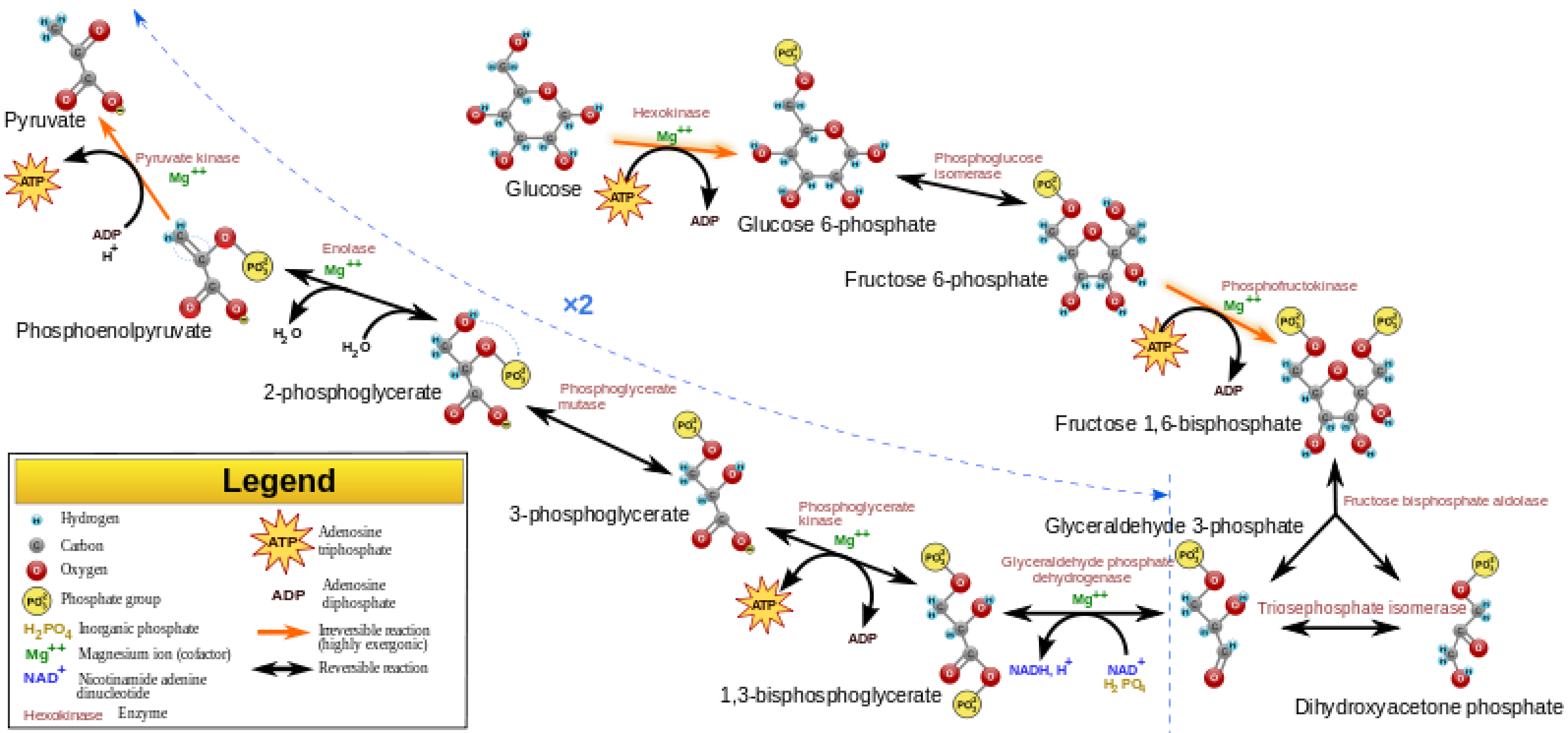
Glycolysis, The Citric Acid Cycle, Oxidative Phosporylation

Energy Producing Metabolic Pathways Glycolysis

- •Glycolysis is the breakdown of glucose to two molecules of pyruvate
- •Glycolysis takes place in the cytoplasm of the cell
- •Enzymes are used to catalyze the reactions
- •These reactions collectively use 2 ATP molecules, but create 4 ATP molecules

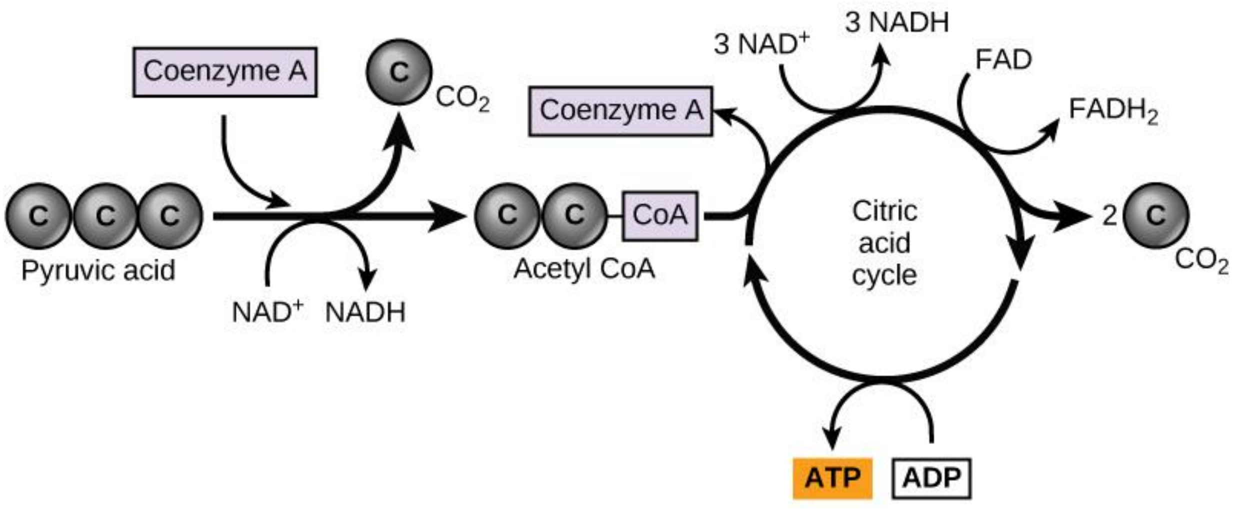


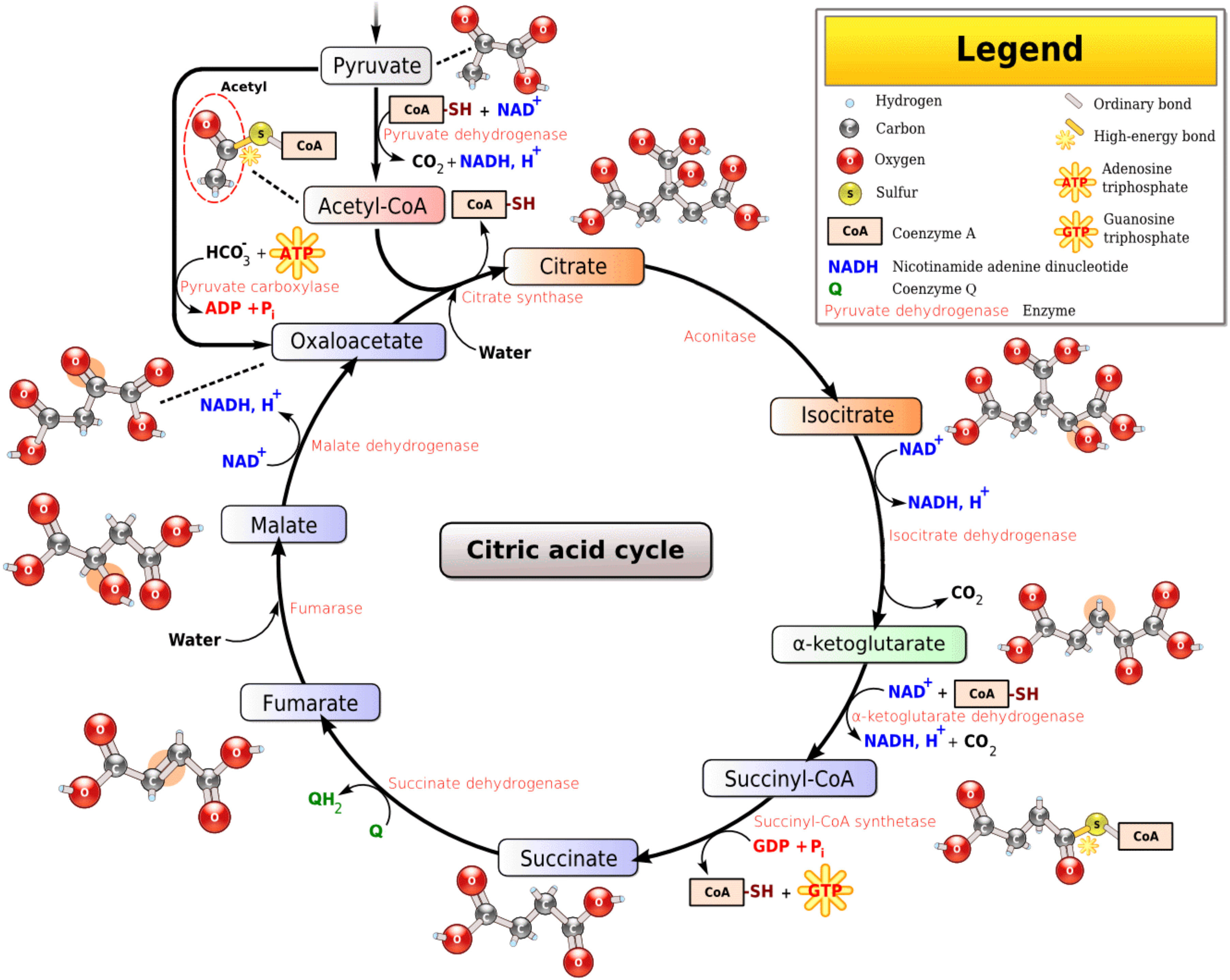
Energy Producing Metabolic Pathways
Glycolysis



Energy Producing Metabolic Pathways Citric Acid Cycle

- Pyruvate is transported into mitochondria and converted into acetyl-CoA
- It is then metabolized by the citric acid cycle (Krebs cycle), again under enzyme control
    - These reactions metabolize pyruvate to CO_2
    - They produces two more ATP molecules
    - They also produce NADH and $FADH_2$ which is involved in the next pathway

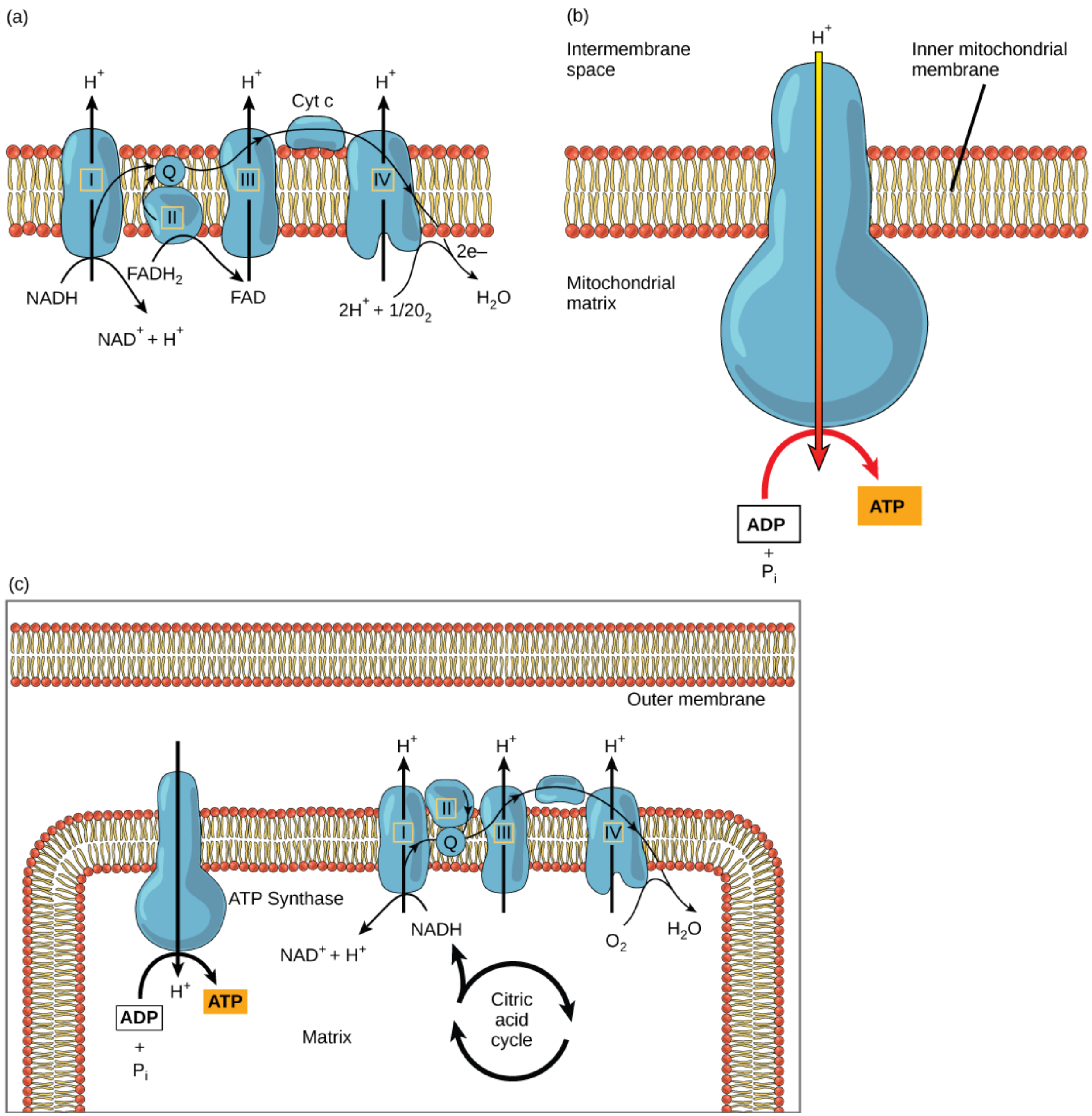




Legend
Hydrogen
Carbon
Oxygen
Sulfur
CoA Coenzyme A
NADH Nicotinamide adenine dinucleotide
Q Coenzyme Q
Pyruvate dehydrogenase Enzyme
Ordinary bond
High-energy bond
ATP Adenosine triphosphate
GTP Guanosine triphosphate
Citric acid cycle
Pyruvate
Acetyl
CoA-SH + NAD+
Pyruvate dehydrogenase
CO2 + NADH, H+
Acetyl-CoA
CoA-SH
HCO3- + ATP
Pyruvate carboxylase
ADP + Pi
Citrate
Citrate synthase
Water
Oxaloacetate
Aconitase
Isocitrate
NAD+
NADH, H+
Isocitrate dehydrogenase
CO2
α-ketoglutarate
NAD+ + CoA-SH
α-ketoglutarate dehydrogenase
NADH, H+ + CO2
Succinyl-CoA
Succinyl-CoA synthetase
GDP + Pi
CoA-SH + GTP
Succinate
Succinate dehydrogenase
QH2
Q
Fumarate
Fumarase
Water
Malate
Malate dehydrogenase
NAD+
NADH, H+

Energy Producing Metabolic Pathways Oxidative Phosphorylation

- Oxydative phosphorylation takes place in the inner membrane of the mitochondria
- As mentioned, the citric acid cycle produces other molecule called NADH and $FADH_2$
- These transfer their electrons which then pass through a series of chemical reactions to their final electron acceptor, oxygen. Water is produced
- In the process, H+ is moved across the membrane, producing a high concentration of H+ in the intermembrane space
- This H+ concentration gradient is used to power the conversion of ADP to ATP
- This process produce even more ATP
    - 32 ATP molecules are created



(a)
H+
H+
Cyt c
H+
I
Q
III
IV
II
2e–
FADH2
NADH
FAD
H2O
2H+ + 1/2O2
NAD+ + H+
(b)
Intermembrane space
H+
Inner mitochondrial membrane
Mitochondrial matrix
ADP
+
Pi
ATP
(c)
Outer membrane
H+
H+
H+
II
I
Q
III
IV
ATP Synthase
NADH
O2
H2O
NAD+ + H+
H+
ATP
ADP
+
Pi
Matrix
Citric acid cycle

Oxidation of Glucose

Glycolysis, Krebs Cycle, Oxidative Phosphorylation

- Collectively 36 molecules of ATP are produced
- Collectively they use oxygen to 'burn' glucose and metabolize it into CO_2 and H_20
    - $C_6H_{12}O_6 + 6O_2 >> 6CO_2 + 6H_2O$

Lecture 4

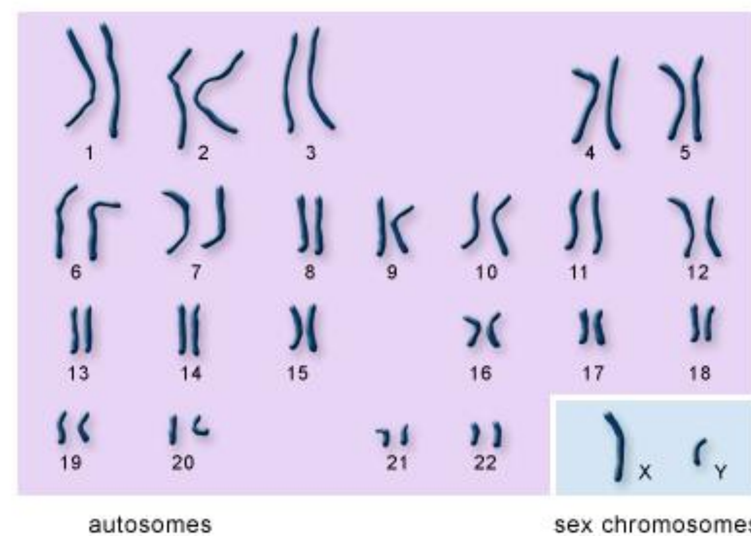
Cell Cycle, Cell Cycle and Cancer, Meiosis and Reproduction

Cell Genetics in Humans

- Human cells, like all eukaryotic cells have a cell cycle in which cell growth, replication, and division occurs
  - This involve regeneration of body cells (such as epithelial cells) and involves a process called mitosis. The daughter cell has the same amount of chromosomes and is essentially an identical duplicate
  - Another type of cell division called meiosis produces gametes (oocytes and sperm) which are necessary for sexual reproduction. These cells contain half the number of chromosomes and need to combine with another cell from the opposite sex (fertilization) to create a new cell and new life

Human Chromosomes and Cell Division

- Human cells have 23 pairs of chromosomes – a total of 46 chromosomes
- For homologous pairs, one comes from the father and one from the mother
- Despite there being genetic diversity between 22 of these pairs, they are similar in shape and in other ways
- The 23rd pair determines sex and includes an X and a Y chromosome (females have XX, Male XY)



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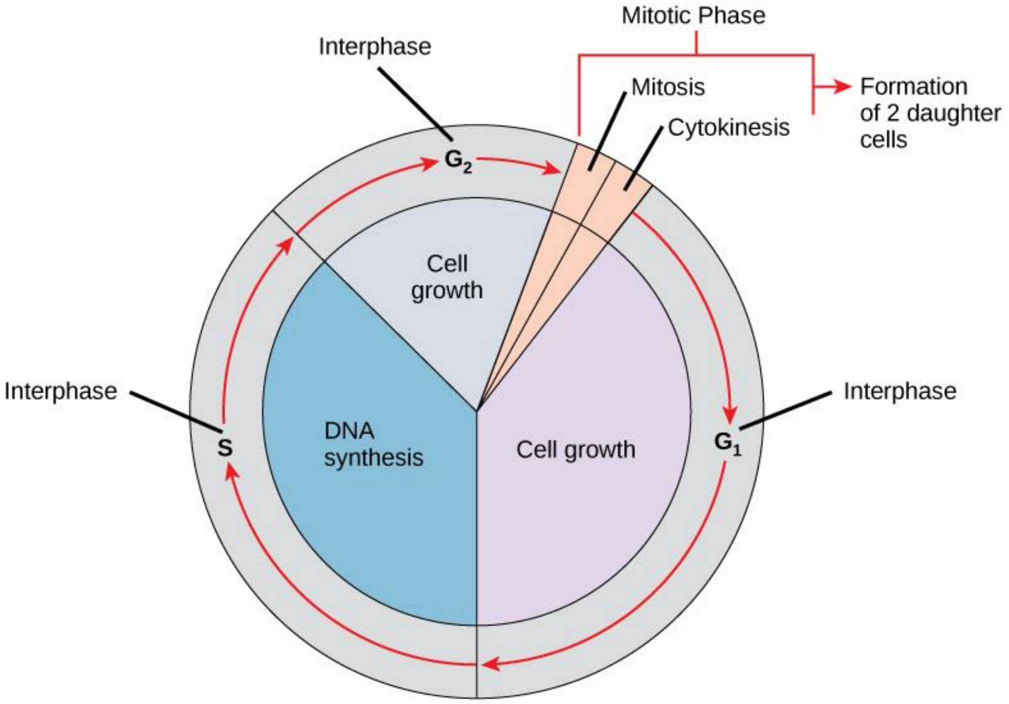
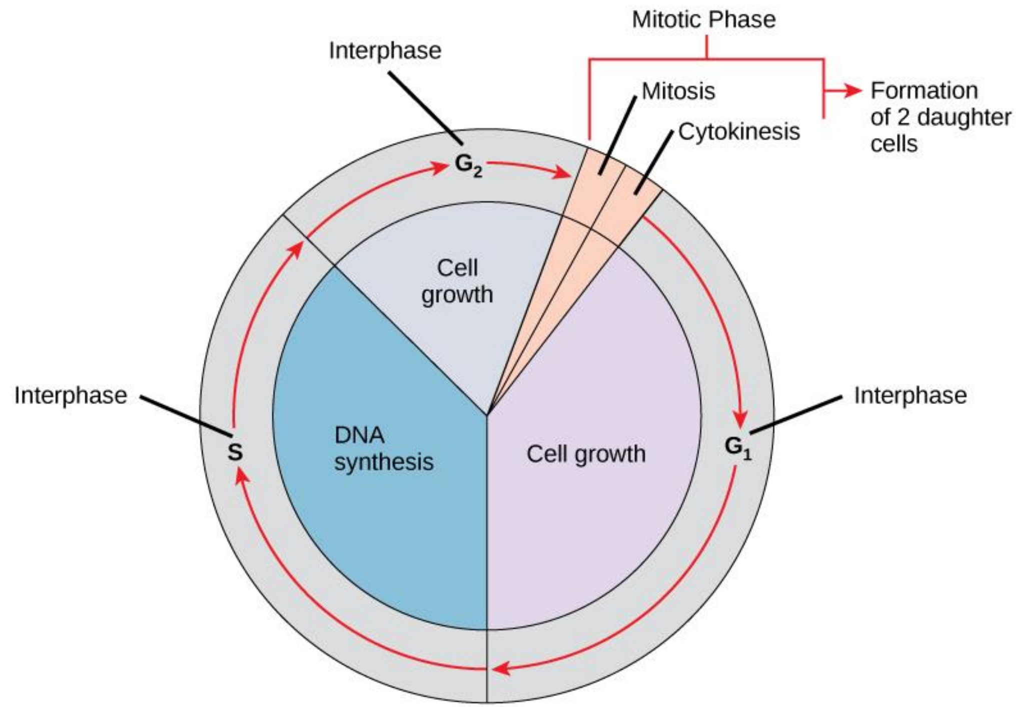
Cell Cycle for Somatic Cells



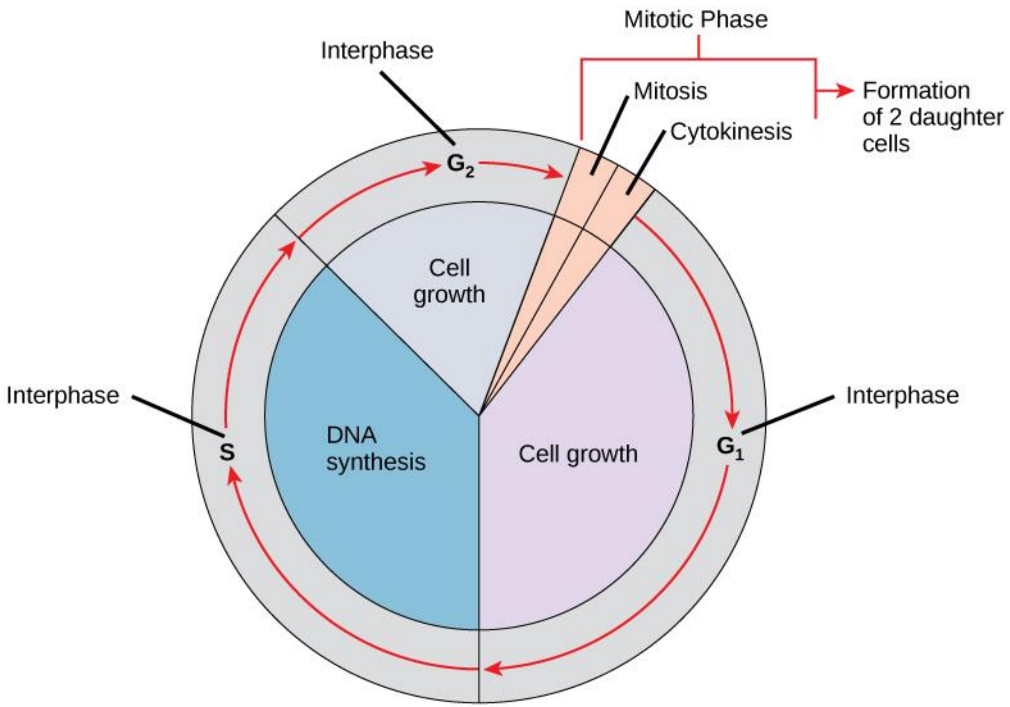
- A cell moves through a series of phases involving cell growth and cell division
- Two daughter cells are produced
- This type of cell division allows multicellular organisms to grow and repair damaged tissue
- These two major phases are:
    - Interphase
    - Mitotic phase

Cell Cycle for Somatic Cells



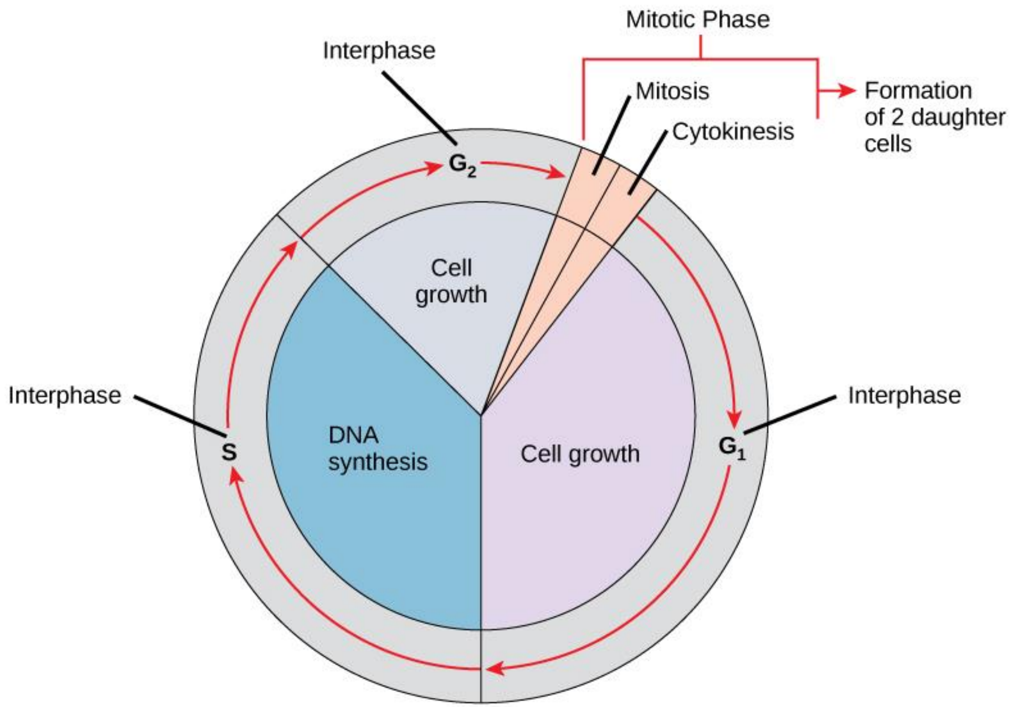
- During interphase, the cell grows and DNA is replicated
- During the mitotic phase, the replicated DNA and cytoplasmic contents divide and the cell is replicated

Cell Cycle for Somatic Cells



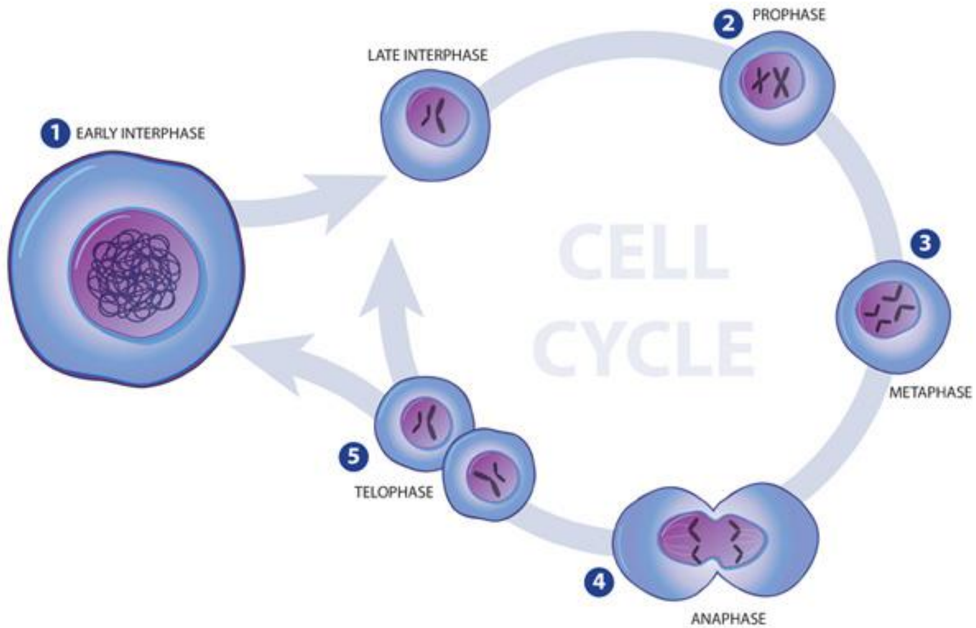
- During interphase,
  - G_1 involves cell growth and protein synthesis,
  - the S phase involves DNA replication
  - and G_2 involves further growth and protein synthesis

Cell Cycle for Somatic Cells



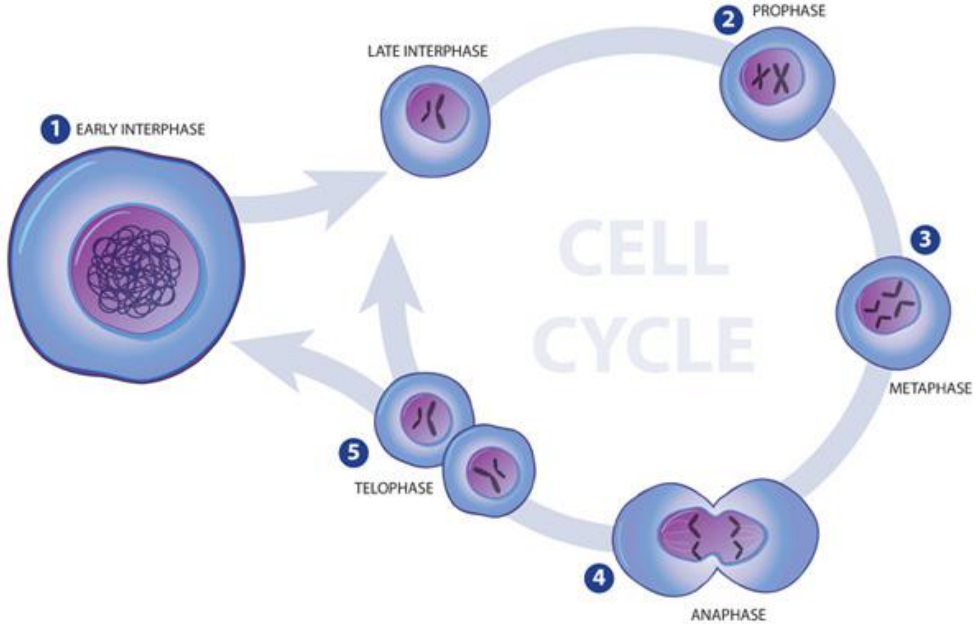
- The mitotic phase follows interphase. It involves:
  - Mitosis – is nuclear division during which duplicated chromosomes are segregated and distributed into daughter nuclei
  - Cytokinesis – process in which the cytoplasm is divided and two daughter cells are formed

Cell Cycle Interphase



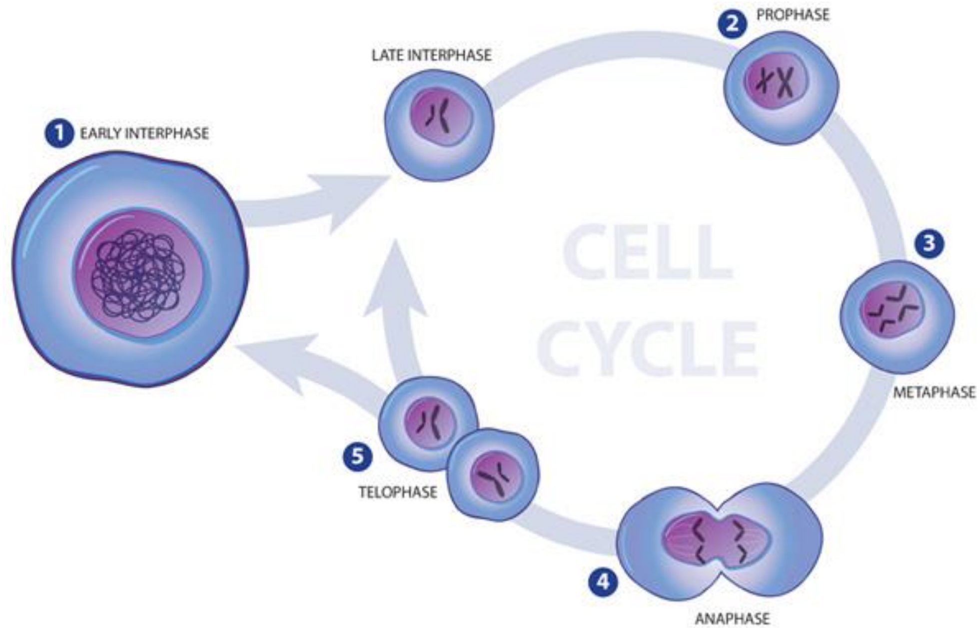
- G1 – 1st stage of interphase, cell grows and matures
- S – DNA is replicated into two identical chromosomes which are in an uncoiled form called chromatin. Each chromatid is attached at structures called centromeres
- G2 – cell prepares for division

Cell Cycle
Mitotic Phase



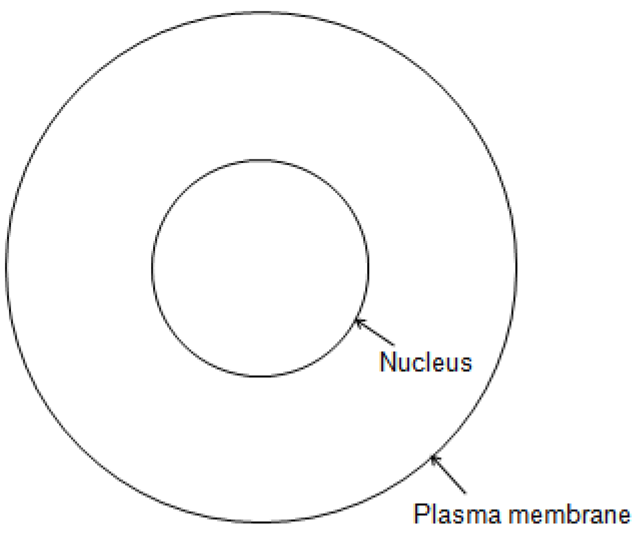
- Mitosis occurs when the nucleus of the cell divides into two identical nuclei with the same number and type of chromosomes
- This followed by cytokinesis when the cytoplasm, divides, thus creating two daughter cells that are genetically equal and approximately identical in size

Cell Cycle Mitotic Phase



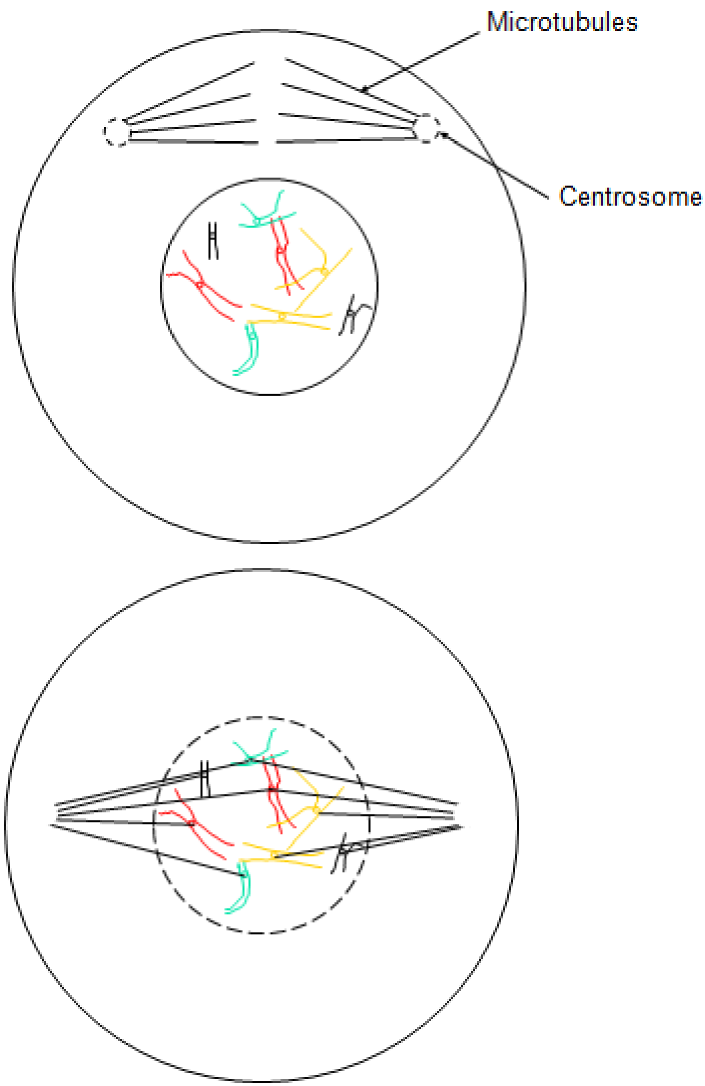
- Mitosis involves several phases
  - Prophase = Prepare (condense chromatin into chromosomes, break down nuclear membrane, assemble mitotic spindle, centriole pairs move toward opposite poles of the cell)
  - Metaphase = Middle (Chromosomes line up in the middle)
  - Anaphase = Apart (Sister chromatids pulled apart to opposite sides of cell)
  - Telophase = Prophase in reverse = de-condense chromosomes, re-form nuclear membrane, break down mitotic spindle

Cell Cycle Summary Interphase



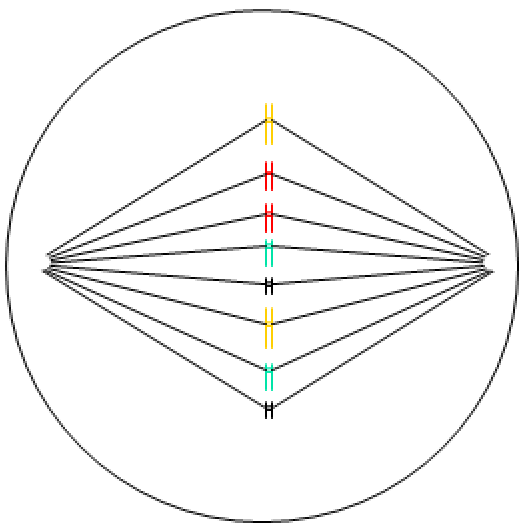
- Chromosomes are not easily visible because they are uncoiled
- Preparation is made for cell division

Cell Cycle Summary
Mitosis Prophase



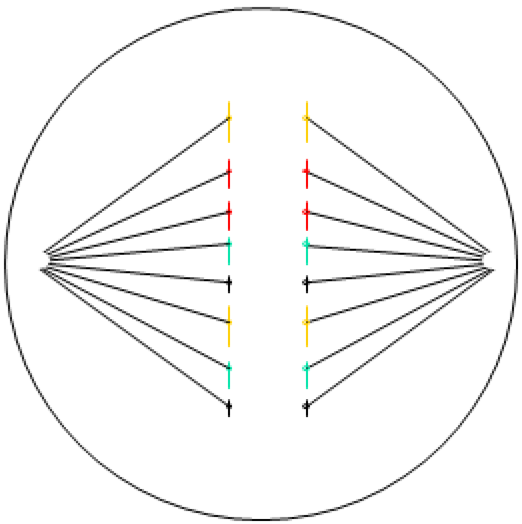
- The chromosomes begin to coil
- The spindle apparatus begins to form as centrosomes move apart
- The nuclear membrane disintegrates.
- Kinetochores form on the chromosomes.
- Kinetochore microtubules attach to the chromosomes

Cell Cycle Summary
Mitosis - Metaphase



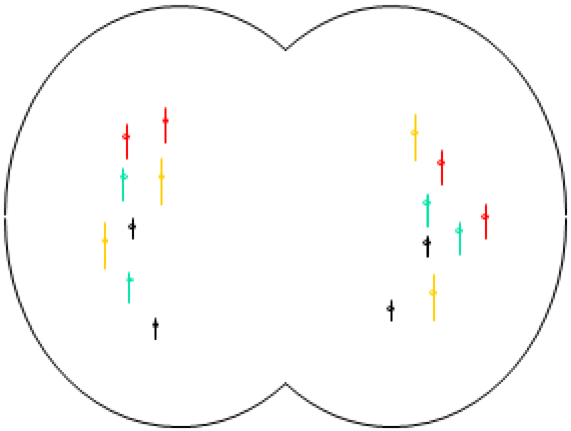
- The chromosomes become aligned on a plane

Cell Cycle Summary Anaphase



- The chromatids separate (The number of chromosomes doubles)

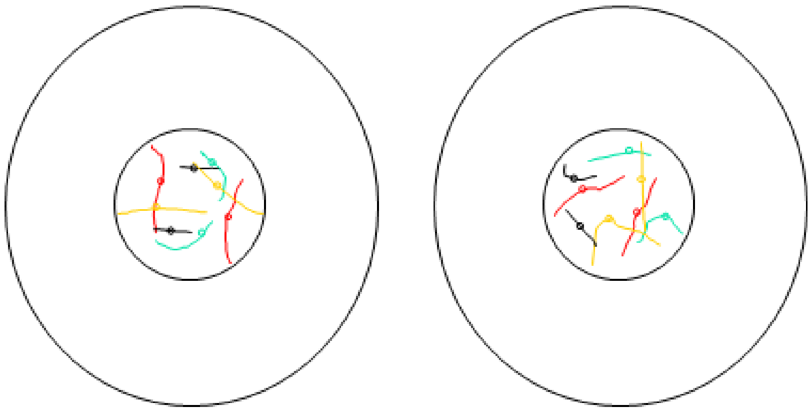
Cell Cycle Summary
Mitosis – Telophase - Cytokinesis



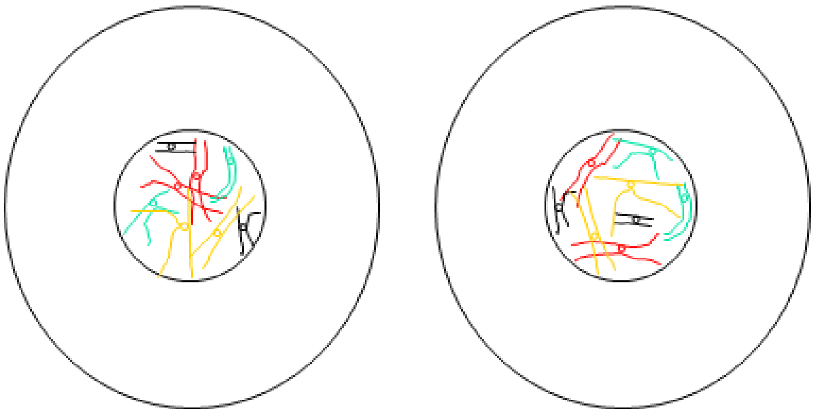
- The nuclear membrane reappears
- The chromosomes uncoil
- The spindle apparatus breaks down
- The cell divides into two

Cell Cycle Summary
Interphase – G1

- The chromosomes have one chromatid



Cell Cycle Summary Interphase S – G2



- The chromosomes are replicated
- Each one has two sister chromatids

Cell Cycle in Humans

- The cell cycle involves the preparation and division of a cell into two identical cells
- In humans, there are 46 chromosomes in the original cell and 46 chromosomes in the daughter cell
- Mitosis involves the division of the DNA into two identical units, starting with 46 chromosomes and ending with 2 cell each containing 46 chromosomes

Cell Cycle and Cancer

- Cancer is the result of unchecked cell division caused by a breakdown of the mechanisms regulating the cell cycle. The loss of control begins with a change in the DNA sequence of a gene that codes for one of the regulatory molecules.
- Faulty instructions lead to a protein that does not function as it should
- Any disruption of the monitoring system can allow other mistakes to be passed on to the daughter cells.
- Each successive cell division will give rise to daughter cells with even more accumulated damage.
- Eventually, all checkpoints become nonfunctional, and rapidly reproducing cells crowd out normal cells, resulting in tumorous growth.

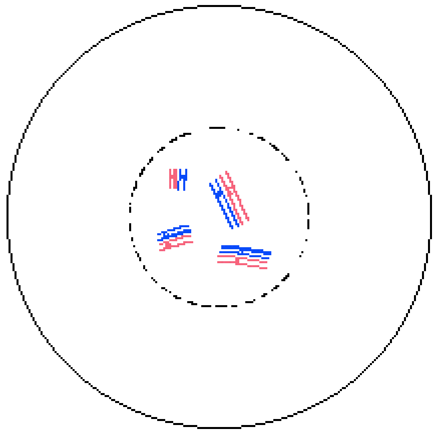
Meiosis

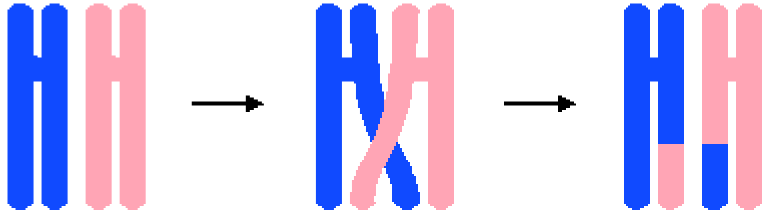
- Sexual reproduction requires fertilization which is a union of two cells from two individual organisms
- Gametes from the mother (eggs or oocytes) and father (sperm) unite to form a new cell which has 46 chromosomes, 23 supplied from the mother and 23 Supplied from the father
- The gametes, therefore must contain half of the genetic material
- Meiosis is a type of nuclear division that results in the reduction (by ½) of the number of chromosome sets. It is the division of the contents of the nucleus that divides the chromosomes among gametes

Meiosis

- Meiosis employs many of the same mechanisms as mitosis. However, the resulting nuclei at the end of a meiotic cell division contain half the chromosome number
- To achieve the reduction in chromosome number, meiosis consists of one round of chromosome duplication and two rounds of nuclear division referred to as:
  - Meiosis 1 – consists of prophase I, metaphase I, …
    - The number of cells is doubled, but the number of chromosomes is not. Each cell contains half the original amount
  - Meiosis 2 – consists of prophase II, metaphase II, …
    - More like mitosis, each cell is doubled and contains the same number of chromosomes
  - Meiosis is preceded by interphase (G1, S, G2) which is almost identical as with mitosis

Meiosis
Prophase I

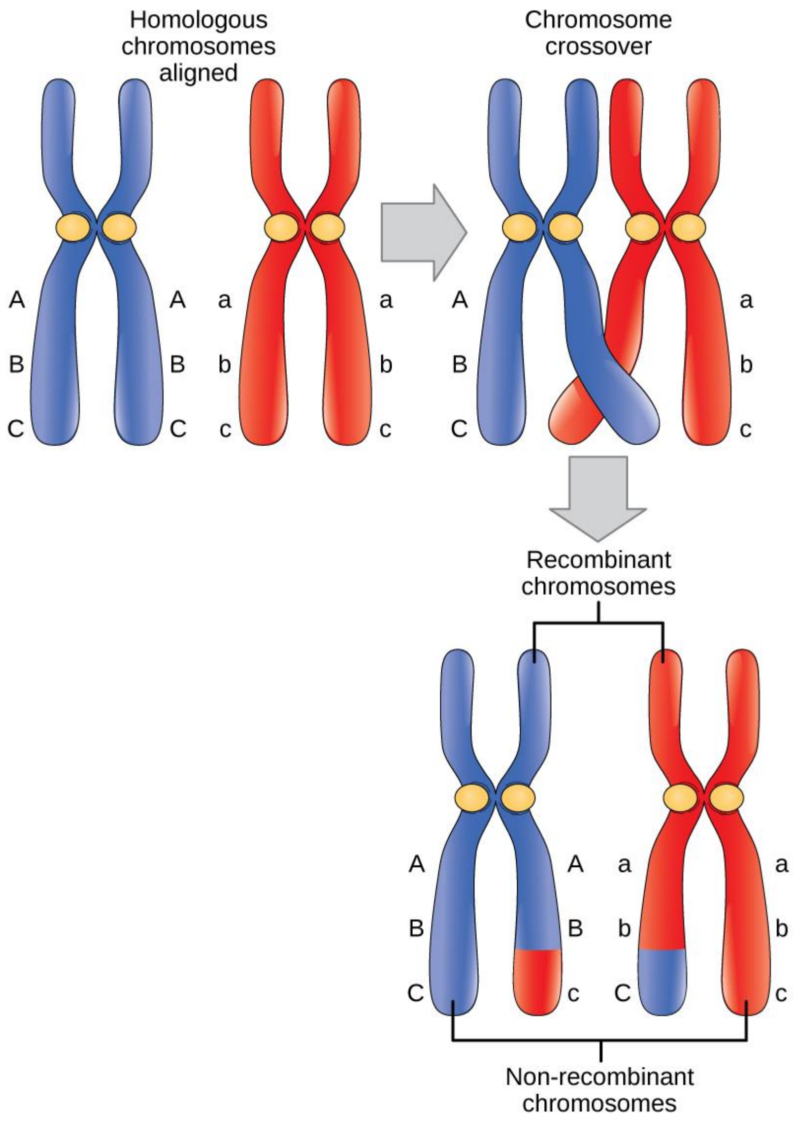




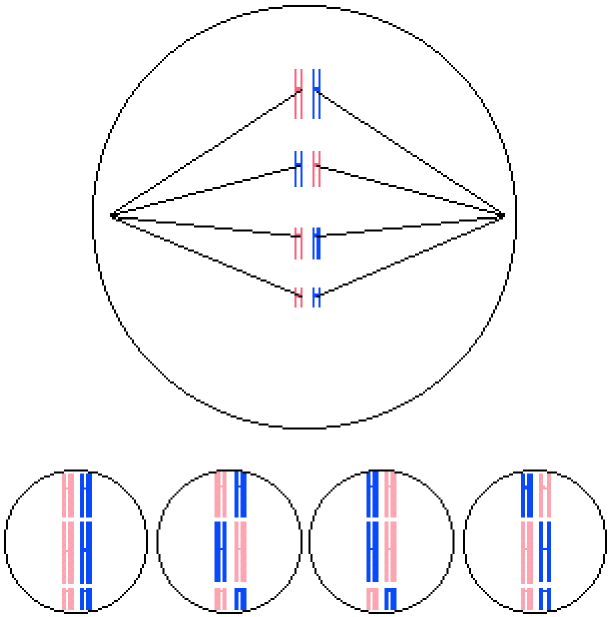
- Homologous chromosomes become paired
- Crossing-over occurs between homologous chromosomes

Meiosis Prophase I

- In this illustration of the effects of crossing over, the blue chromosome came from the individual's father and the red chromosome came from the individual's mother. Crossover occurs between non-sister chromatids of homologous chromosomes. The result is an exchange of genetic material between homologous chromosomes. The chromosomes that have a mixture of maternal and paternal sequence are called recombinant and the chromosomes that are completely paternal or maternal are called non-recombinant.

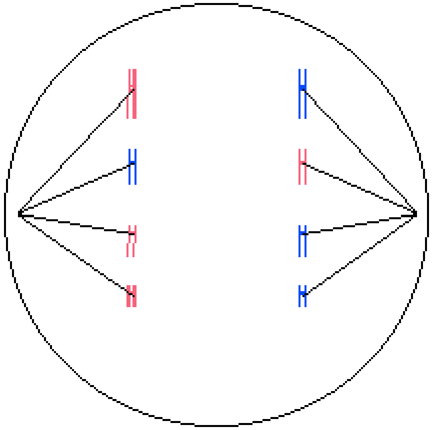


Meiosis Metaphase I



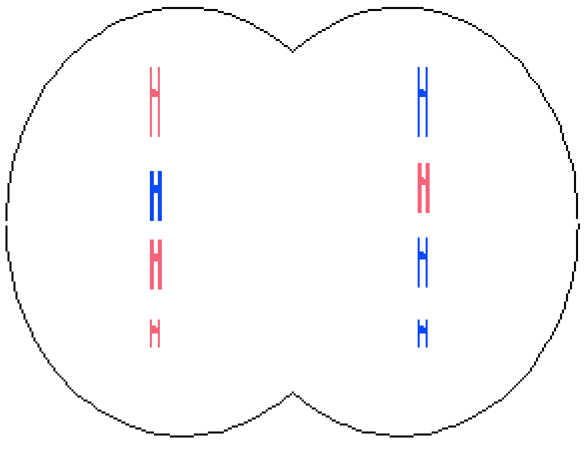
- Homologous pairs become aligned in the center of the cell
- The random alignment pattern is called independent assortment. For example, a cell with 2N = 6 chromosomes could have any of the alignment patterns shown at the left

Meiosis Anaphase I



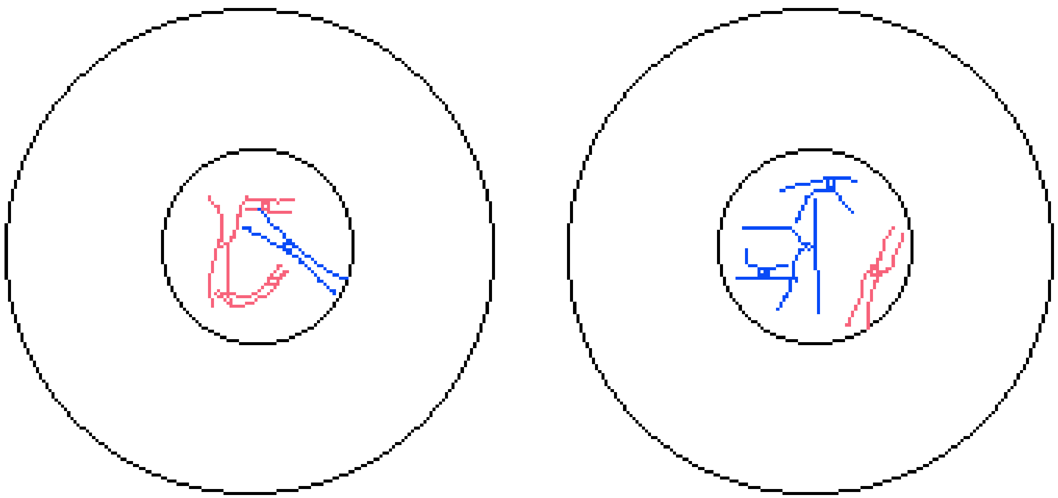
- Homologous chromosomes separate

Meiosis
Telophase I



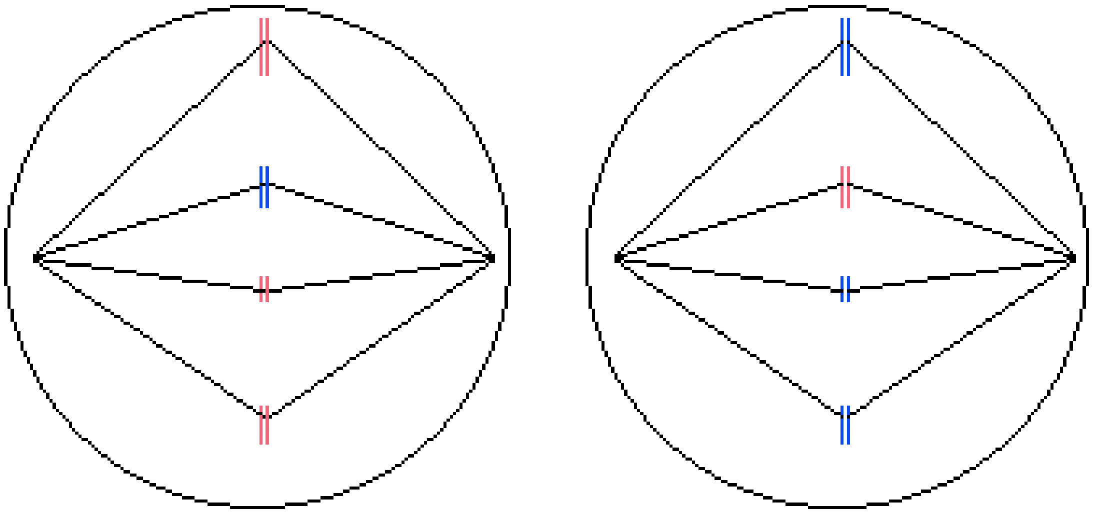
- The cell divides into two cells
- Each daughter cell has half the chromosome number

Meiosis
Prophase II

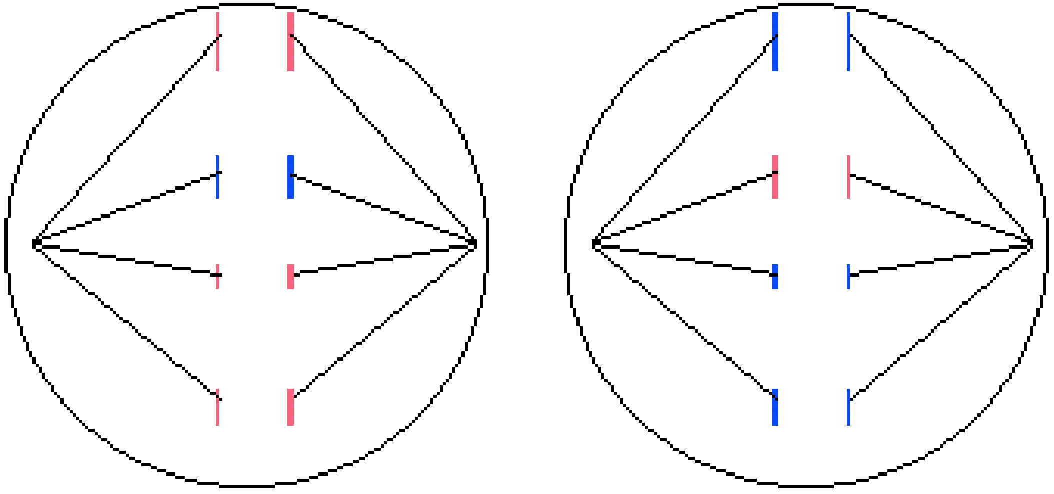


Meiosis 2 is more like Mitosis

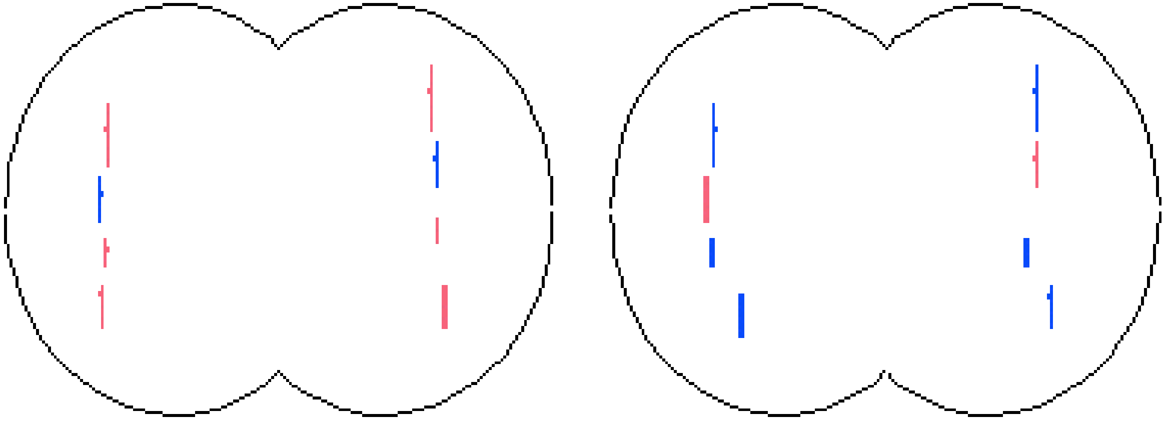
Meiosis
Metaphase II



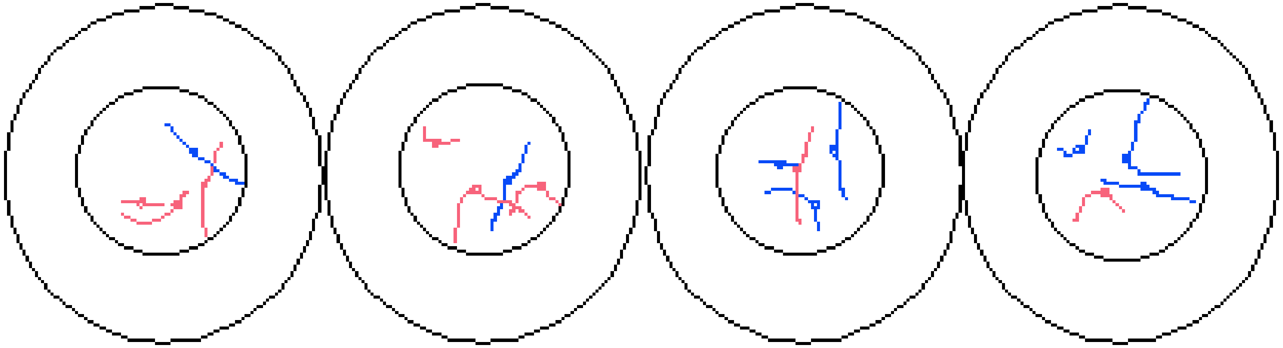
Meiosis
Anaphase II



Meiosis
Telophase II



Meiosis
Daughter Cells



Meiosis in Humans

- Meiosis involves cell division to create gametes (oocytes for females and sperm for males)
- Meiosis involves the production of daughter cells with ½ the number of chromosomes
- Meiosis is involved with sexual reproduction

Mitosis Compared to Meiosis

- Both involve the division of the nucleus in cells
  - Mitosis is cell division involving replacing cells in the body and involves the creation of a daughter cell that has the same number of chromosomes. It is identical to the original genetically.
  - Meiosis has two nuclear divisions resulting in four nuclei. Each nuclei has half the number of chromosomes and there is genetic variation in each daughter cell. Meiosis is used to create gametes for sexual reproduction.

Questions

- Which type of cell division results in an identical daughter cell with the same number of chromosomes?
  - Mitosis
- Which type of cell division ends with daughter cells which have half the number of chromosomes?
  - Meiosis
- Which type of cell division starts with one cell and ends with two cells?
  - Mitosis
- Which type of cell division occurs in body cells?
  - Mitosis
- Which type of cell division starts with one cell and ends with four cells?
  - Meiosis
- Which type of cell division produces gametes?
  - Meiosis

Gene Mutations

- Gene mutations occur in two ways:
  - They can be inherited from a parent or
  - Acquired during a person's lifetime
- Mutations that are passed from parent to child are called hereditary mutations or germline mutations (because they are present in the egg and sperm cells, which are also called germ cells). This type of mutation is present throughout a person's life in virtually every cell in the body. This mutation occurs in meiosis
- Acquired (or somatic) mutations occur in the DNA of individual cells at some time during a person's life. These changes can be caused by environmental factors such as ultraviolet radiation from the sun, or can occur if a mistake is made as DNA copies itself during cell division. Acquired mutations in somatic cells (cells other than sperm and egg cells) cannot be passed on to the next generation. They occur during the cell cycle