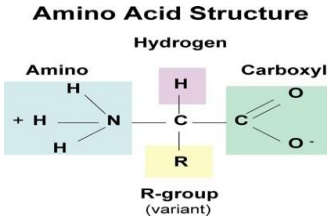
BIO/BIOCHEM HIGH YIELD GUIDE

By Zach Dereniowski

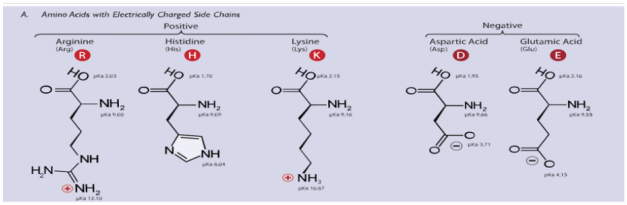
AMINO ACIDS (AA'S), PEPTIDES & PROTEINS

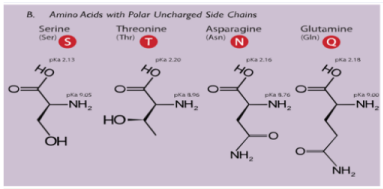


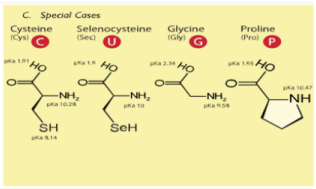
Amino Acids consists of: an amino group, carboxylic acid, a hydrogen atom and an R group attached to the central α-carbon.

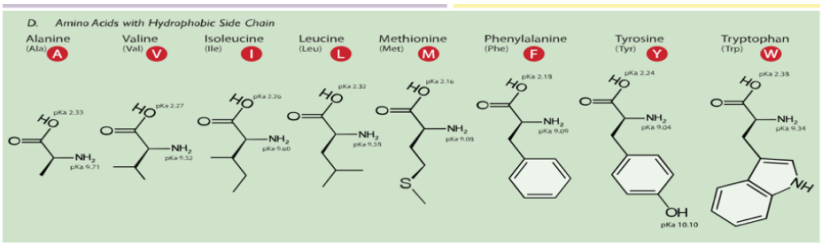
All AA's are chiral (*L)*, except for glycine and have an (S) configuration, except for cysteine.
Side Chains: Chemistry & function of AA's.

Side Chain Chemistry	Amino Acid's
Non-polar & Non-aromatic	Glycine, alanine, valine, leucine, isoleucine, methionine and proline.
Aromatic	Tryptophan, phenylalanine, tyrosine
Polar	Serine, threonine, asparagine, glutamine, cysteine.
Negatively Charged (Acidic)	Aspartic acid & glutamic acid
Positively Charged (Basic)	Lysine, arginine, histidine.



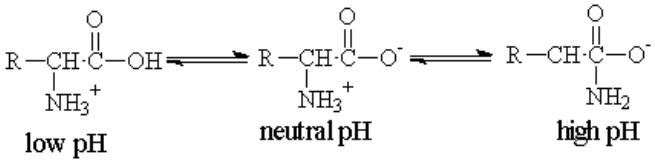






ACID-BASE CHEMISTRY

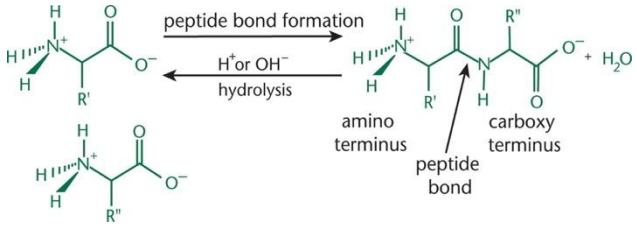
1. AA's = Amphoteric
2. a) Low pH (Acidity): Fully protonated
   b) Neutral pH: Zwitter Ion



c) High pH (Basic): Fully deprotonated

Isoelectric Point (pI): Determined by averaging the pKa values that reference the protonation and deprotonation of the zwitterions (if there are three pKa's, average the two that are closest in range to one another).

PEPTIDE BOND FORMATION & HYDROLYSIS



PROTEIN STRUCTURE

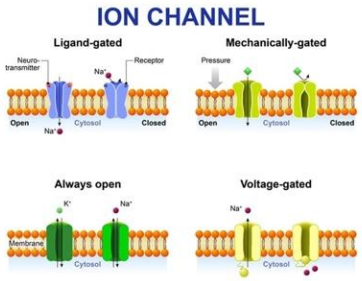
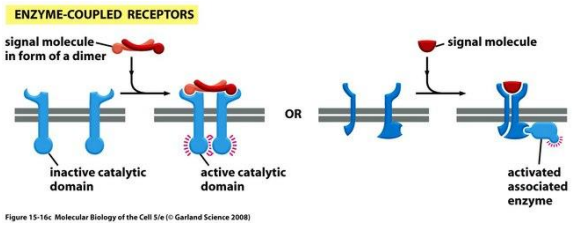
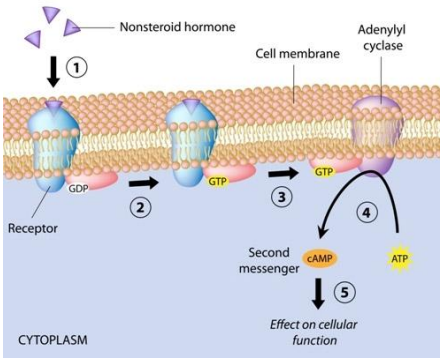
Primary Structure (Assembly)	Linear sequence of AA's.
Secondary Structure (Folding)	Localized structure – Stabilized by hydrogen bonding (α-helices & β-pleated sheets)
Tertiary Structure (Packing)	3D Structure – Stabilized by acid-base interactions, hydrogen bonding, hydrophobic interactions & disulfide bonds.
Quaternary Structure (Interaction)	Interactions between subunits.

NON-ENZYMATIC PROTEINS & FUNCTIONS

Structural Proteins (Fibrous)	Actin, collagen, elastin, keratin and tubulin.
Motor Proteins (Force Generation)	Myosin, kinesin, dynein
Binding Proteins	Bind to specific substrate
Cell Adhesion Molecules (other cells or surfaces)	Cadherins, integrins, selectins.
Antibodies (Immunoglobulins; Ig)	Target specific antigen.

BIOSIGNALING

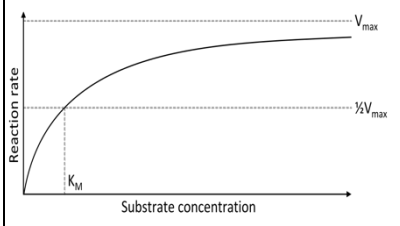
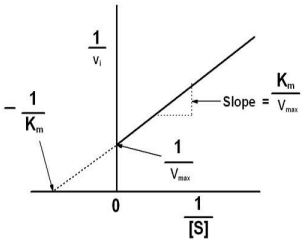
ION CHANNELS	ENZYME-LINKED RECEPTORS	G PROTEIN COUPLED RECEPTORS

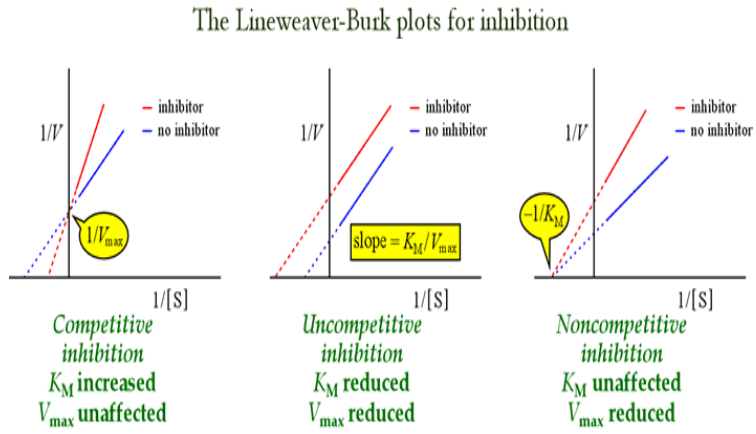
a) Ligand-Gated b) Mechanically-Gated c) Voltage-Gated d) Un-Gated (always open or closed) 	Cell signaling through extracellular ligand binding and initiation of second messenger cascades. 	Membrane bound protein associated with a trimeric G protein – also initiates second messenger systems. 

ENZYMES (LIL HOT)

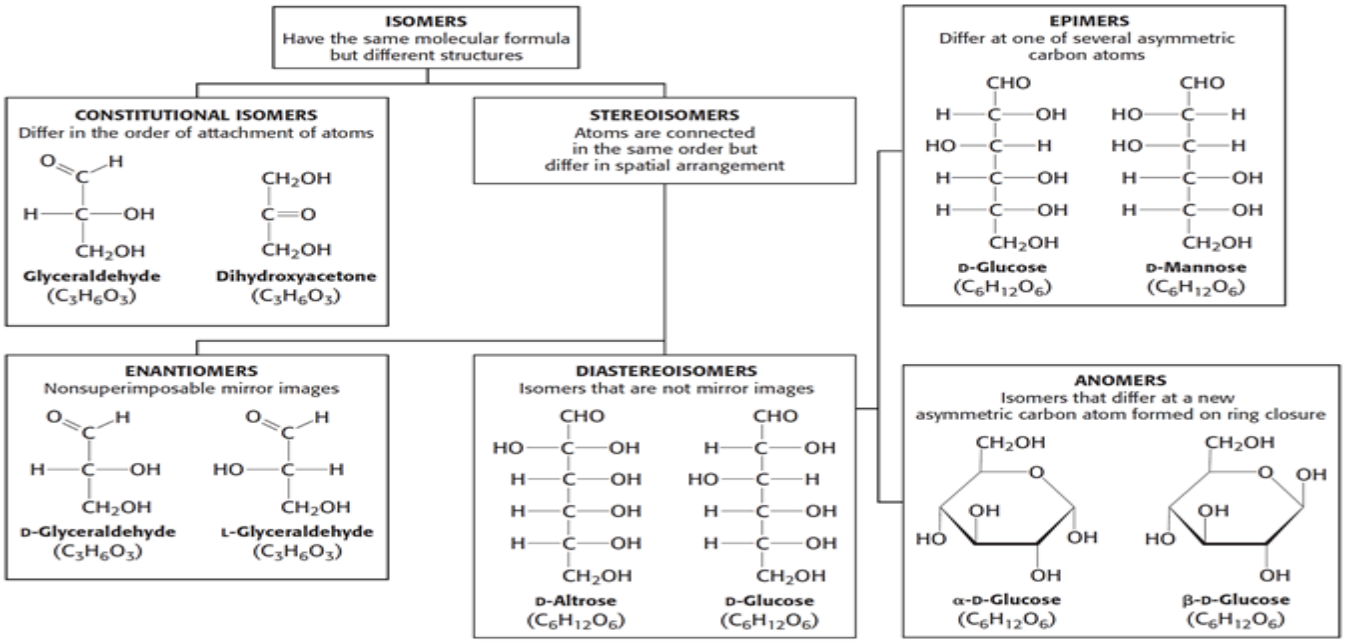
Ligases	Join two biomolecules together.
Isomerases	Catalyze inter-conversion of isomers.
Lyases	Catalyze cleavage without water.
Hydrolases	Catalyze cleavage with water.
Oxidoreductaces	Catalyze oxidation-reduction reactions.
Transferases	Move functional groups from one biomolecule to another.

ENZYME KINETICS

Michaelis Menten Plot	Lineweaver Burk Plot
	



CARBOHYDRATE STRUCTURE & FUNCTION

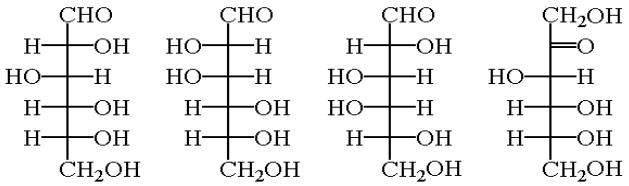


MONOSACCHARIDES

Single carbohydrate units – capable of three main reactions:

a) Oxidation-Reduction
b) Esterification
c) Glycoside Formation – Requires anomeric carbon to link to another sugar.

Common Monosaccharies



D-Glucose ((+)-Dextrose) | D-Mannose | D-Galactose | D-Fructose ((-)-Levulose)

DISACCHARIDES	POLYSACCHARIDES
Sucrose: Glucose-α-1,2-fructose	**Cellulose:** Main structural component of plant cell walls.
Lactose: Galactose-β-1,4-Glucose	**Starches (Amylose/Amylopectin):** Main energy storage forms for plants.
Maltose: Glucose-α-1,4-Glucose	**Glycogen:** Major energy storage for animals.

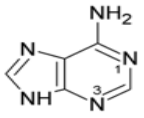
DNA & BIOTECHNOLOGY

DNA STRUCTURE

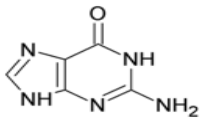
Nucleosides: 5C sugar bound to nitrogenous base.
Nucleotides: Nucleosides + 1-3 Phosphate groups added.

i) DNA Nucleotide: Deoxyribose

Purines

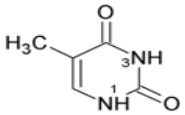


Adenine

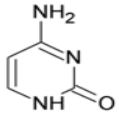


Guanine

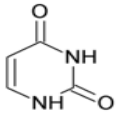
Pyrimidines



Thymine



Cytosine



Uracil

ii) RNA: Ribose

Watson-Crick Model: DNA backbone is composed of alternating sugar and phosphate groups, and is always read 5'->3'. Two strands wound into a **double helix** with **antiparallel** polarity.

Chargaff's Rules: Purines and pyrimidines are equal in number in a DNA molecule.

i) # of A's = # of T's
ii) # of C's = # of G's

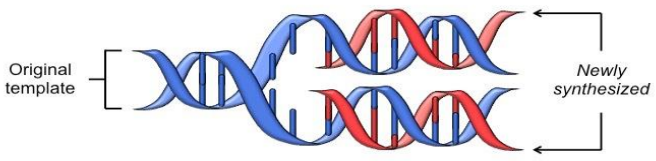
EUKARYOTIC CHROMOSOME ORGANIZATION

1. DNA is organized into 46 chromosomes in human cells.
2. In eukaryotes, DNA is wound around **histone proteins** to form **nucleosomes.**
3. Chromatin: DNA + Associated Histones
4. **Hetero**chromatin: Dense & transcriptionally silent DNA.
5. **Eu**chromatin: Less dense & transcriptionally active DNA.
6. **Telomeres:** Ends of chromosomes (High % of GC Content - 3 Hydrogen Bonds - Prevents unraveling of DNA).
7. **Centromeres:** Holds sister chromatids together until they are separated during anaphase in mitosis.

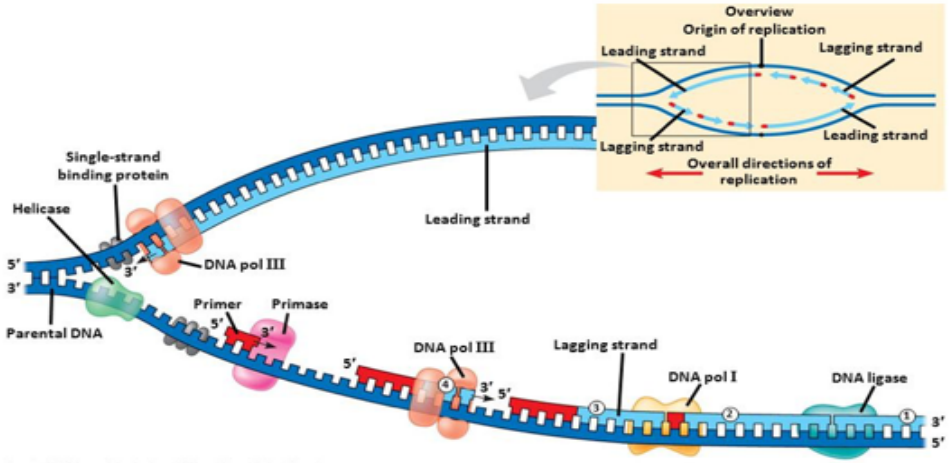
DNA REPLICATION

Step in Replication	Prokaryotic Cells	Eukaryotic Cells
Origin of Replication	One per chromosome	Multiple per chromosome
Unwinding of DNA Double Helix	Helicase	Helicase
Stabilization of Unwound Template Strands	Single-stranded DNA-binding protein	Single-stranded DNA-binding protein
Synthesis of RNA Primers	Primase	Primase
Synthesis of DNA	DNA Polymerase III	DNA Polymerase α and δ
Removal of RNA Primers	DNA Polymerase I (5' 3' Exonuclease)	RNase H (5' 3' Exonuclease)
Replacement of RNA with DNA	DNA Polymerase I	DNA Polymerase δ
Joining of Okazaki Fragments	DNA Ligase	DNA Ligase
Removal of + Supercoils Ahead of Advancing Replication Forks	DNA Topoisomerase (DNA Gyrase)	DNA Topoisomerase (DNA Gyrase)
Synthesis of Telomeres	N/A	Telomerase

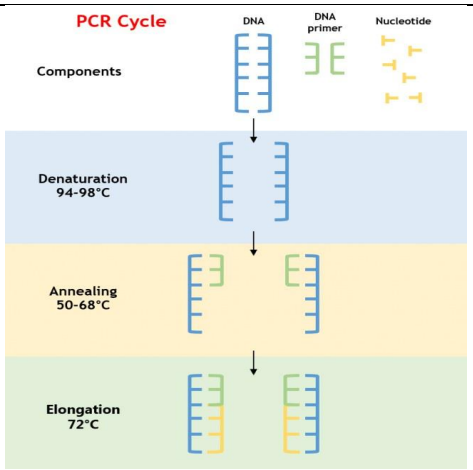
SEMI-CONSERVATIVE



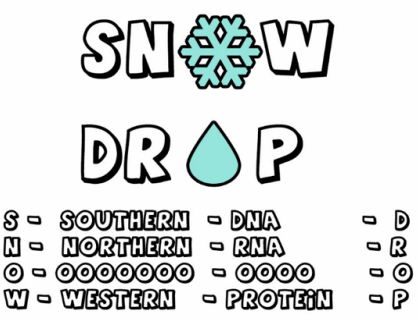
The parent strand is separated, creating two single strands. Each strand is used as a template for the complementary strand.



Leading Strand: Requires only one primer and can be synthesized continuously.
Lagging Strand: Requires many primers and is synthesized in discrete sections called **Okazaki fragments.**

Polymerase Chain Reaction (PCR)	**PCR Stages**
Automated process by which millions of copies of a DNA sequence can be created from a very small sample by hybridization. **Hybridization:** Joining of complementary base pair sequences.	

DNA/RNA/PROTEIN BLOTTING



RNA AND THE GENETIC CODE

Central Dogma: DNA (transcription) -> RNA (translation) -> Proteins

GENETIC CODE

Initiation	AUG
Termination	UAA, UGA, UAG
***Redundancy** and **wobble** (third base in the codon) allows mutations to occur without affecting the protein on a larger scale.	

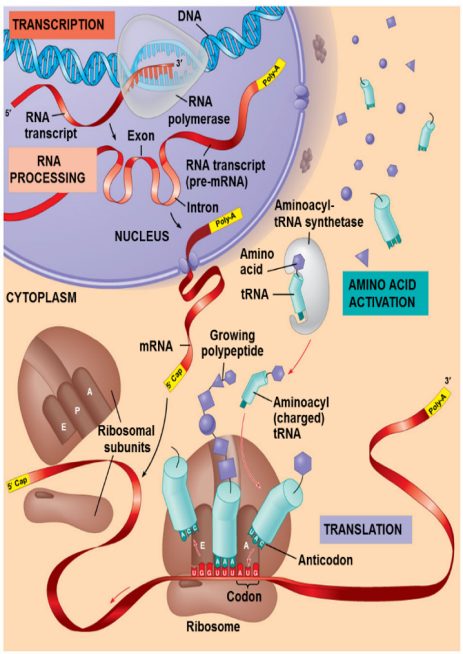
Point Mutations

Silent	No effect.
Nonsense	Premature stop codons.
Missense	Codon that codes different AA.
Frame Shift	Nucleotide addition or deletion and change the reading frame of additional codons.

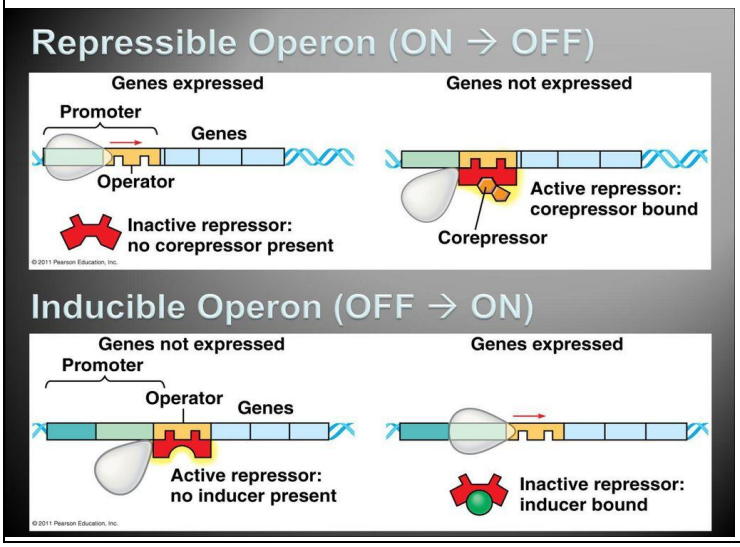
THREE TYPES OF RNA IN TRANSCRIPTION

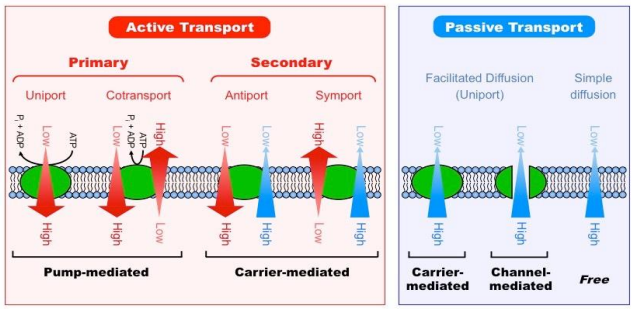
1. **mRNA:** Carries message from DNA in nucleus via transcription – travels into cytoplasm to be translated.
2. **tRNA:** Brings in AA's – recognizes codon on the mRNA using anticodon.
3. **rRNA:** Makes up majority of ribosome – enzymatically active.

Post-Transcriptional Modifications	-7-methylguanylate triphosphate cap added to 5' end. -Poly-A tail added to 3' end. -**Spliceosomes** remove introns and ligate exons together.
Post-Translational Modifications	-Folding by **chaperones.** -Quaternary structure formed. -Covalent addition of other biomolecules (phosphorylation, carboxylation, glycosylation, prenylation).



CONTROL OF GENE EXPRESSION

Prokaryotes	Eukaryotes
Jacob-Monod Model  	**Transcription Factors** Search for promoter and enhancer regions in DNA. i) **Promoters:** Within 25 base pairs of the transcription start site. ii) **Enhancers:** More than 25 base pairs away from the transcription start site.

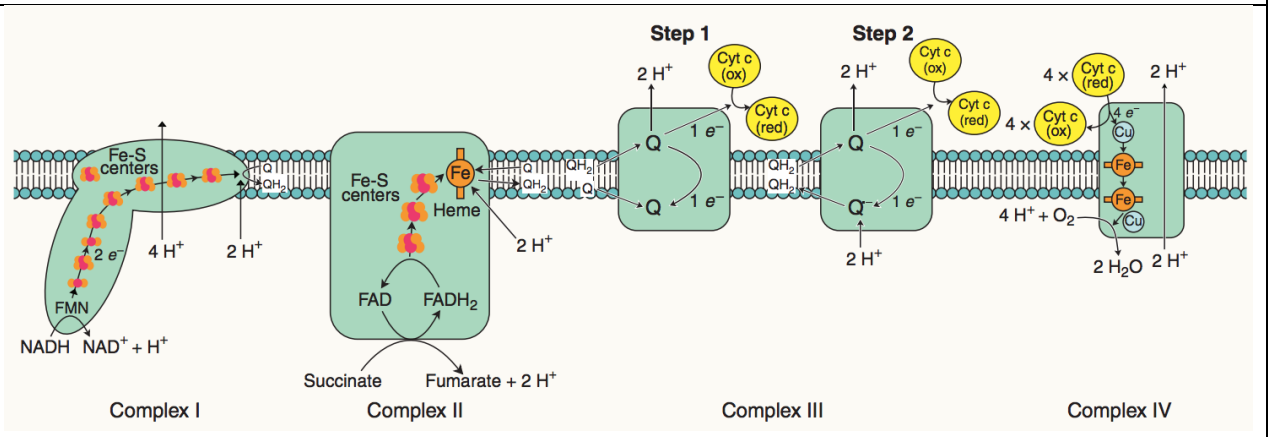


BIOLOGICAL MEMBRANES - TYPES OF MEMBRANE TRANSPORT

Endocytosis & Exocytosis	Engulfing material into cells or releasing material to the exterior of cells (via cell membrane).
Pinocytosis & Phagocytosis	Ingestion of liquid into the cell from vesicles formed from the cell membrane and ingestion of solid material.

CARBOHYDRATE METABOLISM

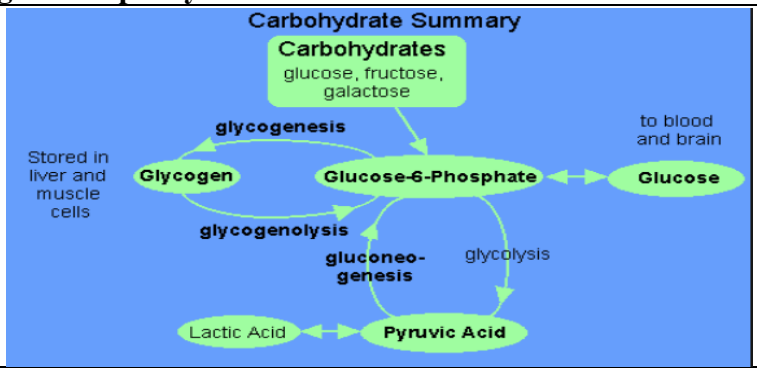
Glycolysis (Cytoplasm)	**Hexokinase:** Traps glucose. **PFK-1:** Rate limiting step (RLS). **G3P DH:** Produces NADH. **3PG Kinase & Pyruvate Kinase:** Substrate level phosphorylation.

Citric Acid Cycle (Mitochondrial Matrix)	**Please Can I Keep Selling Seashells For Money Officer?** Pyruvate Citrate Isocitrate **(RLS = Isocitrate Dehydrogenase)** α-Ketoglutarate Succinyl-CoA Succinate Fumarate Malate Oxaloacetate
Electron Transport Chain (Inner Mitochondrial Membrane)	 **Oxidative Phosphorylation: Proton Motive Force** Electrochemical gradient generated by ETC across inner mitochondrial membrane stores energy that allows ATP formation via **chemiosmotic coupling.** **ATP Synthase:** Enzyme enhancing ADP + Pi -> ATP

ENERGY YIELD SUMMARY VIA CARBOHYDRATE METABOLISM

Aerobic Respiration		*Anaerobic Respiration*	
Glycolysis	2 ATP	**Glycolysis**	2 ATP
CAC	2 ATP	**Fermentation**	0 ATP
ETC	32 ATP	**Total ATP: 2 ATP**	
Total ATP: 36 ATP			

Pathway	**Function**
Gluconeogenesis	Synthesis of glucose from non-carbohydrate sources (pyruvate, lactate, alanine & glycerol). **RLS = Fructose 1,6 – Bisphosphatase**
Glycogenesis	Glucose -> Glycogen **RLS = Glycogen Synthase**

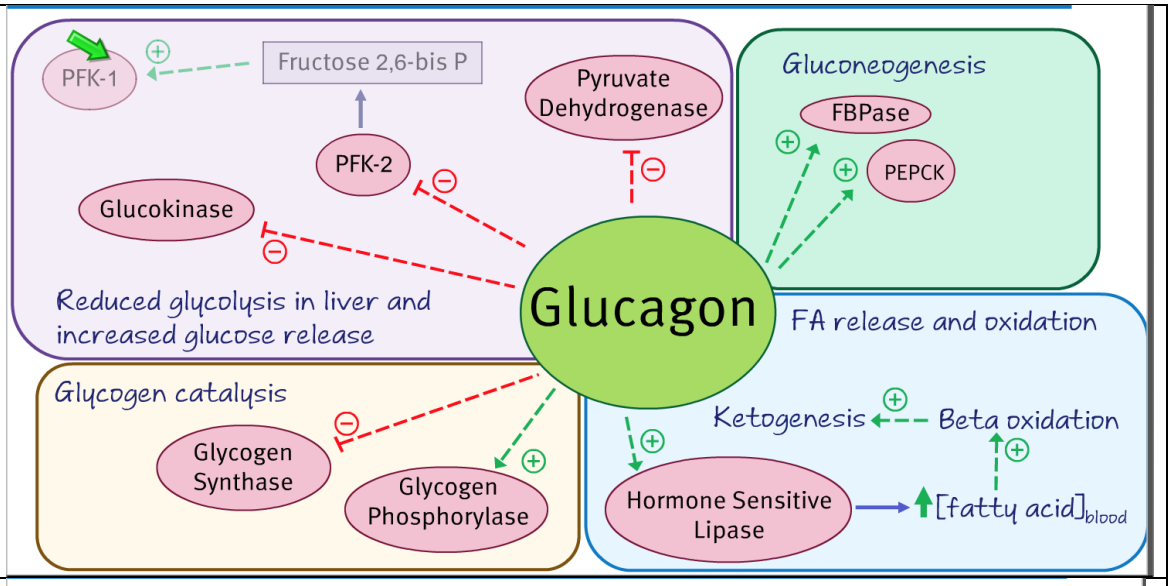
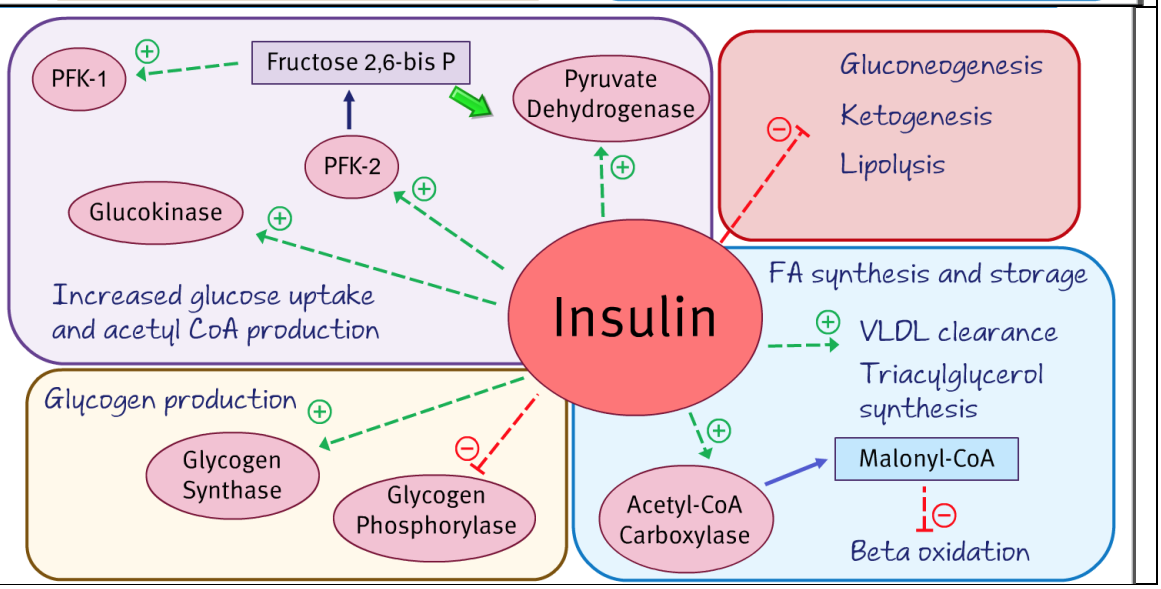
Glycogenolysis	Glycogen -> G1P **RLS = Glycogen Phosphorylase**
SUMMARY	

Pentose Phosphate Pathway: Occurs in cytoplasm of most cells – producing NADPH and sugars for biosynthesis (**RLS = G6P-Dehydrogenase**).

LIPID AND AA METABOLISM:

1. **Lipid Transport:** Via chylomicrons, VLDL, IDL, LDL & HDL.
2. **Cholesterol Metabolism:** HMG-CoA reductase (diet or liver synthesis).
3. **Ketogenesis:** Prolonged starvation state due to excess [Acetyl CoA] in liver.
4. **Ketolysis:** Regenerates Acetyl CoA for energy source in peripheral tissues.
5. **Protein Catabolism:** Digestion occurs in small intestine -> Gluconeogenesis or Ketone Body Formation. Amino groups are fed into **urea cycle** for excretion.

METBOLIC STATES:

ENERGY RELEASE	
ENERGY STORAGE	

TISSUE SPECIFIC METABOLISM

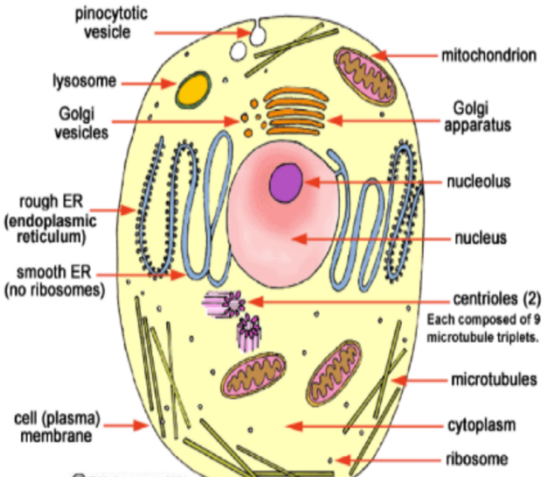
Liver	Maintains blood glucose through glycogenolysis/gluconeogenenesis. Process lipids, cholesterol, bile, urea and toxins.
Adipose	Store and release lipids.
Resting Muscle	Stores carbohydrates as glycogen and uses free FA's for fuel.
Active Muscle	May use: i) Anaerobic Metabolism ii) Oxidative Phosphorylation iii) Direct Phosphorylation iv) FA Oxidation
Cardiac Muscle	Uses FA Oxidation

Brain	Uses glucose except in prolonged starvation – uses ketolysis.

General Biology

ORGANELLES OF EUKARYOTIC CELLS

Nucleus	Contains all genetic material necessary for replication.
Mitochondrion	Metabolic processes & ATP production.
Lysosomes	Contains hydrolytic enzymes capable of breaking down a multitude of substrates.
Rough ER	Interconnected membranous structure with ribosomes studding the outside. Protein synthesis destined for insertion into a membrane or secretion.
Smooth ER	Lipid Synthesis & Detoxification.
Golgi Apparatus	Post-Translational protein modification.
Peroxisomes	Contains hydrogen peroxide – site of Beta-Oxidation & long chain FA's.

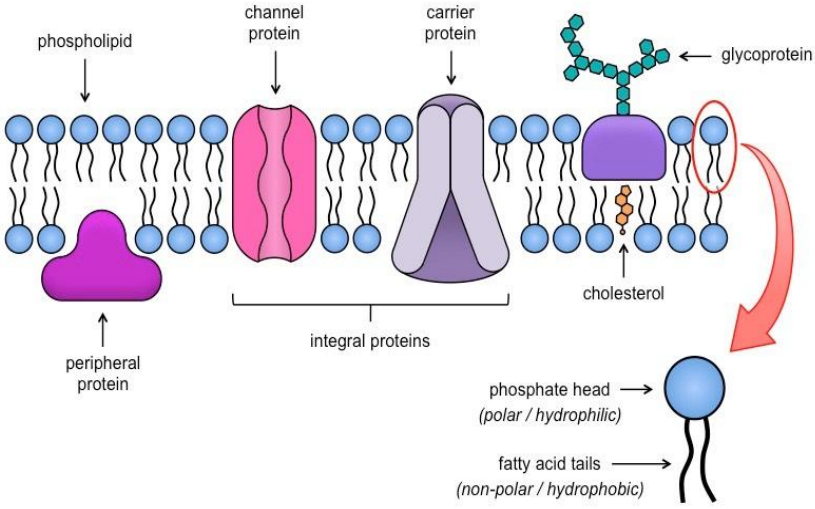


FLUID MOSAIC MODEL

Phospholipid bilayer with cholesterol & embedded proteins.

Exterior: Hydrophilic phosphate head groups

Interior: Hydrophobic fatty acids.



CELL THEORY – 4 TENETS

1. All living things are composed of cells.
2. The cell is the basic functional unit of life.
3. Cells arise only from pre-existing cells.
4. *Recently added*. Cells carry genetic information in the form of DNA (genetic material is passed down parent -> daughter cell)

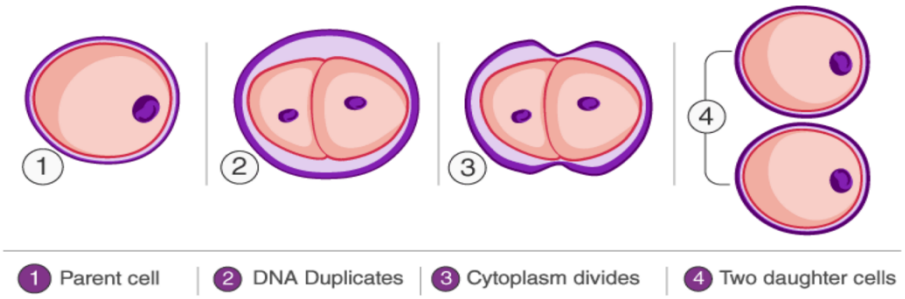
PROKARYOTES:

Shape Classification:

i) **Cocci:** Spherical bacteria
ii) **Bacilli:** Rod-shaped bacteria
iii) **Spirilli:** Spiral-shaped bacteria.

Gram-Positive Bacteria: Large concentration of peptidoglycan (thick wall) =**PURPLE**
Gram Negative Bacteria: Small concentration of peptidoglycan (think wall) = **RED/PINK**

ALL prokaryotes divide by **binary fission.** The circular chromosome replicates & attaches to the cell wall; the plasma membrane and cell wall grow along the midline, forming daughter cells.



CELL DIVISION

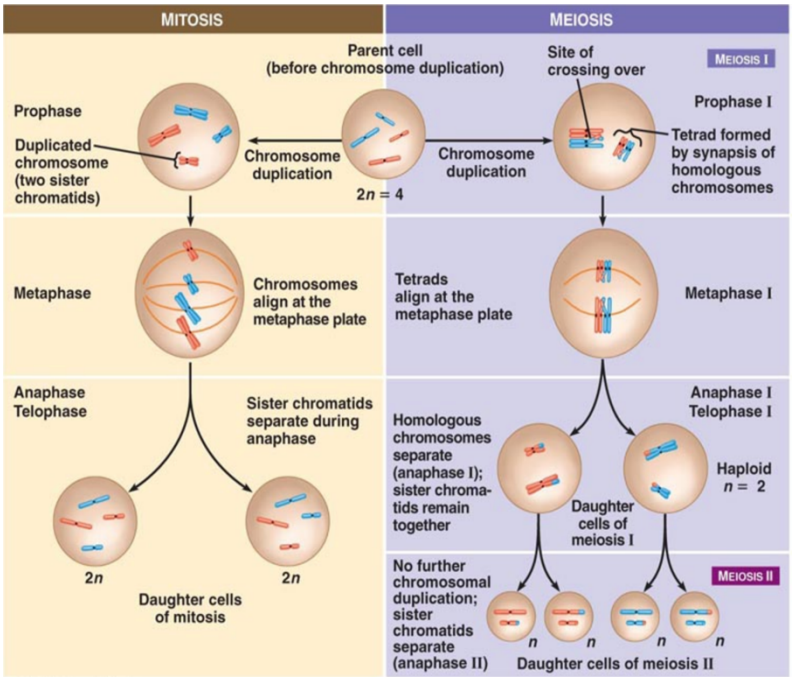
G1: Cell increases its organelles & cytoplasm

S: DNA Replication

G2: Same as G1

Mitosis: Cell divides into two (PMAT: Prophase, Metaphase, Anaphase, Telophase)

Meiosis: PMAT x 2

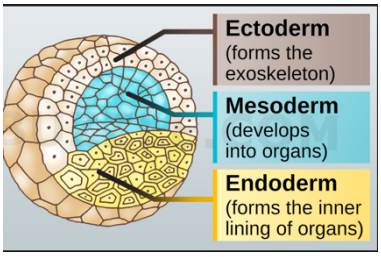


SEXUAL REPRODUCTION

Meiosis I	i) Two pairs of sister chromatids form tetrards during prophase I. ii) Crossing over leads to genetic recombination in prophase I. iii) Homologous chromosomes separate during metaphase I.

Meiosis II	i) ii)	Identical to mitosis – only difference is no replication. Spermatogenesis (sperm formation) & oogenesis (egg formation).

FOUR STAGES OF EARLY DEVELOPMENT



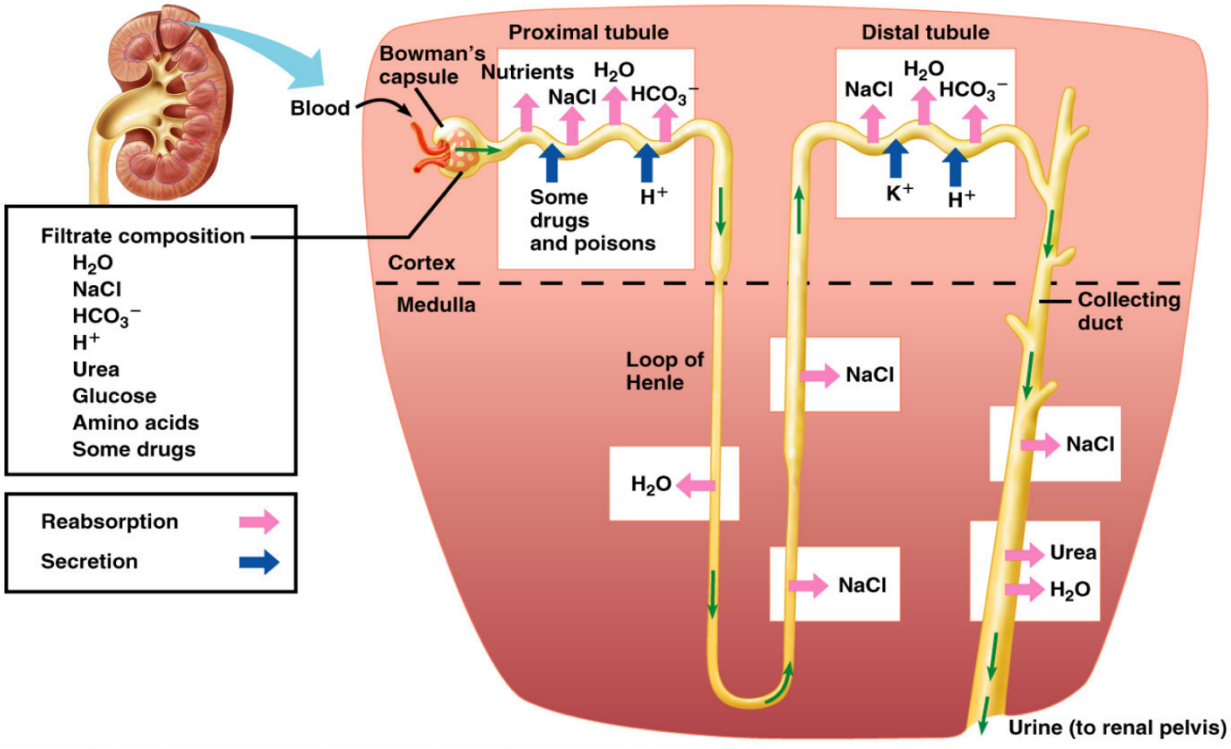
1. **Cleavage:** Mitotic divisions.
2. **Implantation:** Embryo implants during blastula stage.
3. **Gastrulation:** Ectoderm, endoderm, and mesoderm form.
4. **Neurulation:** Germ layers develop a nervous system.

HOMEOSTASIS

LIVER'S ROLES:

1. Gluconeogenesis
2. Processing of nitrogenous wastes (urea)
3. Detoxification of wastes/chemicals/drugs
4. Storage of iron & vitamin A
5. Synthesis of bile & blood proteins
6. Beta-Oxidation of FA's Ketones
7. Inter-conversion of carbohydrates, fats, and AA's.

RENAL PHYSIOLOGY & OSMOREGULATION



HORMONE REGULATION

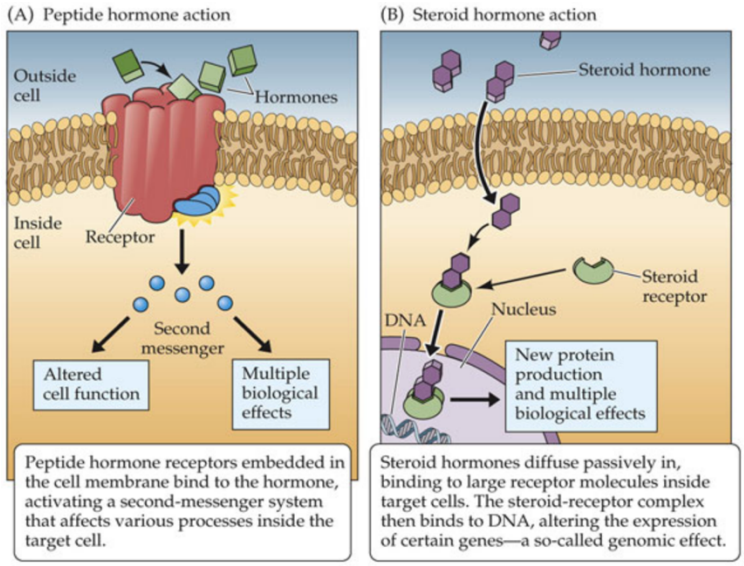
Aldosterone	ADH (Always Drilling Holes)/Vasopressin
Adrenal Cortex -> Aldosterone Blood Pressure & Blood Volume Increase Na+ Reabsoprtion -> Passively Reabsorb H2O	Hypothalamus -> ADH Blood Osmolarity Increase Permeability -> H2O Reabsoprtion -> Prevents further dehydration

ENDOCRINE SYSTEM

Direct Hormones: Directly stimulate organs. **Tropic Hormones:** Stimulate other glands.

Hormone Action Mechanism:

1. **Peptides:** Via second messengers.
2. **Steroids:** Via hormone/receptor binding to DNA.
3. **AA Derivative:** Via either option.

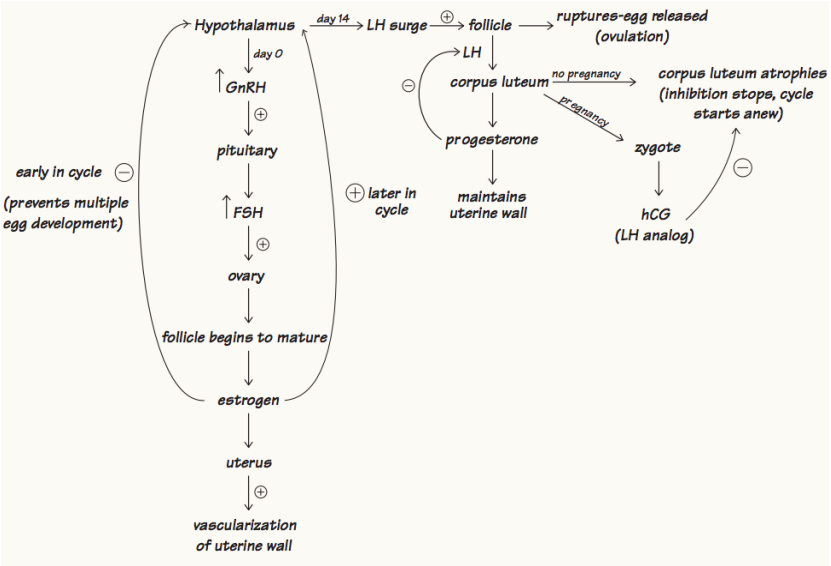


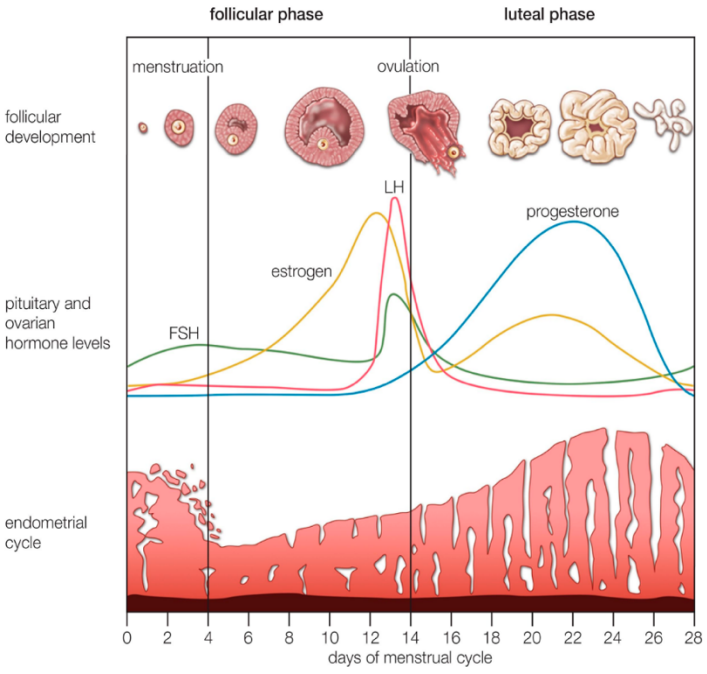
Hormone	Source	Action
Follicle-Stimulating (FSH)	Anterior Pituitary	Stimulates follicle maturation; spermatogenesis.
Luteinizing (LH)		Stimulates ovulation; testosterone synthesis.
Adrenocorticotropic (ACTH)		Stimulates adrenal cortex to make & secrete glucocorticoids.
TSH		Stimulates the thyroid to produce thyroid hormones.
Prolactin		Stimulates milk production & secretion.
Endorphins		Inhibits perception of pain in the brain.

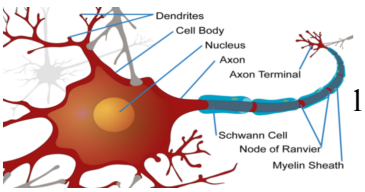
Growth Hormone		Stimulates bone and muscle growth/lipolysis.
Oxytocin	Hypothalamus (stored in Posterior Pituitary)	Stimulates uterine contractions during labor; milk secretion during lactation.
Antidiuretic (ADH/Vasopressin)		Stimulates water reabsorption in kidneys.
Thyroid Hormones (T3 & T4)	Thyroid	Stimulates metabolic activity.
Calcitonin		Decreases (tones down) blood calcium levels.
Parathyroid Hormone	Parathyroid	Increases blood calcium levels.
Glucocorticoids	Adrenal Cortex	Increases blood glucose levels; anti-inflammatory.
Mineralcorticoids		Increases water reabsorption in kidneys.
Epinepherine/Norepinepherine	Adrenal Medulla	Increases blood glucose level & HR.
Glucagon	Pancreas	Stimulates glycogen glucose (liver).
Insulin		Stimulates glucose glycogen (liver)
Somatostatin		Suppresses secretion of glucagon and insulin.
Testosterone	Testes	Maintain male secondary sexual characteristics.
Estrogen	Ovaries/Placenta	Maintain female secondary sexual characteristics.
Progesterone		Promotes growth/maintenance of endometrium.
Melatonin	Pineal	Regulates sleep-wake cycles.
Atrial Natriuretic Peptide	Heart	Assists in osmoregulation & vasodilation (moderate help)
Thymosin	Thymus	Stimulates T-Cell development.

FOUR STAGES OF MENSTRUAL CYCLE

1. **Follicular:** FSH causes growth of follicle.
2. **Ovulation:** LH causes follicle to release egg.
3. **Luteal:** Corpus luteum forms.
4. **Menstruation:** Endometrial lining sheds.

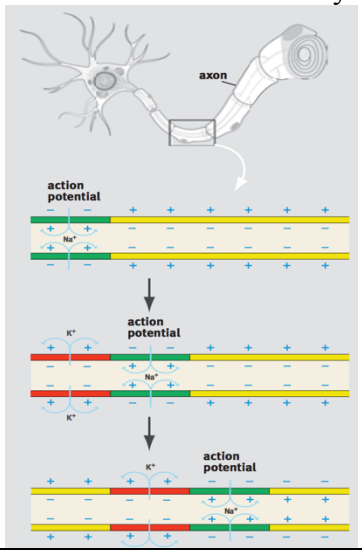


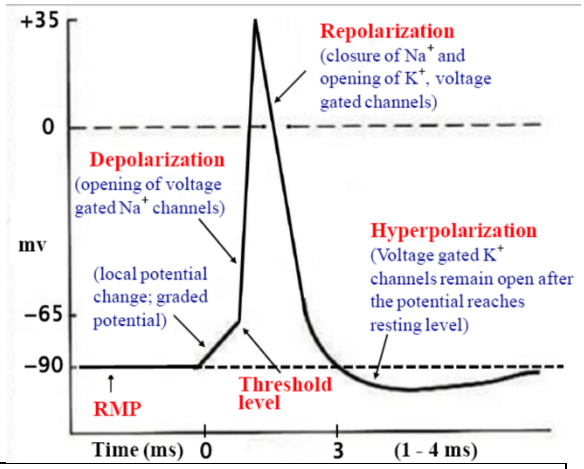




NERVOUS SYSTEM

FUNCTIONAL UNIT OF NEURON

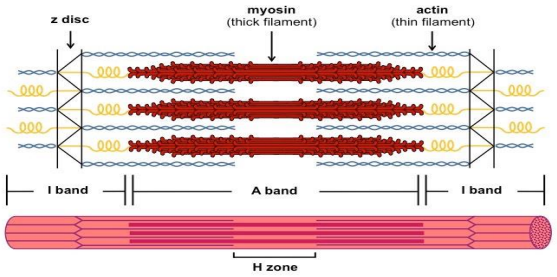
Resting Potential	Action Potential
3 Na+ pumped out for every 2 K+ pumped in. **Synapse** i)Voltage-gated Ca2+ channels open, sending Ca2+ into the cell. ii) Vesicles fuse with presynaptic membrane sending neurotransmitters across synaptic cleft. iii) Neurotransmitter binds to receptors on the postsynaptic membrane triggering depolarization and Action Potential.	Stimulus acts on the neuron, depolarizing the membrane of the cell body. 

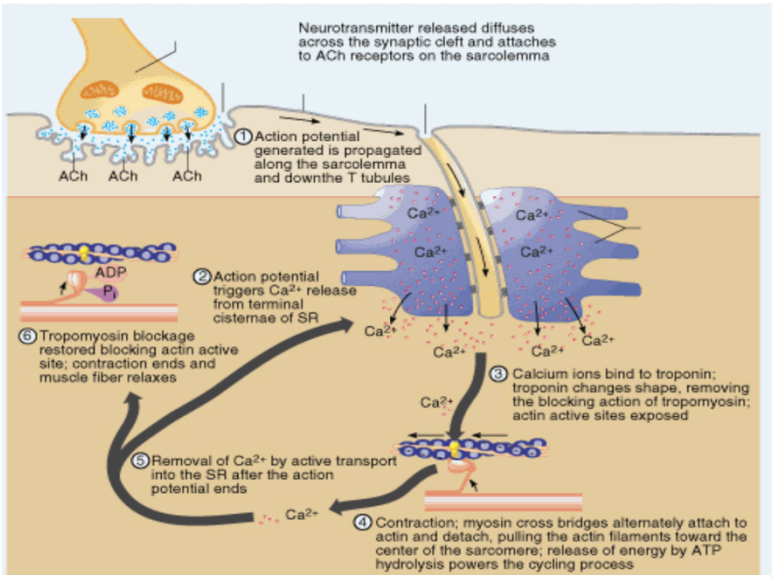


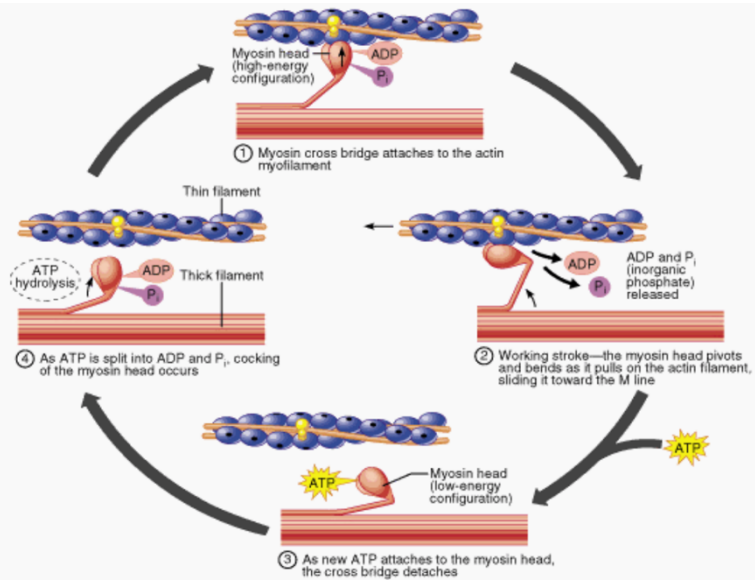
MUSCULOSKELETAL SYSTEM

SARCOMERE

Contractile unit of the fibers in skeletal muscle – actin (thin filaments) & myosin (thick filaments).







BONE FORMATION AND REMODELING

Osteoblast	Builds bone
Osteoclast	Breaks bone down
Reformation	Inorganic ions are absorbed from the blood for use in bone.
Degradation (Resorption)	Inorganic ions are released into the blood.

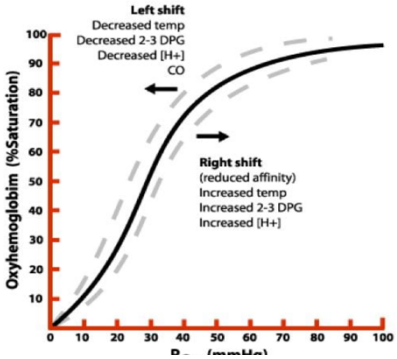
HEART CIRCULATION PATHWAY

Superior & Inferior Vena Cava -> Right Atrium -> Right Ventricle -> Pulmonary Arteries-> Pulmonary Veins -> Left Atrium ->Left Ventricle -> Aorta ->Body

Three Portal Systems:

- Blood travels through an extra capillary bed before returning to the heart – liver (hepatic), kidney, and brain (hypopheseal).

BLOOD COMPONENTS

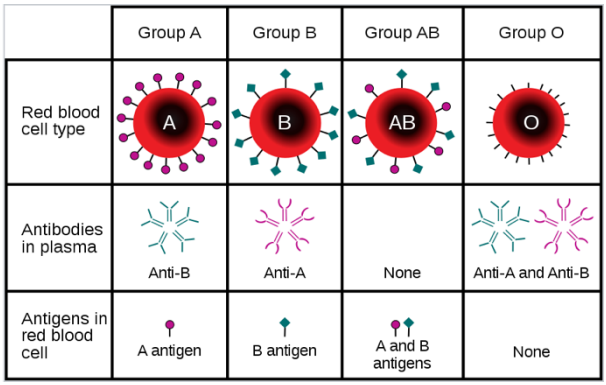


High

- Plasma: Aqueous mix of nutrients, wastes, hormones, blood proteins, gases & salts.
- Erythrocytes (RBC's): Carry oxygen.
- Leukocytes (WBC's): Immune system function.
- Platelets: Clotting
- **CO2 + H2O -> H2CO3 -> H+ + HCO3-**

BLOOD TYPING

- Blood cells with Rh factor are Rh+. These individuals produce no anti-Rh antibody. Rh- blood cells don't have the antigen. These individuals produce an antibody if exposed.



DIGESTION

CARBOHYDRATE DIGESTION

Enzyme	Production Site	Function Site	Hydrolysis Reaction
Salivary Amylase	Salivary Glands	Mouth	Starch -> Maltose
Pancreatic Amylase	Pancreas	SI	Starch -> Maltose
Maltase	Intestinal Glands	SI	Maltose -> 2 Glucoses
Sucrase	Intestinal Glands	SI	Sucrose -> Glucose & Fructose
Lactase	Intestinal Glands	SI	Lactose -> Glucose & Galactose

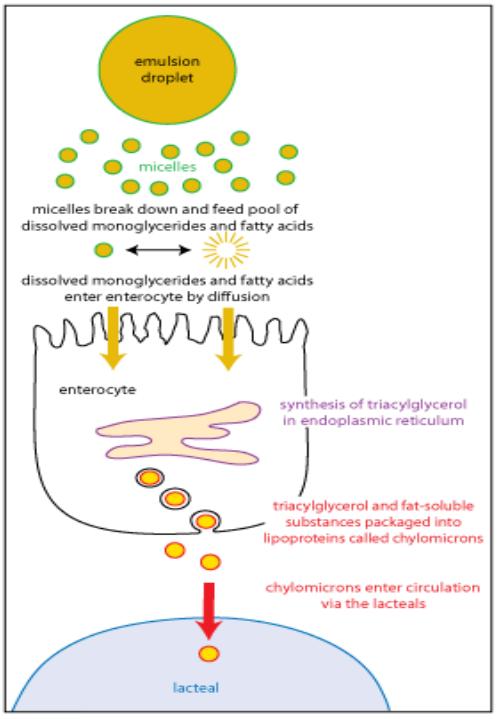
PROTEIN DIGESTION

Enzyme	Production Site	Function Site	Function
Pepsin	Gastric Glands/Chief Cells	Stomach	Hydrolyze specific peptide bonds
Trypsin	Pancreas	Small Intestine	Hydrolyze specific peptide bonds. Chymotrypsinogen -> Chymotrypsin
Chymotrypsin			Hydrolyze specific peptide bonds
Carboxypeptidases A & B			Hydrolyze terminal peptide bond at C-terminus
Aminopeptidase	Intestinal		Hydrolyze terminal peptide bond at N-terminus

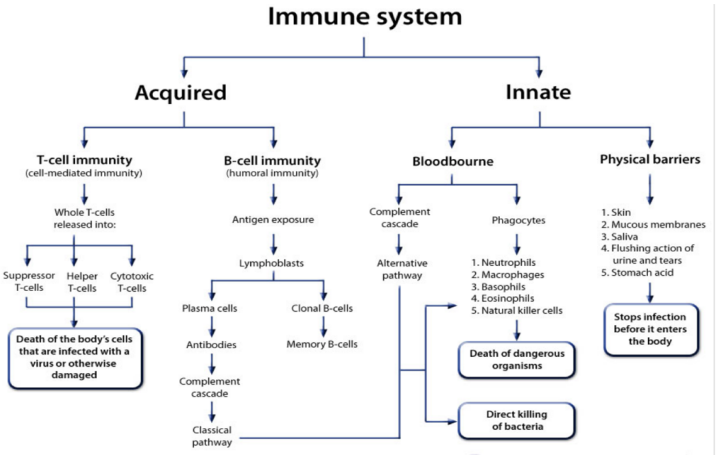
Dipeptidase	Glands		Hydrolyze pairs of AA's.
Enteropepetidase			Trypsionogen -> Trypsin

LIPID DIGESTION

LYMPTHATIC SYSTEM	
i)	Lymph vessels meet at **thoracic duct** in upper chest & neck – draining into the left subclavian vein.
ii)	Vessels carry **lymph** (excess interstitial fluid) and **lacteals** collect fats by absorbing chylomicrons in the SI.
iii)	**Lymph nodes** are swellings along the vessels with phagocytic cells – remove foreign particles from lymph.



IMMUNE SYSTEM

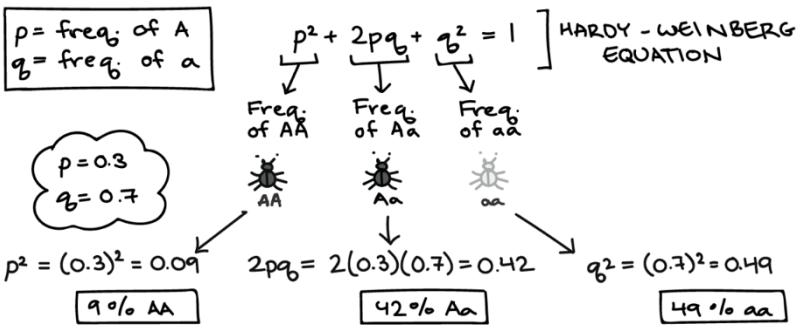


CLASSICAL GENETICS

Law of Segregation	Homologous alleles separate so that each gamete has one copy of each gene.
Law of Independent Assortment	Alleles of unlinked genes assort independently in meiosis.

Patterns of Inheritance	**Autosomal Recessive:** Skips generations **Autosomal Dominant:** Appears in every generation. **X-Linked:** No male-to-male transmission, and more males affected.

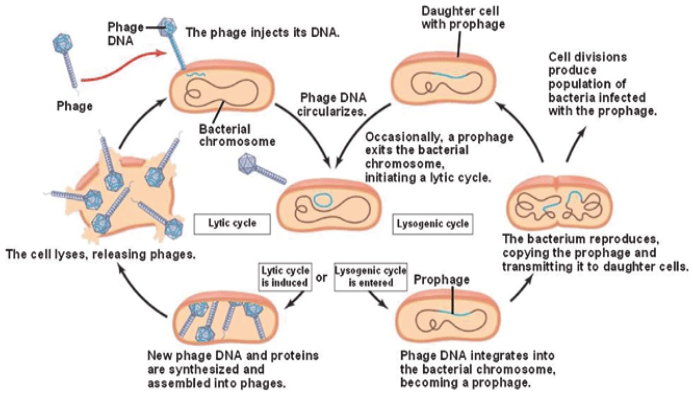
HARDY-WEINBERG EVOLUTION



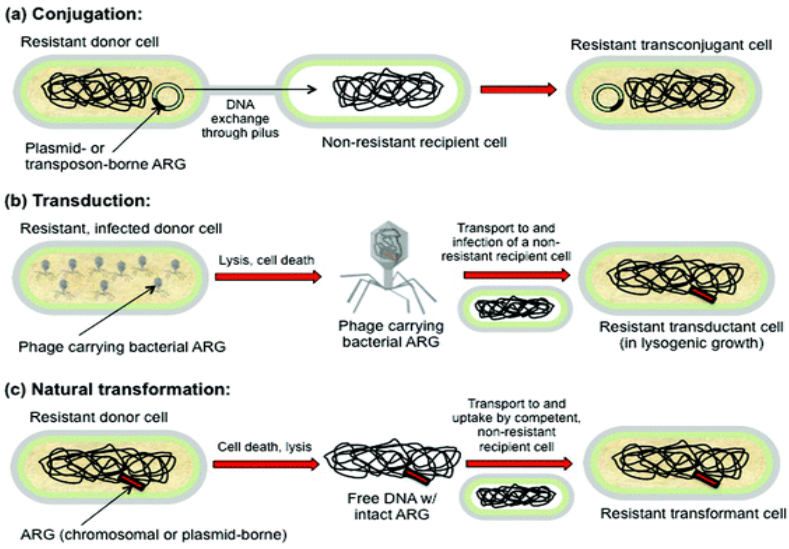
GENETICS OF PROKARYOTIC CELLS

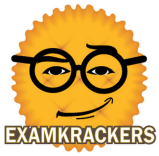
Many bacteria contain **plasmids,** or extra-genomic material. Plasmids that can be integrated into the genome are known as **episomes.**

Prokayotic Viruses: A-cellular structures of double- or single-stranded DNA or RNA in a protein coat.
Lytic Cycle: Virus kills the host cell.
Lysogenic Cycle: Virus enters host genome.



CONJUGATION/TRANSDUCTION/TRANSFORMATION (PROKARYOTIC)





Remember you can do this. If you have an above average work ethic and practice becoming am awesome test taker than you will excel!!