

CELLULAR AND MOLECULAR BIOLOGY (BIOL 190)

Course Curriculum

Basic Introduction to the Organization of Life

1. Describe the hierarchical organization of living systems (atoms to biosphere)
2. Introduce the characteristics of life and how those characteristics are used to define life
3. Know that cells are the basic unit of life
4. Define structure vs function, energy flow vs chemical cycling
5. Introduce and then use the themes of emergent properties now and throughout the semester

Evolution Explains the Unity and Diversity of Life

1. Recognize there are biochemical similarities among all living things
2. Distinguish between the three domains of life and the four kingdoms within Eukarya
3. Understand the basic idea of descent with modification and that Darwin proposed natural selection as a primary mechanism of evolution

Science is a Way of Knowing

1. Introduction to the Scientific Method
2. Explain how a hypothesis is different from a scientific theory

The Nature of Atoms

1. Describe an element based on its composition of protons, neutrons, and electrons
2. Define atomic number, mass number, atomic mass, ions and isotopes, molecular mass
3. Explain where electrons are found in an atom and how electron distribution (particularly valence electrons) influences the chemical properties of atoms

Chemical Bonds, Molecular Shape, and Chemical Reactions

1. Distinguish between non-polar covalent bonds, polar covalent bonds, single vs double covalent bonds, ionic bonds, hydrogen bonds
2. Introduce the collision theory Know that chemical reactions are the breaking and forming of chemical bonds; define reactants, products, and chemical equilibrium

Characteristics and Properties of Water

1. Define polar molecule and electronegativity, and explain how the structure of water leads to hydrogen bonds forming between water molecules
2. Define cohesion, adhesion, surface tension, solubility, aqueous solution, hydrophilic, hydrophobic

Acids and Bases

1. Define acids, bases, buffers, pH scale, hydrogen ions, hydroxide ions
2. Relate changes in pH to changes in $[H^+]$, or hydrogen ion concentration

Carbon: The Framework of Biological Macromolecules

1. Describe how many simultaneous covalent bonds can be formed with one carbon atom
2. Describe the different kinds of isomers (structural, cis-trans, and enantiomers)
3. Describe the structure and basic characteristics of the following functional groups: hydroxyl, carbonyl, carboxyl, amino, sulfhydryl, phosphate, methyl
4. List the four major kinds of biological macromolecules (carbohydrates, proteins, lipids, and nucleic acids); define monomers, polymers, dehydration synthesis and hydrolysis

Carbohydrates: Energy Storage, Fuel, and Structural Molecules

1. Describe the structure of simple sugars with three to six carbons (know example monosaccharides, particularly glyceraldehyde, ribose, and glucose or fructose)
2. Relate the structures of disaccharides (eg, sucrose) and polysaccharides to their functions (including starch such as amylose, glycogen, cellulose, chitin)

Lipids: Diverse Group of Hydrophobic Molecules

1. Explain the structure of triglycerols and that fats function as energy-storage molecules
2. Describe the differences between saturated and unsaturated fatty acids
3. Describe the structure of phospholipids, understand how they arrange to form membrane, and know that there are other types of lipids (eg, steroids, cholesterol)

Proteins: Molecules with Diverse Structures and Functions

1. Know the structure of amino acids, recognize non-polar, polar, and charged amino acids and their connections to structure and function
2. Describe the levels of protein structure and the forces or bonds that hold these structures together (ie, primary, secondary, tertiary, quaternary)
3. Understand the relationship between amino acid sequence and three-dimensional polypeptide or protein structure (such as the sickle-cell hemoglobin example)
4. Understand the relationship between protein structure and function and list the major functions of proteins: catalysts (enzymes), defense, storage, transport, hormones, receptors, contractile or motor proteins, and structural proteins
5. Define peptide bond, side chain, α helix, β pleated sheet, disulfide bridges, and subunits

Nucleic Acids: Information Molecules (and others are involved in energy conversions)

1. Describe the structure of nucleotides and how they bind to form polynucleotides
2. Contrast the structures and basic functions of DNA vs RNA
3. Recognize other nucleotides involved in energy metabolism (such as ATP, NAD⁺, FAD)
4. Define deoxyribose, ribose, phosphate group, bases, cytosine, thymine, uracil, adenine, guanine, sugar-phosphate backbone, phosphodiester linkage, double helix, complementary, 5' end, 3' end, antiparallel as it related to DNA replication

Cells: The Fundamental Units of Life

1. Recognize the structural and functional similarities in all cells (plasma membrane, DNA, ribosomes, cytosol), and distinguish between prokaryotic vs eukaryotic cells
2. Describe factors that limit cell size, and the relationship between surface area and volume

Eukaryotic Cells: Genetic Instructions in the Nucleus

1. Understand the nucleus is a large double-membrane bound organelle covered in pores and contains chromosomes, which are complexes of DNA and protein (chromatin)
2. Know that DNA remains in the nucleus, but that different types of RNA are made from the DNA (such as mRNA, rRNA, tRNA) and that RNA can exit the nucleus, necessary for transcription/translation
3. Explain that ribosomes are the sites of protein synthesis and can exist free in the cytosol or bound to endoplasmic reticulum or the nuclear envelope

The Endomembrane System: smooth ER, rough ER, Golgi, lysosomes, vacuoles

1. Identify the different parts of the endomembrane system (vs non endo-system organelles)
2. Contrast the different structures and functions of the internal membranes and compartments and know if they occur in animal cells, plant cells, or in both

3. Evaluate the importance of each step in the protein processing pathway in producing a protein for export (the relationship between nucleus, ribosomes, rough ER, and Golgi)

Mitochondria and Chloroplasts: Cellular Generators (introductory, more details later)

1. Compare the structures and basic functions of mitochondria (conversion of food energy into ATP) and chloroplasts (capture of light energy to fix atmospheric carbon into sugar)
2. Explain the probable origin of these non-endomembrane system organelles

Cytoskeleton: Extracellular Structures, Cell Movement, and Cell-to-Cell Interactions

1. Identify the different cytoskeletal elements and their functions
2. Classify the elements and importance of extracellular matrix (ECM) in animal cells
3. Differentiate between types of cell junctions (tight, anchoring such as desmosomes, and gap junctions in animals; plasmodesmata in plants)

The Structure of Membranes and the Fluid Mosaic Model

1. Describe the structure of phospholipids and their orientation in biological membranes
2. Explain the fluid mosaic model of membrane structure
3. Describe factors that influence membrane fluidity; and define selectively permeable, amphipathic, bilayer, saturated vs unsaturated hydrocarbons

Membrane Proteins: Multifunctional Components

1. Describe the functions of membrane proteins, including: transport, enzyme, signaling, identity (cell-cell recognition), intracellular joining, anchoring (attachment to ECM)
2. Illustrate how proteins can associate with the membrane (integral vs peripheral) and identify a transmembrane domain

Passive Transport Across Membranes: Movement with No Energy Investment

1. Compare and contrast simple diffusion and facilitated diffusion, and differentiate between channel proteins and carrier proteins
2. Predict the direction of water movement by osmosis and the direction of diffusion of one or two solutes according to their respective concentration gradients
3. Define and apply the following terms: tonicity, isotonic, hypertonic, hypotonic, turgid/flaccid/plasmolysis in plant cells, movement with vs against the gradient

Active Transport Across Membranes: Using Energy to Go Against the Gradient

1. Differentiate between active transport and diffusion/facilitated diffusion
2. Describe the steps and the function of the Na^+/K^+ pump in active transport
3. Define electrochemical gradient, proton pump, cotransport

Bulk Transport Across the Plasma Membrane by Endocytosis and Exocytosis

1. Distinguish between endocytosis (pinocytosis and phagocytosis) and exocytosis
2. Illustrate how endocytosis can be specific (receptor-mediated)

Plasma Membrane Plays Key Role in Cell Signaling

1. Teach the overall concept that cells communicate through protein receptors
2. Know the three stages of cell signaling: reception, transduction, and response
3. Understand that receptors can exist in the plasma membrane, or the signal must pass through the plasma membrane to reach an intracellular receptor

An Introduction to Metabolism: Metabolic Pathways

1. Understand that a metabolic pathway is a series of defined steps, each catalyzed by a specific enzyme, converting a specific reactant molecule into a specific product

2. Define energy, catabolic vs anabolic, and know that there many forms of energy including kinetic, thermal, potential energy and chemical energy
3. Recognize that the main source of energy for the biosphere is the sun, and that metabolism is the sum total of all reactions in an organism

The Laws of Thermodynamics and Free Energy

1. Describe the first and second laws of thermodynamics
2. Relate free energy changes to the outcome of chemical reactions, both endergonic (positive ΔG , energy requiring) and exergonic (negative ΔG , energy releasing)
3. Understand that cells work by coupling exergonic reactions to endergonic reactions, the energy releasing reactions are "used" to run the energy requiring reactions

ATP: The Energy Currency of Cells

1. Describe the structure of ATP and the role of ATP in short-term energy storage
2. Distinguish which bonds in ATP are "high energy" and how this energy is related to phosphate groups being negatively charged
3. Understand that the hydrolysis of one ATP (to ADP + phosphate) is exergonic or energy releasing ($\Delta G = -73$ kcal/mol) and this free energy can perform work
4. The regeneration of ATP by phosphorylating ADP back into ATP must happen continuously to meet the energy needs of cells; this occurs through cellular respiration (converting food energy into the energy stored in ATP; details covered later)

Enzymes: Biological Catalysts Speed Up Reactions

1. Discuss the specificity of enzymes and how they function by lowering activation energy
2. Explain that enzymes bind to their substrates (reactants), form an enzyme-substrate complex, and result in a product
3. List factors that influence the rate of enzyme-catalyzed reactions (such as temperature and pH), and explain inhibition (both competitive and noncompetitive)
4. Contrast the course of a reaction with and without an enzyme catalyst
5. Define active site, induced fit, transition state, allosteric regulation, feedback inhibition

Overview of Cellular Respiration

1. Summarize the basic inputs (organic molecules and O₂) and outputs (CO₂, H₂O, and ATP) of aerobic cellular respiration
2. Understand that catabolic pathways, like respiration and fermentation, release stored potential energy in organic compounds (ie, food) to regenerate ATP from ADP + P
3. Explain the principles of oxidation and reduction (ie, redox) and know that electron transfer plays a major role in catabolic reactions and the release of energy
4. Define: reducing and oxidizing agents, electron donor vs acceptor, electronegativity
5. Recognize NAD⁺ as an electron carrier, and know when it holds 2 electrons and 1 proton it is reduced to NADH and that these electrons and protons come from food (ie, glucose)
6. Name the three stages of aerobic cellular respiration: 1) glycolysis, 2) pyruvate oxidation and citric acid cycle, and 3) the electron transport chain and chemiosmosis
7. Understand the controlled release of energy in many small steps allows for the production of ATP, while releasing the same amount of energy in one step results in combustion

Glycolysis: Oxidizing Glucose to Pyruvate (stage 1)

1. Focus on the inputs and outputs of the stage
2. Describe the steps of glycolysis, follow the carbons and the generation of NADH & ATP

3. Know where glycolysis occurs in eukaryotic cells, how many pyruvates are produced from one glucose, and that only a small amount of energy has been harvested at this point

The Oxidation of Pyruvate to Acetyl-CoA and the Citric Acid Cycle (stage 2)

1. Focus on the inputs and outputs of the stage
2. Describe how each pyruvate from glycolysis enters the mitochondria and is oxidized, forming Acetyl CoA, NADH, and CO₂; and know that this step produces no ATP
3. Describe how each Acetyl CoA enters the Citric Acid Cycle, which is also known as the Krebs Cycle or the Tricarboxylic Acid Cycle/TCA
4. Understand that some energy from glucose is being carried in the NADH and FADH₂ produced during glycolysis, the oxidation of pyruvate and the citric acid cycle
5. Know that the ATP produced so far are made by direct transfer of a phosphate group from an organic substrate to ADP via an enzyme, a process called substrate-level phosphorylation

The Electron Transport Chain and Chemiosmosis or Oxidative Phosphorylation (stage 3)

1. Recognize that electrons move from less to more electronegative electron carriers “down the chain” in a series of redox reactions, and that the last electron carrier passes electrons to highly electronegative oxygen (ultimately forming H₂O)
2. Understand that as electrons move “down the chain” they go from higher to lower free energy ($-\Delta G$) and this release of energy pumps protons into the intermembrane space of the mitochondria, establishing a proton (or [H⁺]) gradient (exact mechanism unknown) Understand that the electron chain requires a terminal electron acceptor
3. Know establishing a proton gradient is the major function of the electron transport chain
4. Recognize that there is another protein complex embedded in the inner membrane of mitochondria called ATP synthase
5. Understand that protons flow through ATP synthase, causing a rotor-type complex to turn, which catalyzes the production of ATP (analogous to the flow of water through a hydroelectric dam turning a turbine to produce electricity)
6. Understand that chemiosmosis is the process where energy stored in the proton gradient is used to produce ATP, and that this way of producing ATP is known as oxidative phosphorylation (as opposed to substrate-level phosphorylation)
7. Understand why one FADH₂ contributes less energy than does one NADH to the synthesis of ATP, know that many factors influence the efficiency of respiration, and realize that the efficiency of aerobic respiration is high compared to other conversions

Oxidation without Oxygen (O₂): Anaerobic Respiration vs Fermentation

1. Realize that anaerobic respiration uses another molecule besides oxygen as the final electron acceptor and fermentation does not use oxygen or the electron transport chain
2. Fermentation extends glycolysis by regenerating NAD⁺ through the transfer of the electrons and protons in NADH to pyruvate (lactic acid fermentation) or to derivatives of pyruvate (alcohol fermentation), and both fermentation types are used in food production

Catabolism of Proteins and Fats

1. Recognize that proteins and fats can be used as alternative energy sources
2. Identify the entry points for the components of proteins and fats in energy metabolism
3. Recognize the relationship between molecular structure and oxidative energy yields

Overview of Photosynthesis

1. Summarize the basic inputs (CO₂, H₂O, and light energy) and outputs (organic molecules and O₂) of photosynthesis

2. Understand that photosynthesis converts light energy to the chemical energy of food; the light reactions capture solar energy and transform it into chemical energy and the Calvin cycle uses that chemical energy to make the organic molecules of food
3. Define autotroph, heterotroph, producers, consumer, chloroplast, inner and outer membrane, thylakoid, granum, and stroma

Light Reactions: Converting solar energy into ATP/NADPH (photo part of photosynthesis)

1. Know that the light reactions occur in the thylakoid membrane and convert light energy, water, NADP⁺, ADP, and P into NADPH, ATP, and oxygen
2. Understand that photosystems are composed of a reaction center complex with a primary electron acceptor surrounded by light harvesting complexes containing chlorophyll pigment molecules bound to proteins
3. Recognize that photosystems are embedded in thylakoid membranes, along with other complexes and proteins involved in the flow of electrons from water into NADPH
4. Know that Photosystem II captures light energy and extracts electrons from water, producing oxygen as a by-product, passing electrons to a primary acceptor; electrons are then passed down an electron transport chain (like in cellular respiration, but recognize the source of electrons is different in respiration vs photosynthesis)
5. Know that electrons pass from Photosystem II to chlorophyll in Photosystem I, and light energy drives electrons to the primary acceptor in Photosystem I, where they are passed down to the final electron acceptor NADP⁺ (to ultimately form NADPH)
6. Understand a proton gradient is created in the thylakoid space from 1) protons pumped there during electron transport, 2) the splitting of water, leaving protons behind in the space, and 3) forming NADPH lowers the concentration of protons outside of the space
7. Realize that just like in cellular respiration the proton gradient in the thylakoid is a form of potential energy harvested via ATP synthase to produce ATP
8. Define photophosphorylation, electromagnetic spectrum, visible light, photons, photosynthetic pigments, chlorophyll

Carbon Fixation: The Calvin Cycle (synthesis part of photosynthesis)

1. Know that the Calvin Cycle is an anabolic process in the stroma that uses ATP and NADPH to build basic carbohydrates out of carbon from CO₂ in the air
2. Recognize the three basic phases of the Calvin cycle are 1) carbon fixation, 2) reduction, and, 3) the regeneration of the CO₂ acceptor RuBP

Eukaryotic Cell Division: Cell Cycle and Mitosis

1. List the phases of the Cell Cycle and describe the events that take place during each phase (including G₁, S, and G₂ of interphase)
2. Distinguish between homologues and sister chromatids, between replicated and non-replicated chromosomes, and know when DNA replication or synthesis takes place
3. Explain the major events that occur during each of the five major stages of mitosis (prophase, prometaphase, metaphase, anaphase, and telophase) and cytokinesis
4. Understand the importance of chromosome orientation during metaphase, and what separates during anaphase of mitosis
5. Define genome, chromosomes, chromatin, somatic cells, sister chromatids, centromere, kinetochore, metaphase plate, mitosis, and cytokinesis

Control of the Cell Cycle

1. Explain the role of checkpoints in the control of the cell cycle and how loss of cell cycle controls can result in cancer cells
2. Define growth factor, density-dependent inhibition, anchorage dependence, benign vs malignant tumor, metastasis

Sexual Life Cycles and Meiosis

1. Understand that eukaryotic animal cells go through interphase of the Cell Cycle (including DNA replication or synthesis) before undergoing meiosis
2. Describe the human life cycle, including meiosis, fertilization, mitosis and development explaining which stages/cells are unicellular vs multicellular, and haploid vs diploid
3. Define heredity, genetics, gametes vs somatic cells, asexual vs sexual reproduction, clones, life cycle, karyotype, homologs, sex chromosomes vs autosomes, diploid vs haploid, random fertilization, zygote, ovary, testis, sperm, egg, meiosis I and meiosis II

Producing Gametes: Meiosis reduces number of chromosome sets from diploid to haploid

1. Explain the major events that occur during each of the major stages of meiosis I (prophase I, metaphase I, anaphase I, and telophase I and cytokinesis) and meiosis II (prophase II, metaphase II, anaphase II, and telophase II and cytokinesis)
2. Describe independent assortment of homologous chromosomes and crossing over between non-sister homologs and explain how they contribute to genetic variation
3. Understand the importance of chromosome orientation during metaphase I vs metaphase II of meiosis, and what separates during anaphase I vs anaphase II of meiosis
4. Define maternal vs paternal chromosomes, synapsis, chiasmata, recombinant chromosomes, identical vs non-identical daughter cells

Summing Up: Mitosis vs Meiosis

1. Describe the distinct features of meiosis, including crossing-over, allele segregation, and independent assortment
2. Contrast the roles of mitosis vs meiosis, the differences in chromatid cohesion in mitosis vs meiosis, and the starting and ending cell(s) of each process

Mendel and the Gene Idea

1. Define character, trait, true-breeding, hybrid, P generation, F1 generation, F2 generation, alleles, dominant allele, recessive allele, Punnett square, law of segregation, law of independent assortment, homozygote, heterozygote, phenotype, genotype

Monohybrid Crosses: Demonstrating the Principle of Segregation

1. Evaluate the phenotypic and genotypic outcomes of a monohybrid cross ($Aa \times Aa$)
2. Explain how a monohybrid cross illustrates Mendel's principle of segregation and how the segregation of alleles relates to the behavior of homologs in meiosis

Dihybrid Crosses: Demonstrating the Principle of Independent Assortment-Optional

1. Evaluate the phenotypic and genotypic outcomes of a dihybrid cross ($AaBb \times AaBb$)
2. Explain how a dihybrid cross illustrates Mendel's principle of independent assortment and how the segregation of alleles for genes on two different chromosomes relate to the behavior of two homologous pairs of chromosomes in meiosis

Extensions to Mendel

1. Describe how inheritance patterns are often more complex than those predicted by simple Mendelian genetics (or when condition of 2 alleles, 1 dominant, 1 recessive, is not met)
2. Explain and give examples of the following extensions to Mendel's model: incomplete dominance (eg, snapdragon color), codominance and multiple alleles (eg, ABO blood groups in humans), pleiotropy (eg, multiple symptoms associated with certain hereditary diseases), epistasis (eg, coat color in Labrador retrievers), polygenic inheritance (eg, skin color in humans), and environmental impacts on phenotype (eg, heart disease)
3. Define qualitative vs quantitative characters, carrier, recessively vs dominantly inherited disorders, multifactorial disorders

The Chromosomal Basis of Inheritance

1. Relate the law of segregation, the law of independent assortment, the probability of different allelic combinations, and the outcome of a Punnett square to the movements of chromosomes during meiosis
2. Understand that alleles are alternate versions of a gene
3. Realize that for a heterozygous genotype each allele (eg, A and a, from Aa) is a unique DNA sequence located at homologous positions (or loci) on homologous chromosomes

Sex Chromosomes, Sex Determination, and Sex Linkage

1. Describe the relationship between sex chromosomes and sex determination
2. Describe sex-linked inheritance
3. Define X chromosome, Y chromosome

Select Human Genetic Disorders Related to Alterations in Chromosome Number/Structure

1. Describe the consequences of nondisjunction in humans, including deletion, duplication, inversion, translocation

The Molecular Basis of Inheritance: The Structure of DNA, the Genetic Material

1. Understand the evidence supporting DNA as the genetic material
2. Understand Chargaff's Rules
3. Describe the molecular structure of DNA including deoxyribose sugar-phosphate backbone, the four nitrogenous bases, and base-pair complementarity
4. Define double helix, antiparallel

Basic Characteristics of DNA Replication

1. Understand the three major models of DNA replication: semiconservative

The Details of DNA Replication: In Prokaryotes, but fundamentally similar in Eukaryotes

1. Understand that more than a dozen enzymes and other proteins participate in DNA replication, and the details provided are based on DNA replication in E coli (prokaryote)
2. Explain the role of each of the following in DNA replication: origin of replication in prokaryotes, origins of replication in eukaryotes, replication fork, single-strand binding proteins, topoisomerase, helicase, primase, primer, DNA polymerases (I and III), leading strand, lagging strand, nucleotides, template strands, Okazaki fragments, DNA ligase
3. Explain why DNA replication is discontinuous on one strand, and why repeated rounds of replication produce shorter and shorter DNA molecules; define telomeres and telomerase
4. Understand the accuracy of DNA replication is high because there are DNA polymerases that proofread and repair mismatches
5. Define mismatch repair, nuclease, nucleotide excision repair, mutations
6. Understand that mutations can be good, bad, or neutral with respect to the phenotype of an organism, and explain how mutations are important to evolution

Some Details on Chromosome Structure in Eukaryotes

1. Describe chromatin packing in a eukaryotic chromosome including the following terms: DNA, histones
2. Explain the difference between heterochromatin and euchromatin

Gene Expression: From Gene to Protein

1. Understand that proteins are the link between genotype and phenotype and that gene expression is the process by which DNA directs the synthesis of proteins (or RNA)
2. Understand that gene expression includes two stages: transcription and translation and RNA processing
3. Know eukaryotes in terms of where transcription and translation occur
4. Define messenger RNA, ribosomes, primary transcript

The Genetic Code: The correspondence between 3-base mRNA codons and amino acids

1. Explain the relationship between codons and amino acids and be able to use a codon table to translate a strand of mRNA
2. Define triplet code, codon, template strand, stop codons, start codon, reading frame

Details of Transcription: Starting with common processes in prokaryotes and eukaryotes

1. Understand that an RNA transcript is synthesized by an RNA polymerase and know the stages of transcription: initiation, elongation, and termination
2. Define these terms, which are common to both prokaryotes and eukaryotes: RNA polymerase, promoter, terminator, transcriptional unit, start point, template strand
3. Compare and contrast RNA and DNA polymerases (eg, 5'→3' assembly, primer use)

Unique to Eukaryotic Transcription: Transcription Factors, AAUAAA, RNA processing

1. Understand that transcription factors mediate the binding of RNA polymerase II and that transcription termination in eukaryotes involves a polyadenylation signal (AAUAAA)
2. Define transcription initiation complex, TATA box, pre-mRNA, polyadenylation signal
3. Modifications that occur during RNA processing in eukaryotes, including adding the 5' cap and the poly-A tail, and RNA splicing
4. Define untranslated regions (5' UTR, 3' UTR), introns, exons, spliceosomes, alternative RNA splicing, pre-mRNA vs mature mRNA

The Molecular Components of Translation: Structure and Function of Ribosomes

1. Explain the basic process of how a mRNA is translated into a polypeptide chain at a ribosome and with tRNAs functioning as the "interpreters" between RNA & amino acids
2. Describe the structure of transfer RNA, including the anticodon and amino acid attachment site, the importance of the concept of wobble
3. Describe the basic structure of ribosomes as a two-subunit complex of rRNA and protein with three mRNA binding sites, known as A, P, and E sites
4. Define start codon, small ribosomal subunit, large ribosomal subunit, initiation, translation initiation complex, elongation, termination, release factors
5. Compare the functions of different RNAs: mRNA, tRNA, and rRNA
6. Know that translation forms the primary structure, which is not yet a finished protein

Mutation: Altered Genes and Possible Impacts on Protein Structure and Function

1. Describe the following point mutations: nucleotide-pair substitution, silent mutation, missense mutation, nonsense mutation, frameshift mutation (insertion or deletion)

Regulation of Gene Expression: The Basics of How Genes Are Turned On and/or Off

1. Understand that not all genes are being transcribed and translated constantly, and that there is efficiency in turning genes on when they are needed and off when they are not
2. Know that there are two ways to regulate a metabolic pathway: regulating enzyme activity and regulating the production of enzymes

Operons and the Basic Concept of Gene Regulation in Prokaryotes

1. Understand how evolution/natural selection might favor cells that can conserve energy and resources by regulating gene expression

Basic Introduction to Gene Regulation in Eukaryote

1. Understand that eukaryotic genes regulation of eukaryotic genomes is done at many stages