AAMC MCAT Science Topics

rearranged into regular order

Physics

- **Kinematics**
  - **Translational Motion (PHY)**
    - Units and dimensions
    - Vectors, components
    - Vector addition
    - Speed, velocity (average and instantaneous)
    - Acceleration
- **Newton's Laws**
  - **Force (PHY)**
    - Newton's First Law, inertia
    - Newton's Second Law ($F = ma$)
    - Newton's Third Law, forces equal and opposite
    - Friction, static and kinetic
    - Center of mass
  - **Equilibrium (PHY)**
    - Vector analysis of forces acting on a point object
    - Torques, lever arms
- **Work, Energy, and Power**
  - **Work (PHY)**
    - Work done by a constant force: $W = Fd\cos\theta$
    - Mechanical advantage
    - Work Kinetic Energy Theorem
    - Conservative forces
  - **Energy of Point Object Systems (PHY)**
    - Kinetic Energy: KE = 1⁄2 $mv2$; units
    - Potential Energy
      - PE = mgh (gravitational, local)
      - PE = 1⁄2 kx^2 (spring)
    - Conservation of energy
    - Power, units
- **Simple Harmonic Motion**
  - **Periodic Motion (PHY)**
    - Amplitude, frequency, phase
      - PE = 1⁄2 kx^2 (spring)
- **Fluid Mechanics**
  - **Fluids (PHY)**
    - Density, specific gravity
    - Buoyancy, Archimedes' Principle
    - Hydrostatic pressure
      - Pascal'sLaw
      - Hydrostatic pressure; $P = \rho gh$ (pressure vs. depth)
    - Viscosity: Poiseuille Flow
    - Continuity equation ($A \cdot v$ = constant)
    - Concept of turbulence at high velocities
    - Surface tension
    - Bernoulli's equation
    - Venturi effect, pitot tube
  - **Circulatory System (BIO)**
    - Arterial and venous systems; pressure and flow characteristics
- **Waves**
    - **Transverse and longitudinal waves**
    - **Wavelength and propagation speed**
  - **Sound (PHY)**
    - Production of sound
    - Relative speed of sound in solids, liquids, and gases
    - Intensity of sound, decibel units, log scale
    - Attenuation (Damping)
    - Doppler Effect
      - moving sound source or observer
      - reflection of sound from a moving object
    - Pitch
    - Resonance in pipes and strings
    - Ultrasound
    - Shock waves
- **Heat and Temperature**
    - Measurement of heat changes (calorimetry)
      - Heat capacity, specific heat
      - Heat capacity, specific heat
    - Heat transfer – conduction, convection, radiation (PHY)
- **The Ideal Gas and Kinetic Theory**
  - **Gas Phase (GC, PHY)**
    - Absolute temperature, (K) Kelvin Scale
    - Pressure, simple mercury barometer
    - Molar volume at 0°C and 1 atm = 22.4 L/mol
    - Ideal gas
      - Definition
      - Ideal Gas Law: $PV = nRT$
      - Boyle's Law: PV = constant
      - Charles' Law: V/T= constant
      - Avogadro's Law: V/n = constant
    - Kinetic Molecular Theory of Gases
      - Heat capacity at constant volume and at constant pressure (PHY)
      - Boltzmann's Constant (PHY)
    - Deviation of real gas behavior from Ideal Gas Law
      - Qualitative
      - Quantitative (Van der Waals' Equation)
    - Partial pressure, mole fraction
    - Dalton's Law relating partial pressure to composition
  - **The First Law of Thermodynamics**
    - Thermodynamic system – state function
    - Zeroth Law – concept of temperature
    - First Law – conservation of energy in thermodynamic processes
    - PV diagram: work done = area under or enclosed by curve (PHY)
  - **The Second Law of Thermodynamics**
    - Second Law – concept of entropy
      - Entropy as a measure of "disorder"
      - Relative entropy for gas, liquid, and crystal states
- **Electricity**
  - **Electrostatics (PHY)**
    - Charge, conductors, charge conservation
    - Insulators
    - Coulomb's Law
    - Electric field **E**
      - Field lines
      - Field due to charge distribution
    - Electrostatic energy, electric potential at a point in space
- **DC Current**
  - **Circuit Elements (PHY)**
    - Current $I = \Delta Q/\Delta t$, sign conventions, units
    - Electromotive force, voltage
    - Resistance
      - Ohm's Law: $I=V/R$
      - Resistors in series
      - Resistors in parallel
      - Resistivity:$\rho=R\bullet A/L$
    - Capacitance
      - Parallel plate capacitor
      - Energy of charged capacitor
      - Capacitors in series
      - Capacitors in parallel
      - Dielectrics
    - Conductivity
      - Metallic
      - Electrolytic
    - Meters
- **Magnetism**
  - **Magnetism (PHY)**
    - Definition of magnetic field **B**
    - Motion of charged particles in magnetic fields; Lorentz force
    - Paramagnetism and diamagnetism
- **The Properties of Light**
    - Properties of electromagnetic radiation
      - Velocity equals constant c, *in vacuo*

        - Perpendicularly oscillating electric and magnetic fields
        - Direction of propagation is perpendicular to both
    - Classification of electromagnetic spectrum, photon energy $E = hf$
    - Visual spectrum, color
    - Reflection from plane surface: angle of incidence equals angle of reflection
    - Refraction, refractive index n; Snell's law: $n1 \sin \theta 1 = n2 \sin \theta 2$
    - Dispersion, change of index of refraction with wavelength
    - Conditions for total internal reflection
    - Polarization of light: linear and circular
- **Geometric Optics**

  Geometrical Optics (PHY)
    - Spherical mirrors
        - Center of curvature
        - Focal length
        - Real and virtual images
    - Thin lenses
        - Converging and diverging lenses
        - Use of formula $1/p + 1/q = 1/f$, with sign conventions
        - Lens strength, diopters
    - Combination of lenses
    - Lens aberration
    - Optical Instruments, including the human eye
- **Wave Optics**

  Light, Electromagnetic Radiation (PHY)
    - Concept of Interference; Young Double-slit Experiment
    - Thin films, diffraction grating, single-slit diffraction
    - Other diffraction phenomena, X-ray diffraction
- **Modern Physics** *Also See Atomic Theory*
    - Heisenberg Uncertainty Principle
    - Photoelectric effect
- **Nuclear Physics**
    - Neutrons, protons, isotopes
    - Nuclear forces, binding energy
    - Radioactive decay
        - α, β, γ decay
        - Half-life, exponential decay, semi-log plots

General Chemistry

- **Atomic Theory**

  Atomic Nucleus (PHY, GC)
    - Atomic number, atomic weight
    - Mass spectrometer

  Electronic Structure (PHY, GC)
    - Orbital structure of hydrogen atom
    - Principal quantum number n, # of electrons per orbital (GC)
    - Ground state, excited states
    - Absorption and emission line spectra
    - Use of Pauli Exclusion Principle
    - Conventional notation for electronic structure (GC)
    - Bohr atom
    - Effective nuclear charge (GC)
- **Periodic Trends**

  The Periodic Table - Classification of Elements into Groups by Electronic Structure (GC)
    - Alkali metals
    - Alkaline earth metals: their chemical characteristics
    - Halogens: their chemical characteristics
    - Noble gases: their physical and chemical characteristics
    - Transition metals
    - Representative elements
    - Metals and non-metals
    - Oxygen group

  The Periodic Table - Variations of Chemical Properties with Group and Row (GC)
    - Valence electrons
    - First and second ionization energy
        - Definition
        - Prediction from electronic structure for elements in different groups or rows
    - Electron affinity
        - Definition
        - Variation with group and row
    - Electronegativity
        - Definition
        - Comparative values for some representative elements and important groups
    - Electron shells and the sizes of atoms
    - Electron shells and the sizes of ions
- **The Chemical Bond**

  Covalent Bond (GC)
    - Lewis Electron Dot formulas
        - Resonance structures
        - Formal charge
        - Lewis acids and bases
    - Partial ionic character
        - Role of electronegativity in determining charge distribution
        - Dipole moment
    - σ and π bonds
        - Hybrid orbitals: sp^3, sp^2, sp and respective geometries
        - Valence shell electron pair repulsion and the shapes of molecules (e.g., NH3, H2O, CO2)
        - Structural formulas for molecules involving H, C, N, O, F, S, P, Si, Cl
        - Delocalized electrons and resonance in ions and molecules
    - Multiple bonding
        - Effect on bond length and bond energies
        - Rigidity in molecular structure

  Intermolecular Forces

  Liquid Phase - Intermolecular Forces (GC)
    - Hydrogen bonding
    - Dipole Interactions
    - Van der Waals' Forces (London dispersion forces)
- **Stoichiometry**

  Stoichiometry (GC)
    - Molecular weight
    - Empirical versus molecular formula
    - Metric units commonly used in the context of chemistry
    - Description of composition by percent mass
    - Mole concept, Avogadro's number NA
    - Definition of density
    - Oxidation number
        - Common oxidizing and reducing agents
        - Disproportionation reactions
    - Description of reactions by chemical equations
        - Conventions for writing chemical equations
        - Balancing equations, including redox equations
        - Limiting reactants
        - Theoretical yields
- **Thermochemistry**
    - Endothermic/exothermic reactions (GC)
        - Enthalpy, H, and standard heats of reaction and formation
        - Hess' Law of Heat Summation
        - Bond dissociation energy as related to heats of formation (GC)
- **The States of Matter**
    - Coefficient of expansion (PHY)
    - Heat of fusion, heat of vaporization
    - Phase diagram: pressure and temperature
- **Chemical Thermodynamics and the Equilibrium State**
    - Second Law – concept of entropy
        - Entropy as a measure of "disorder"
        - Relative entropy for gas, liquid, and crystal states
    - Free energy: G (GC)
    - Spontaneous reactions and $\Delta G°$ (GC)
    - Bioenergetics/thermodynamics
        - Free energy / Keq
    - Equilibrium constant
    - Relationship of the equilibrium constant and $\Delta G°$
        - Concentration

- Le Châtelier's Principle
  - Endothermic/exothermic reactions
  - Free energy: G
  - Spontaneous reactions and $\Delta G°$
- Equilibrium in reversible chemical reactions
  - Law of Mass Action
  - Equilibrium Constant
  - Application of Le Châtelier's Principle
- Relationship of the equilibrium constant and $\Delta G°$

Chemical Kinetics

Rate Processes in Chemical Reactions
Kinetics and Equilibrium (GC)

- Reaction rate
- Dependence of reaction rate on concentration of reactants
  - Rate law, rate constant
  - Reaction order
- Rate-determining step
- Dependence of reaction rate upon temperature
  - Activation energy
- Activated complex or transition state
  - Interpretation of energy profiles showing energies of reactants, products, activation energy, and ΔH for the reaction
  - Use of the Arrhenius Equation
- Kinetic control versus thermodynamic control of a reaction
- Catalysts

Solutions

Ions in Solutions (GC, BC)

- Anion, cation: common names, formulas and charges for familiar ions (e.g., NH^{4+} ammonium, PO_4^{3-} phosphate, SO_4^{2-} sulfate)
  - Hydration, the hydronium ion

Solubility (GC)

- Units of concentration (e.g., molarity)
- Solubility product constant; the equilibrium expression Ksp
- Common-ion effect, its use in laboratory separations
  - Complex ion formation
  - Complex ions and solubility
  - Solubility and pH
  - Osmosis
- Colligative properties; osmotic pressure (GC)
- Henry's Law (GC)

Acids and Bases

Acid/Base Equilibria (GC, BC)

- Brønsted–Lowry definition of acid, base
- Ionization of water
  - Kw, its approx. value (Kw = [H][OH] = 10 at 25°C, 1 atm)
  - Definition of pH: pH of pure water
- Conjugate acids and bases (e.g., NH4+ and NH3)
- Strong acids and bases (e.g., nitric, sulfuric)
- Weak acids and bases (e.g., acetic, benzoic)
  - Dissociation of weak acids and bases with or without added salt
  - Hydrolysis of salts of weak acids or bases
  - Calculation of pH of solutions of salts of weak acids or bases
- Equilibrium constants Ka and Kb: pKa, pKb
- Buffers
  - Definition and concepts (common buffer systems)
  - Influence on titration curves

Titration (GC)

- Indicators
- Neutralization
- Interpretation of the titration curves

Coordination Chemistry

  - Complex ion formation
  - Complex ions and solubility

Oxidation-Reduction & Electrochemistry

- Oxidation number
  - Common oxidizing and reducing agents
  - Disproportionation reactions
- Redox titration

Electrochemistry

- **Biological oxidation-reduction**
  - Half-reactions
  - Soluble electron carriers
  - Flavoproteins
- Concentration cell: direction of electron flow, Nernst equation
- Electrolytic cell
  - Electrolysis
  - Anode, cathode
  - Electrolyte
  - Faraday's Law relating amount of elements deposited (or gas l iberated) at an electrode to current
  - Electron flow; oxidation, and reduction at the electrodes
- Galvanic or Voltaic cells
  - Half-reactions
  - Reduction potentials; cell potential
  - Direction of electron flow
- Concentration cell
- Batteries
  - Electromotive force, Voltage
  - Lead-storage batteries
  - Nickel-cadmium batteries

Specialized Cell - Nerve Cell (BIO)

- Myelin sheath, Schwann cells, insulation of axon
- Nodes of Ranvier: propagation of nerve impulse along axon

Organic Chemistry

Stereochemistry

- **Stereochemistry of covalently bonded molecules (**OC**)**
  - Isomers
- Structural isomers
- Stereoisomers (e.g., diastereomers, enantiomers, cis/trans isomers)
- Conformational isomers
  - Polarization of light, specific rotation
  - Absolute and relative configuration
- Conventions for writing R and S forms
- Conventions for writing E and Z forms
- Cyclic structure and conformations of hexoses
- Epimers and anomers
- **Racemic mixtures, separation of enantiomers (OC)**

Molecular Structure and Absorption Spectra (OC)

- Infrared region
  - Intramolecular vibrations and rotations
  - Recognizing common characteristic group absorptions, fingerprint region
- Visible region (GC)
  - Absorption in visible region gives complementary color (e.g., carotene)
  - Effect of structural changes on absorption (e.g., indicators)
- Ultraviolet region
  - π-Electron and non-bonding electron transitions
  - Conjugated systems
- NMR spectroscopy
  - Protons in a magnetic field; equivalent protons
  - Spin-spin splitting

Reactions of Alcohols and Ethers

Alcohols (OC)

- Description
  - Nomenclature
  - Physical properties (acidity, hydrogen bonding)
- Important reactions
  - Oxidation
  - Substitution reactions: SN1 or SN2
  - Protection of alcohols
  - Preparation of mesylates and tosylates

Reactions of Aldehydes and Ketones

Aldehydes and Ketones (OC)

- Description
  - Nomenclature
  - Physical properties
- Important reactions
- Nucleophilic addition reactions at C=O bond

        - Acetal, hemiacetal
        - Imine, enamine
        - Hydride reagents
        - Cyanohydrin
    - Reactions at adjacent positions: enolate chemistry
        - Keto-enol tautomerism (α-racemization)
        - Aldol condensation, retro-aldol
        - Kinetic versus thermodynamic enolate
    - Oxidation of aldehydes
    - General principles
        - Effect of substituents on reactivity of C=O; steric hindrance
        - Acidity of α-H; carbanions
- **Reactions of Carboxylic Acids and Derivatives**

Carboxylic Acids (OC)

- Description
    - Nomenclature
    - Physical properties
- Important reactions
    - Carboxyl group reactions
- Amides (and lactam), esters (and lactone), anhydride formation
- Reduction
- Decarboxylation
- Reactions at 2-position, substitution

Acid Derivatives (Anhydrides, Amides, Esters) (OC)

- Description
    - Nomenclature
    - Physical properties
- Important reactions
    - Nucleophilic substitution
    - Transesterification
    - Hydrolysis of amides
- General principles
    - Relative reactivity of acid derivatives
    - Steric effects
    - Electronic effects
    - Strain (e.g., β-lactams)

- **Reactions of Organic Phosphorus Compounds**
    - Phosphoryl group transfers and ATP
        - ATP hydrolys is $\Delta G << 0$
        - ATP group transfers
- **Reactions of Organic Sulfur Compounds**
    - Sulfur linkage for cysteine and cystine
    - Preparation of mesylates and tosylates
- **Phenols**
    - Oxidation and reduction (e.g., hydroquinones, ubiquinones): biological $2e^-$ redox centers
- **Polycyclic and Heterocyclic Aromatic Compounds**
    - Biological aromatic heterocycles

Biology

- **Proteins**

Amino Acids (BC, OC)

- Description
    - Absolute configuration at the α position
    - Amino acids as dipolar ions
    - Classifications
- Acidic or basic
- Reactions
- Hydrophobic or hydrophilic
    - Sulfur linkage for cysteine and cystine
    - Peptide linkage: polypeptides and proteins
    - Hydrolysis

Protein Structure (BIO, BC, OC)

- Structure
    - 1° structure of proteins
    - 2° structure of proteins
    - 3° structure of proteins; role of proline, cystine, hydrophobic bonding
    - 4° structure of proteins (BIO,BC)
- Conformational stability
    - Denaturing and folding
    - Hydrophobic interactions
    - Solvation layer (entropy) (BC)
- Separation techniques
    - Isoelectric point
    - Electrophoresis

Non-Enzymatic Protein Function (BIO, BC)

- Binding (BC)
- Immune system
- Motors

Enzyme Structure and Function (BIO, BC)

- Function of enzymes in catalyzing biological reactions
- Enzyme classification by reaction type
- Reduction of activation energy
- Substrates and enzyme specificity
- Active Site Model
- Induced-fit Model
- Mechanism of catalysis
    - Cofactors
    - Coenzymes
    - Water-soluble vitamins
- Effects of local conditions on enzyme activity

Control of Enzyme Activity (BIO, BC)

- Kinetics
    - General (catalysis)
    - Michaelis–Menten
    - Cooperativity
- Feedback regulation
- Inhibition−types
    - Competitive
    - Non-competitive
    - Mixed (BC)
    - Uncompetitive (BC)
- Regulatory enzymes
    - Allosteric enzymes
    - Covalently-modified enzymes
    - Zymogen

- **Carbohydrates**

Carbohydrates (BC, OC)

- Description
    - Nomenclature and classification, common names
    - Absolute configuration
    - Cyclic structure and conformations of hexoses
    - Epimers and anomers
- Hydrolysis of the glycoside linkage
- Monosaccharides
- Disaccharides
- Polysaccharides
- Hydrolysis of the glycoside linkage
- Keto-enol tautomerism of monosaccharides
- Disaccharides (BC)
- Polysaccharides (BC)

- **Nucleic Acids**

Nucleic Acid Structure and Function (BIO, BC)

- Description
- Nucleotides and nucleosides
    - Sugar phosphate backbone
    - Pyrimidine, purine residues
- Deoxyribonucleic acid (DNA): double helix, Watson–Crick model
- Base pairing specificity: A with T, G with C
- Function in transmission of genetic information (BIO)
- DNA denaturation, reannealing, hybridization
- Chemistry (BC)
- Other functions (BC)

- **Lipids**

Metabolism of Fatty Acids and Proteins (BIO, BC)

- Description of fatty acids (BC)
- Digestion, mobilization, and transport of fats

Lipids (BC, OC)

- Description, Types

    - Structural
  - Triacyl glycerols
    - Storage
  - Free fatty acids: saponification
  - Phospholipids and phosphatids
  - Sphingolipids (BC)
  - Waxes
  - Terpenes and terpenoids
  - Signals/cofactors
    - Fat-soluble vitamins
    - Steroids
    - Prostaglandins (BC)

Biological Membranes

Plasma Membrane (BIO, BC)

- General function in cell containment
- Composition of membranes
  - Lipid components (BIO, BC, OC)
- Phospholipids (and phosphatids)
- Steroids
- Waxes
- Protein components
- Fluid mosaic model
- Membrane dynamics
- Solute transport across membranes
  - Thermodynamic considerations
  - Osmosis
  - Colligative properties; osmotic pressure (GC)
  - Passive transport
  - Active transport
  - Sodium/potassium pump
  - Membrane channels
- Membrane potential
- Membrane receptors
- Exocytosis and endocytosis
- Intercellular junctions (BIO)
  - Gap junctions
  - Tight junctions
  - Desmosomes

Biosignalling (BC)

- Gated ion channels
  - Voltage gated
  - Ligand gated
- Receptor enzymes
- G protein-coupled receptors

The Prokaryotic Cell

- Lack of nuclear membrane and mitotic apparatus
- Lack of typical eukaryotic organelles
- Presence of cell wall in bacteria
- Flagellar propulsion, mechanism

Growth and Physiology of Prokaryotic Cells (BIO)

- Reproduction by fission
- High degree of genetic adaptability, antibiotic resistance
- Exponential growth
- Existence of anaerobic and aerobic variants
- Parasitic and symbiotic
- Chemotaxis

Genetics of Prokaryotic Cells (BIO)

- Existence of plasmids, extragenomic DNA
- Transformation: incorporation into bacterial genome of DNA fragments from external medium
- Conjugation
- Transposons (also present in eukaryotic cells)

The Eukaryotic Cell

Cell Theory (BIO)

- History and development
- Impact on biology

Membrane-Bound Organelles and Defining Characteristics of Eukaryotic Cells (BIO)

- Defining characteristics of eukaryotic cells:
  - membrane bound nucleus
  - presence of organelles
  - mitotic division
- Nucleus
  - Compartmentalization, storage of genetic information
  - Nucleolus: location and function
  - Nuclear envelope, nuclear pores
- Mitochondria
  - Site of ATP production
  - Inner and outer membrane structure (BIO, BC)
  - Self-replication
- Lysosomes: membrane-bound vesicles containing hydrolytic enzymes
- Endoplasmic reticulum
  - Rough and smooth components
  - Rough endoplasmic reticulum site of ribosomes
  - Double membrane structure
  - Role in membrane biosynthesis
  - Role in biosynthesis of secreted proteins
- Golgi apparatus: general structure and role in packaging and secretion
- Peroxisomes: organelles that collect peroxides
- Cytoskeleton (BIO)
  - General function in cell support and movement
  - Microfilaments: composition, role in cleavage and contractility
  - Microtubules: composition and role in support and transport
  - Intermediate filaments, role in support
  - Composition and function of cilia and flagella
  - Centrioles, microtubule organizing centers

Bioenergetics and Cellular Respiration

Principles of Bioenergetics (BC)

- Bioenergetics/thermodynamics
  - Free energy/*K*eq
  - Concentration
- Phosphorylation/ATP
  - ATP hydrolysis $\Delta G << 0$
  - ATP group transfers
- Biological oxidation–reduction
  - Half-reactions
  - Soluble electron carriers
  - Flavoproteins

Glycolysis, Gluconeogenesis, and the Pentose Phosphate Pathway (BIO, BC)

- Glycolysis (aerobic), substrates and products
  - Feeder pathways:glycogen, starch metabolism
- Fermentation (anaerobic glycolysis)
- Gluconeogenesis (BC)
- Pentose phosphate pathway (BC)
- Net molecular and energetic results of respiration processes

Principles of Metabolic Regulation (BC)

- Regulation of metabolic pathways (BIO, BC)
  - Maintenance of a dynamic steady state
- Regulation of glycolysis and gluconeogenesis
- Metabolism of glycogen
- Regulation of glycogen synthesis and breakdown
  - Allosteric and hormonal control
- Analysis of metabolic control

Citric Acid Cycle (BIO, BC)

- Acetyl-CoA production (BC)
- Reactions of the cycle, substrates and products
- Regulation of the cycle
- Net molecular and energetic results of respiration processes

Oxidative Phosphorylation (BIO, BC)

- Electron transport chain and oxidative phosphorylation
  - substrates and products
  - general features of the pathway
- Electron transfer in mitochondria
  - NADH, NADPH
  - Flavoproteins
  - Cytochromes
- ATP synthase, chemiosmotic coupling
  - Proton motive force
- Net molecular and energetic results of respiration processes
- Regulation of oxidative phosphorylation
- Mitochondria, apoptosis, oxidative stress (BC)

Integration of Metabolism

- **Oxidation of fatty acids**
  - Saturated fats
  - Unsaturated fats
- Ketone bodies (BC)
- Anabolism of fats (BIO)
- Non-template synthesis: biosynthesis of lipids and polysaccharides (BIO)
- Metabolism of proteins (BIO)

Hormonal Regulation and Integration of Metabolism (BC)

- Higher level integration of hormone structure and function
- Tissue specific metabolism
- Hormonal regulation of fuel metabolism
- Obesity and regulation of body mass

Gene Expression

Genetic Code (BIO)

- Central Dogma: DNA → RNA → protein
- The triplet code
- Codon–anticodon relationship
- Degenerate code, wobble pairing
- Missense, nonsense codons
- Initiation, termination codons
- Messenger RNA (mRNA)

Transcription (BIO)

- Transfer RNA (tRNA); ribosomal RNA (rRNA)
- Mechanism of transcription
- mRNA processing in eukaryotes, introns, exons
- Ribozymes, spliceosomes, small nuclear ribonucleoproteins (snRNPs), small nuclear RNA (snRNAs)
- Functional and evolutionary importance of introns

Translation (BIO)

- Roles of mRNA, tRNA, rRNA
- Role and structure of ribosomes
- Initiation, termination co-factors
- Post-translational modification of proteins

Eukaryotic Chromosome Organization (BIO)

- Chromosomal proteins
- Single copy vs. repetitive DNA
- Supercoiling
- Heterochromatin vs. euchromatin
- Telomeres, centromeres

Genetics of Prokaryotic Cells (BIO)

- Existence of plasmids, extragenomic DNA
- Transformation: incorporation into bacterial genome of DNA fragments from external medium
- Conjugation
- Transposons (also present in eukaryotic cells)

Control of Gene Expression in Prokaryotes (BIO)

- Operon Concept, Jacob–Monod Model
- Gene repression in bacteria
- Positive control in bacteria

Control of Gene Expression in Eukaryotes (BIO)

- Transcriptional regulation
- DNA binding proteins, transcription factors
- Gene amplification and duplication
- Post-transcriptional control, basic concept of splicing (introns, exons)
- Cancer as a failure of normal cellular controls, oncogenes, tumor suppressor genes
- Regulation of chromatin structure
- DNA methylation
- Role of non-coding RNAs

DNA Replication and Cellular Reproduction

DNA Replication (BIO)

- Mechanism of replication: separation of strands, specific coupling of free nucleic acids
- Semi-conservative nature of replication
- Specific enzymes involved in replication
- Origins of replication, multiple origins in eukaryotes
- Replicating the ends of DNA molecules

Repair of DNA (BIO)

- Repair during replication
- Repair of mutations

Mitosis (BIO)

- Mitotic process: prophase, metaphase, anaphase, telophase, interphase
- Mitotic structures
  - Centrioles, asters, spindles
  - Chromatids, centromeres, kinetochores
  - Nuclear membrane breakdown and reorganization
  - Mechanisms of chromosome movement
- Phases of cell cycle: G0, G1, S, G2, M
- Growth arrest
- Control of cell cycle
- Loss of cell cycle controls in cancer cells

Biosignalling (BC)

- Oncogenes, apoptosis

Mendelian Genetics

Mendelian Concepts (BIO)

- Phenotype and genotype
- Gene
- Locus
- Allele: single and multiple
- Homozygosity and heterozygosity
- Wild-type
- Recessiveness
- Complete dominance
- Co-dominance
- Incomplete dominance, leakage, penetrance, expressivity
- Hybridization: viability
- Gene pool

Analytic Methods (BIO)

- Hardy–Weinberg Principle
- Testcross (Backcross; concepts of parental, F1, and F2 generations)
- Gene mapping: crossover frequencies
- Biometry: statistical methods

Recombination and Mutation

Meiosis and Other Factors Affecting Genetic Variability (BIO)

- Significance of meiosis
- Important differences between meiosis and mitosis
- Segregation of genes
  - Independent assortment
  - Linkage
  - Recombination
  - Single crossovers
  - Double crossovers
  - Synaptonemal complex
  - Tetrad
  - Sex-linked characteristics
  - Very few genes on Y chromosome
  - Sex determination
  - Cytoplasmic/extranuclear inheritance
- Mutation
  - General concept of mutation — error in DNA sequence
  - Types of mutations: random, translation error, transcription error, base substitution, inversion, addition, deletion, translocation, mispairing
  - Advantageous vs. deleterious mutation
  - Inborn errors of metabolism
  - Relationship of mutagens to carcinogens
- Genetic drift
- Synapsis or crossing-over mechanism for increasing genetic diversity

The Molecular Biology Laboratory

Separations and Purifications (OC, BC)

- Extraction: distribution of solute between two immiscible solvents
- Distillation
- Chromatography
  - Basic principles involved in separation process
- Column chromatography, gas-liquid chromatography
- High pressure liquid chromatography
  - Paper chromatography
  - Thin-layerchromatography
- Separation and purification of peptides and proteins (BC)
  - Electrophoresis
  - Quantitative analysis
  - Chromatography

- Size-exclusion
- Ion-exchange
- Affinity

Recombinant DNA and Biotechnology (BIO)

- Gene cloning
- Restriction enzymes
- DNA libraries
- Generation of cDNA
- Hybridization
- Expressing cloned genes
- Polymerase chain reaction
- Gel electrophoresis and Southern blotting
- DNA sequencing
- Analyzing gene expression
- Determining gene function
- Stem cells
- Practical applications of DNA technology: medical applications, human gene therapy, pharmaceuticals, forensic evidence, environmental cleanup, agriculture
- Safety and ethics of DNA technology

Viruses

Virus Structure (BIO)

- General structural characteristics (nucleic acid and protein, enveloped and nonenveloped)
- Lack organelles and nucleus
- Structural aspects of typical bacteriophage
- Genomic content — RNA or DNA
- Size relative to bacteria and eukaryotic cells

Viral Life Cycle (BIO)

- Self-replicating biological units that must reproduce within specific host cell
- Generalized phage and animal virus life cycles
  - Attachment to host, penetration of cell membrane or cell wall, and entry of viral genetic material
  - Use of host synthetic mechanism to replicate viral components
  - Self-assembly and release of new viral particles
- Transduction: transfer of genetic material by viruses
- Retrovirus life cycle: integration into host DNA, reverse transcriptase,
  - HIV
- Prions and viroids: subviral particles

Bacteria and Archaea

Classification and Structure of Prokaryotic Cells (BIO)

- Prokaryotic domains
  - Archaea
  - Bacteria
- Major classifications of bacteria by shape
  - Bacilli (rod-shaped)
  - Spirilli (spiral-shaped)
  - Cocci (spherical)

Animal Development and Embryology

Reproductive System (BIO)

- Gametogenesis by meiosis
- Ovum and sperm
  - Differences information
  - Differences in morphology
  - Relative contribution to next generation
- Reproductive sequence: fertilization; implantation; development; birth

Embryogenesis (BIO)

- Stages of early development (order and general features of each)
  - Fertilization
  - Cleavage
  - Blastula formation
  - Gastrulation
- First cell movements
- Formation of primary germ layers (endoderm, mesoderm, ectoderm)
  - Neurulation
- Major structures arising out of primary germ layers
- Neural crest
- Environment–gene interaction in development

Mechanisms of Development (BIO)

- Cell specialization
  - Determination
  - Differentiation
  - Tissue types
- Cell–cell communication in development
- Cell migration
- Pluripotency: stem cells
- Gene regulation in development
- Programmed cell death
- Existence of regenerative capacity in various species
- Senescence and aging

Mammalian Tissues and Histology

Tissues Formed From Eukaryotic Cells (BIO)

- Epithelial cells
- Connective tissue cells

The Nervous System

Nervous System: Structure and Function (BIO)

- Major Functions
  - High level control and integration of body systems
  - Adaptive capability to external influences
- Organization of vertebrate nervous system
- Sensor and effector neurons
- Sympathetic and parasympathetic nervous systems: antagonistic control
- Reflexes
  - Feedback loop, reflex arc
  - Role of spinal cord and supraspinal circuits
- Integration with endocrine system: feedback control

Nerve Cell (BIO)

- Cell body: site of nucleus, organelles
- Dendrites: branched extensions of cell body
- Axon: structure and function
- Myelin sheath, Schwann cells, insulation of axon
- Nodes of Ranvier: propagation of nerve impulse along axon
- Synapse: site of impulse propagation between cells
- Synaptic activity: transmitter molecules
- Resting potential: electrochemical gradient
- Action potential
  - Threshold, all-or-none
  - Sodium/potassium pump
- Excitatory and inhibitory nerve fibers: summation, frequency of firing
- Glial cells, neuroglia

Sensory Systems

Vision (PSY, BIO)

- Structure and function of the eye
- Visual processing
  - Visual pathways in the brain
  - Parallel processing (PSY)
  - Feature detection (PSY)

Hearing (PSY, BIO)

- Structure and function of the ear
- Auditory processing (e.g., auditory pathways in the brain)
- Sensory reception by hair cells

Other Senses (PSY, BIO)

- Somatosensation (e.g., pain perception)
- Taste (e.g., taste buds/chemoreceptors that detect specific chemicals)
- Smell
  - Olfactory cells/chemoreceptors that detect specific chemicals
  - Pheromones (BIO)
  - Olfactory pathways in the brain (BIO)
- Kinesthetic sense (PSY)
- Vestibular sense

The Endocrine System

Endocrine System: Hormones and Their Sources (BIO)

- Function of endocrine system: specific chemical control at cell, tissue, and organ level
- Definitions of endocrine gland, hormone
- Major endocrine glands: names, locations, products
- Major types of hormones
- Neuroendrocrinology — relation between neurons and hormonal systems

Endocrine System: Mechanisms of Hormone Action (BIO)

- Cellular mechanisms of hormone action
- Transport of hormones: blood supply
- Specificity of hormones: target tissue
- Integration with nervous system: feedback control
- Regulation by second messengers

Hormonal Regulation and Integration of Metabolism (BC)

- Higher level integration of hormone structure and function
- Tissue specific metabolism
- Hormonal regulation of fuel metabolism
- Obesity and regulation of body mass

The Musculoskeletal System

Muscle System (BIO)

- Important functions
  - Support : mobility
  - Peripheral circulatory assistance
  - Thermoregulation (shivering reflex)
- Structure of three basic muscle types: striated, smooth, cardiac
- Muscle structure and control of contraction
  - T-tubule system
  - Contractile apparatus
  - Sarcoplasmic reticulum
  - Fiber type
  - Contractile velocity of different muscle types
- Regulation of cardiac muscle contraction
- Oxygen debt: fatigue
- Nervous control
  - Motor neurons
  - Neuromuscular junction, motor end plates
  - Sympathetic and parasympathetic innervation
  - Voluntary and involuntary muscles

Specialized Cell - Muscle Cell (BIO)

- Structural characteristics of striated, smooth, and cardiac muscle
- Abundant mitochondria in red muscle cells: ATP source
- Organization of contractile elements:
  - actin and myosin filaments
  - crossbridges
  - sliding filament model
- Sarcomeres: “I” and “A” bands, “M” and “Z” lines, “H” zone
- Presence of troponin and tropomyosin
- Calcium regulation of contraction

Skeletal System (BIO)

- Functions
  - Structural rigidity and support
  - Calcium storage
  - Physical protection
- Skeletal structure
  - Specialization of bone types, structures
  - Joint structures
  - Endoskeleton vs. exoskeleton
- Bone structure
  - Calcium/protein matrix
  - Cellular composition of bone
- Cartilage: structure and function
- Ligaments, tendons
- Endocrine control

The Cardiovascular System

Circulatory System (BIO)

- Functions: circulation of oxygen, nutrients, hormones, ions and fluids, removal of metabolic waste
- Role in thermoregulation
- Four-chambered heart: structure and function
- Endothelial cells
- Systolic and diastolic pressure
- Pulmonary and systemic circulation
- Arterial and venous systems (arteries, arterioles, venules, veins)
  - Structural and functional differences
  - Pressure and flow characteristics
- Capillary beds
  - Mechanisms of gas and solute exchange
  - Mechanism of heat exchange
  - Source of peripheral resistance
- Nervous and endocrine control

Blood

- Composition of blood
  - Plasma,chemicals,bloodcells
  - Erythrocyte production and destruction; spleen, bone marrow
  - Regulation of plasma volume
- Coagulation, clotting mechanisms
- Oxygen transport by blood
  - Hemoglobin, hematocrit
  - Oxygen content
  - Oxygen affinity
- Carbon dioxide transport and level in blood

The Respiratory SystemRespiratory System (BIO)

- General function
  - Gas exchange, thermoregulation
  - Protection against disease : particulate matter
- Structure of lungs and alveoli
- Breathing mechanisms
  - Diaphragm, rib cage, differential pressure
  - Resiliency and surface tension effects
- Thermoregulation: nasal and tracheal capillary beds; evaporation, panting
- Particulate filtration: nasal hairs, mucus/cilia system in lungs
- Alveolar gas exchange
  - Diffusion, differential partial pressure
  - Henry’s Law(GC)
- pH control
- Regulation by nervous control - CO_2 sensitivity

The Lymphatic System and Immunity

Lymphatic System (BIO)

- Structure of lymphatic system
- Major functions
  - Equalization of fluid distribution
  - Transport of proteins and large glycerides
  - Production of lymphocytes involved in immune reactions
  - Return of materials to the blood

Immune System (BIO)

- Innate (non-specific) vs. adaptive (specific) immunity
- Adaptive immune system cells
  - T-lymphocytes
  - B-lymphocytes
- Innate immune system cells
  - Macrophages
  - Phagocytes
- Tissues
  - Bonemarrow
  - Spleen
  - Thymus
  - Lymph nodes
- Concept of antigen and antibody
- Antigen presentation
- Clonal selection
- Antigen-antibody recognition
- Structure of antibody molecule
- Recognition of self vs. non-self, autoimmune diseases
- Major histocompatibility complex

The Urinary System

Excretory System (BIO)

- Roles in homeostasis
  - Blood pressure
  - Osmoregulation
  - Acid–basebalance
  - Removal of soluble nitrogenous waste
- Kidney structure
  - Cortex
  - Medulla
- Nephron structure
  - Glomerulus
  - Bowman’s capsule
  - Proximal tubule
  - Loop of Henle
  - Distal tubule
  - Collecting duct

- Formation of urine
  - Glomerular filtration
  - Secretion and reabsorption of solutes
  - Concentration of urine
  - Counter-current multiplier mechanism
- Storage and elimination: ureter, bladder, urethra
- Osmoregulation: capillary reabsorption of H_2O, amino acids, glucose, ions
- Muscular control: sphincter muscle

The Digestive System and Nutrition

Digestive System (BIO)

- Ingestion
  - Saliva as lubrication and source of enzymes
  - Ingestion; esophagus, transport function
- Stomach
  - Storage and churning of food
  - Low pH, gastric juice, mucal protection against self-destruction
  - Production of digestive enzymes, site of digestion
  - Structure(gross)
- Liver
  - Structural relationship of liver within gastrointestinal system
  - Production of bile
  - Role in blood glucose regulation, detoxification
- Bile
  - Storage in gall bladder
  - Function
- Pancreas
  - Production of enzymes
  - Transport of enzymes to small intestine
- Small Intestine
  - Absorption of food molecules and water
  - Function and structure of villi
  - Production of enzymes, site of digestion
  - Neutralization of stomach acid
  - Structure (anatomic subdivisions)
- Large Intestine
  - Absorption of water
  - Bacterial flora
  - Structure (gross)
- Rectum: storage and elimination of waste, feces
- Muscular control
  - Peristalsis
- Endocrine control
  - Hormones
  - Target tissues
- Nervous control: the enteric nervous system

The Reproductive System

Reproductive System (BIO)

- Male and female reproductive structures and their functions
  - Gonads
  - Genitalia
  - Differences between male and female structures
- Hormonal control of reproduction
  - Male and female sexual development
  - Female reproductive cycle
  - Pregnancy, parturition, lactation
  - o Integration with nervous control

Skin

Skin System (BIO)

- Structure
  - Layer differentiation, celltypes
  - Relative impermeability to water
- Functions in homeostasis and osmoregulation
- Functions in thermoregulation
  - Hair, erectile musculature
  - Fat layer for insulation
  - Sweat glands, location in dermis
  - Vasoconstriction and vasodilation in surface capillaries
- Physical protection
  - Nails, calluses, hair
  - Protection against abrasion, disease organisms
- Hormonal control: sweating, vasodilation, and vasoconstriction

Evolution

Evolution (BIO)

- Natural selection
  - Fitness concept
  - Selection by differential reproduction
  - Concepts of natural and group selection
  - Evolutionary success as increase in percent representation in the gene pool of the next generation
- Speciation
  - Polymorphism
  - Adaptation and specialization
  - Inbreeding
  - Outbreeding
  - Bottlenecks
- Evolutionary time as measured by gradual random changes in genome
  - Genetic drift