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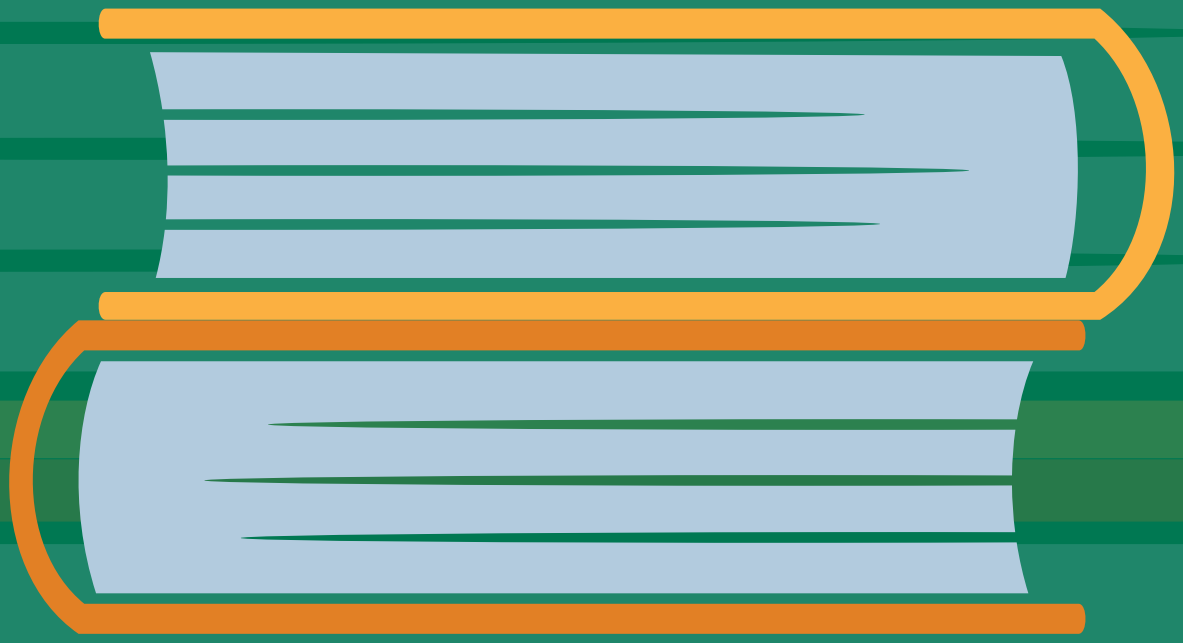
A Roadmap to MCAT® Content in Biochemistry Textbooks



Association of
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About the Roadmap

The publishers of the textbooks listed in this publication have provided a "roadmap" to where the MCAT Foundational Concepts and Content Categories can be found in their publications, by indicating the chapter and/or specific page number(s).

To use this Biochemistry Roadmap, locate the topic you're interested in and read across the columns to see which textbook covers that topic and whether the topic is covered in introductory biology and/or first-year biochemistry courses. Any concepts that don't appear in the roadmap are covered only in introductory biology.

This Biochemistry Roadmap emphasizes biochemistry, a topic introduced to the MCAT exam in 2015. However, we found that the biochemistry textbooks include some of the biology content covered on the MCAT exam. When that was the case, we included information about biology topics, too. Please note that not all of the biology topics are included because the primary focus of this roadmap is on textbooks covering biochemistry. Where a biology topic is included, it is listed as BIO in the Topic column. For a full list of all content tested on the exam, go to the What's on the MCAT Exam? interactive tool.

The abbreviations in parentheses indicate the courses in which undergraduate students at many college and universities learn about the topics and associated subtopics. The course abbreviations are:

- BC: first-semester biochemistry
- BIO: two-semester sequence of introductory biology
- GC: two-semester sequence of general chemistry
- OC: two-semester sequence of organic chemistry

In preparing for the MCAT exam, you will be responsible for learning the topics and associated subtopics at the levels at which they are taught at many colleges and universities in the courses listed in parentheses. A small number of subtopics have course abbreviations indicated in parentheses. In those cases, you are responsible only for learning the subtopics as they are taught in the course(s) indicated.

The left two columns in each table indicate which topics are covered in introductory biology (darker green shading) and which are covered in first-semester biochemistry (lighter green shading).

If you are a publisher of an introductory textbook on biochemistry and would like to add your publication and information to this reference document, please email mcatprep@aamc.org.

The Medical College Admission Test® (MCAT®) is a program of the Association of American Medical Colleges.

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Textbooks Included in Roadmap

Textbook	Link
Boundless Biology, by Boundless. Mountain View, CA: Creative Commons: Accessed April 15, 2017.	https://www.boundless.com/biology
Boundless Physiology, by Boundless. Mountain View, CA: Creative Commons: Accessed April 15, 2017.	https://www.boundless.com/physiology
Fundamentals of Biochemistry, 5th ed., by D Voet, JG Voet, and CW Pratt. Hoboken, NJ: Wiley, 2016.	

Foundational Concept 1: Biomolecules have unique properties that determine how they contribute to the structure and function of cells, and how they participate in the processes necessary to maintain life.

Content Category 1A: Structure and function of proteins and their constituent amino acids

Macromolecules formed from amino acids adopt well-defined, three-dimensional structures with chemical properties that are responsible for their participation in virtually every process occurring within and between cells. The three-dimensional structure of proteins is a direct consequence of the nature of the covalently-bonded sequence of amino acids, their chemical and physical properties, and the way in which the whole assembly interacts with water.

Enzymes are proteins that interact in highly regio- and stereo-specific ways with dissolved solutes. They either facilitate the chemical transformation of these solutes, or allow for their transport innocuously. Dissolved solutes compete for protein-binding sites, and protein conformational dynamics give rise to mechanisms capable of controlling enzymatic activity.

The infinite variability of potential amino acid sequences allows for adaptable responses to pathogenic organisms and materials. The rigidity of some amino acid sequences makes them suitable for structural roles in complex living systems.

Content in this category covers a range of protein behaviors which originate from the unique chemistry of amino acids themselves. Amino acid classifications and protein structural elements are covered. Special emphasis is placed on enzyme catalysis including mechanistic considerations, kinetics, models of enzyme-substrate interaction, and regulation.

Content Category 1A: Structure and function of proteins and their constituent amino acids

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		Amino Acids (BC, OC) Description • Absolute configuration at the α position • Amino acids as dipolar ions • Classifications » Acidic or basic » Hydrophobic or hydrophilic Reactions • Sulfur linkage between a pair of cysteines • Peptide linkage: polypeptides and proteins • Hydrolysis	Ch. 3 Biological Macromolecules		Ch. 4 Amino Acids, pp. 80-96
		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	Ch. 3 Biological Macromolecules		Ch. 5 Proteins: Primary Structure, pp. 97-130 Ch. 6 Proteins: Three-Dimensional Structure, pp. 131-179
		Nonenzymatic Protein Function (BIO, BC) • Binding • Immune system • Motors			Ch. 7 Protein Function: Myoglobin and Hemoglobin, Muscle Contraction and Antibodies, pp. 180-220

*If a chapter is listed in this row, the abbreviations apply to all sections listed below.

(continued)

Content Category 1A: Structure and function of proteins and their constituent amino acids (continued)

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		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	Ch. 6 Metabolism		Ch.11 Enzymatic Catalysis, pp. 322-360
		Control of Enzyme Activity (BIO, BC)* • Kinetics » General (catalysis) » Michaelis-Menten » Cooperativity • Feedback regulation • Inhibition—types » Competitive » Noncompetitive » Mixed (BC) » Uncompetitive (BC) • Regulatory enzymes » Allosteric enzymes » Covalently modified enzymes » Zymogen	Ch. 6 Metabolism		Ch. 12 Enzyme Kinetics, Inhibition, and Control, pp. 361-401

*If a chapter is listed in this row, the abbreviations apply to all sections listed below.

Content Category 1B: Transmission of genetic information from the gene to the protein

Biomolecules and biomolecular assemblies interact in specific, highly-regulated ways to transfer sequence information between biopolymers in living organisms. By storing and transferring biological information, DNA and RNA enable living organisms to reproduce their complex components from one generation to the next. The nucleotide monomers of these biopolymers, being joined by phosphodiester linkages, form a polynucleotide molecule with a "backbone" composed of repeating sugar-phosphate units and "appendages" of nitrogenous bases. The unique sequence of bases in each gene provides specific information to the cell.

DNA molecules are composed of two polynucleotides that spiral around an imaginary axis, forming a double helix. The two polynucleotides are held together by hydrogen bonds between the paired bases and van der Waals interactions between the stacked bases. The pairing between the bases of two polynucleotides is very specific, and its complementarity allows for a precise replication of the DNA molecule.

The DNA inherited by an organism leads to specific traits by dictating the synthesis of the biomolecules (RNA molecules and proteins) involved in protein synthesis. While every cell in a multicellular organism inherits the same DNA, its expression is precisely regulated such that different genes are expressed by cells at different stages of development, by cells in different tissues, and by cells exposed to different stimuli.

The topics included in this Content Category concern not only the molecular mechanisms of the transmission of genetic information from the gene to the protein (transcription and translation), but also the biosynthesis of the important molecules and molecular assemblies that are involved in these mechanisms. The control of gene expression in prokaryotes and eukaryotes is also included.

Broadly speaking, the field of biotechnology uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use. The biotechnological techniques emphasized in this Content Category, however, are those that take advantage of the complementary structure of the double-stranded DNA molecule to synthesize, sequence, and amplify them, and to analyze and identify unknown polynucleotide sequences. Included within this treatment of biotechnology are those practical applications which directly impact humans, such as medical applications, human gene therapy, and pharmaceuticals.

Content in this category covers the biopolymers including ribonucleic acid (RNA), deoxyribonucleic acid (DNA), proteins, and the biochemical processes involved in carrying out the transfer of biological information from DNA.

Content Category 1B: Transmission of genetic information from the gene to the protein

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		Nucleic Acid Structure and Function (BIO, OC, BC)* • Description • Nucleotides and nucleosides » Sugar phosphate backbone » Pyrimidine, purine residues • Deoxyribonucleic acid (DNA): double helix, Watson–Crick model of DNA structure • Base pairing specificity: A with T, G with C • Function in transmission of genetic information (BIO) • DNA denaturation, reannealing, hybridization	Ch. 3 Biological Macromolecules Ch. 14 DNA Structure and Function		Ch. 3 Nucleotides, Nucleic Acids, and Genetic Information, pp. 42-79 Ch. 23 Nucleotide Metabolism, pp. 803-830
		DNA Replication (BIO) • Mechanism of replication: separation of strands, specific coupling of free nucleic acids • Semiconservative nature of replication • Specific enzymes involved in replication • Origins of replication, multiple origins in eukaryotes • Replicating the ends of DNA molecules	Ch. 14 DNA Structure and Function		Ch. 25 DNA Replication, Repair and Recombination, pp. 879-937
		Repair of DNA (BIO) • Repair during replication • Repair of mutations	Ch. 14 DNA Structure and Function		Ch. 25 DNA Replication, Repair, and Recombination, pp. 909-915
		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)	Ch. 15 Genes and Proteins		Ch. 27 Protein Synthesis: Section 1, The Genetic Code, pp. 983-987

*If a chapter is listed in this row, the abbreviations apply to all sections listed below.

(continued)

Content Category 1B: Transmission of genetic information from the gene to the protein (continued)

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		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	Ch. 15 Genes and Proteins Ch. 16 Gene Expression		Ch. 26 Transcription and RNA processing, pp. 938-987
		Translation (BIO) • Roles of mRNA, tRNA, rRNA • Role and structure of ribosomes • Initiation, termination co-factors • Posttranslational modification of proteins	Ch. 15 Genes and Proteins		Ch. 27 Protein Synthesis: Section 4, Translation, pp. 1004-1023
		Eukaryotic Chromosome Organization (BIO) • Chromosomal proteins • Single copy vs repetitive DNA • Supercoiling • Heterochromatin vs euchromatin • Telomeres, centromeres	Ch. 15 Genes and Proteins		Ch. 24 Nucleic Acid Structure: Section 5, Eukaryotic Chromosome Structure, pp. 867-877
		Control of Gene Expression in Prokaryotes (BIO) • Operon Concept, Jacob-Monod Model • Gene repression in bacteria • Positive control in bacteria	Ch. 16 Gene Expression		Ch. 28 Regulation of Gene Expression: Section 2, Regulation of Prokaryotic Gene Expression, pp. 1043-1051

(continued)

Content Category 1B: Transmission of genetic information from the gene to the protein (continued)

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		Control of Gene Expression in Eukaryotes (BIO) • Transcriptional regulation • DNA binding proteins, transcription factors • Gene amplification and duplication • Posttranscriptional 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 noncoding RNAs	Ch. 16 Gene Expression		Ch. 28 Regulation of Gene Expression: Section 3, Regulation of Eukaryotic Gene Expression, pp. 1052-1079
		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	Ch. 17 Biotechnology and Genomics		Ch. 25 DNA Replication, Repair, and Recombination: Section 6, Recombination, pp. 916-937

Content Category 1C: Transmission of heritable information from generation to generation and the processes that increase genetic diversity

The information necessary to direct life functions is contained within discrete nucleotide sequences transmitted from generation to generation by mechanisms that, by nature of their various processes, provide the raw materials for evolution by increasing genetic diversity. Specific sequences of deoxyribonucleic acids store and transfer the heritable information necessary for the continuation of life from one generation to the next. These sequences, called genes—being part of longer DNA molecules—are organized, along with various proteins, into biomolecular assemblies called chromosomes.

Chromosomes pass from parents to offspring in sexually-reproducing organisms. The processes of meiosis and fertilization maintain a species' chromosomes count during the sexual life cycle. Because parents pass on discrete heritable units that retain their separate identities in offspring, the laws of probability can be used to predict the outcome of some, but not all, genetic crosses.

The behavior of chromosomes during meiosis and fertilization is responsible for most of the genetic variation that arises each generation. Mechanisms that contribute to this genetic variation include independent assortment of chromosomes, crossing over, and random fertilization. Other mechanisms, such as mutation, random genetic drift, bottlenecks, and immigration, exist with the potential to affect the genetic diversity of individuals and populations. Collectively, the genetic diversity that results from these processes provides the raw material for evolution by natural selection.

The content in this category covers the mechanisms by which heritable information is transmitted from generation to generation, and the evolutionary processes that generate and act upon genetic variation.

Content Category 1C: Transmission of heritable information from generation to generation and the processes that increase genetic diversity

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		Evidence that DNA is Genetic Material (BIO)			Ch. 3 Nucleotides, Nucleic Acids, and Genetic Information: Section 3, Overview of Nucleic Acid Function, pp. 50-53
		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	Ch. 12 Mendel's Experiments and Heredity	Ch. 28 Reproduction, Chromosomes, and Meiosis	

(continued)

Content Category 1C: Transmission of heritable information from generation to generation and the processes that increase genetic diversity (continued)

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		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 or 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	Ch. 11 Meiosis and Sexual Reproduction	Ch. 28 Reproduction, Chromosomes, and Meiosis	Ch. 25 DNA Replication, Repair, and Recombination, pp. 879-937

(continued)

Content Category 1C: Transmission of heritable information from generation to generation and the processes that increase genetic diversity (continued)

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		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	Ch. 18 Evolution and the Origin of Species		Ch. 1 Introduction to the Chemistry of Life, pp. 1-22
		Principles of Bioenergetics (BC, GC) • Bioenergetics and thermodynamics » Free energy/Keq ▪ Equilibrium constant ▪ Relationship between the equilibrium constant and ΔG° » Concentration ▪ Le Châtelier's Principle » Endothermic and exothermic reactions » Free energy: G ▪ Spontaneous reactions and ΔG° • Phosphoryl group transfers and ATP » ATP hydrolysis ΔG << 0 » ATP group transfers • Biological oxidation-reduction » Half-reactions » Soluble electron carriers » Flavoproteins			Ch. 12 Enzyme Kinetics, Inhibition, and Control, pp. 361-401

(continued)

Content Category 1C: Transmission of heritable information from generation to generation and the processes that increase genetic diversity (continued)

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		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			Ch. 8 Carbohydrates, pp. 221-244

Content Category 1D: Principles of bioenergetics and fuel molecule metabolism

Living things harness energy from fuel molecules in a controlled manner in order to sustain all of the processes responsible for maintaining life. Cell maintenance and growth is energetically costly. Cells harness the energy stored in fuel molecules, such as carbohydrates and fatty acids, and convert it into smaller units of chemical potential known as adenosine triphosphate (ATP).

The hydrolysis of ATP provides a ready source of energy for cells that can be coupled to other chemical processes in order to make them thermodynamically favorable. Fuel molecule mobilization, transport, and storage are regulated according to the needs of the organism.

The content in this category covers the principles of bioenergetics and fuel molecule catabolism. Details of oxidative phosphorylation including the role of chemiosmotic coupling and biological electron transfer reactions are covered, as are the general features of fatty acid and glucose metabolism. Additionally, regulation of these metabolic pathways, fuel molecule mobilization, transport, and storage are covered.

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		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	Ch. 7 Cellular Respiration	Ch. 23 Nutrition Metabolism and Temperature Regulation	Ch. 14 Introduction to Metabolism, pp. 442-477 Ch. 15 Glucose Catabolism, pp. 448-522
		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	Ch. 6 Metabolism Ch. 7 Cellular Respiration	Ch. 23 Nutrition Metabolism and Temperature Regulation	Ch. 14 Introduction to Metabolism, pp. 442-477 Ch. 15 Glucose Catabolism, pp. 448-522 Ch.16 Glycogen Metabolism and Gluconeogenesis

*If a chapter is listed in this row, the abbreviations apply to all sections listed below.

(continued)

Content Category 1D: Principles of bioenergetics and fuel molecule metabolism (continued)

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		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	Ch. 7 Cellular Respiration	Ch. 23 Nutrition Metabolism and Temperature Regulation	Ch. 17 Citric Acid Cycle, pp. 558-587
		Metabolism of Fatty Acids and Proteins (BIO, BC)* • Description of fatty acids (BC) • Digestion, mobilization, and transport of fats • Oxidation of fatty acids » Saturated fats » Unsaturated fats • Ketone bodies (BC) • Anabolism of fats (BIO) • Nontemplate synthesis: biosynthesis of lipids and polysaccharides (BIO) • Metabolism of proteins (BIO)		Ch. 23 Nutrition Metabolism and Temperature Regulation	Ch. 14 Introduction to Metabolism, p. 442-477
		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)	Ch. 7 Cellular Respiration		Ch. 14 Introduction to Metabolism, pp. 442-477

*If a chapter is listed in this row, the abbreviations apply to all sections listed below.

(continued)

Content Category 1D: Principles of bioenergetics and fuel molecule metabolism (continued)

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		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			Ch. 14 Introduction to Metabolism, pp. 442-477 Ch. 15 Glucose Catabolism, pp. 448-522 Ch.16 Glycogen Metabolism and Gluconeogenesis, pp. 523-557

Foundational Concept 2: Highly-organized assemblies of molecules, cells, and organs interact to carry out the functions of living organisms.

Content Category 2A: Assemblies of molecules, cells, and groups of cells within singlecellular and multicellular organisms

The processes necessary to maintain life are executed by assemblies of molecules, cells, and groups of cells, all of which are organized into highly-specific structures as determined by the unique properties of their component molecules. The processes necessary to maintain life require that cells create and maintain internal environments within the cytoplasm and within certain organelles that are different from their external environments.

Cell membranes separate the internal environment of the cell from the external environment. The specialized structure of the membrane, as described in the fluid mosaic model, allows the cell to be selectively permeable and dynamic, with homeostasis maintained by the constant movement of molecules across the membranes through a combination of active and passive processes driven by several forces, including electrochemical gradients.

Eukaryotic cells also maintain internal membranes that partition the cell into specialized regions. These internal membranes facilitate cellular processes by minimizing conflicting interactions and increasing surface area where chemical reactions can occur. Membrane-bound organelles localize different processes or enzymatic reactions in time and space.

Through interactions between proteins bound to the membranes of adjacent cells, or between membrane-bound proteins and elements of the extracellular matrix, cells of multicellular organisms organize into tissues, organs, and organ systems. Certain membrane-associated proteins also play key roles in providing identification of tissues or recent events in the cell's history for purposes of recognition of "self" versus foreign molecules.

The content in this category covers the composition, structure, and function of cell membranes; the structure and function of the membrane-bound organelles of eukaryotic cells; and the structure and function of the major cytoskeletal elements. It covers the energetics of and mechanisms by which molecules, or groups of molecules, move across cell membranes. It also covers how cell–cell junctions and the extracellular matrix interact to form tissues with specialized functions. Epithelial tissue and connective tissue are covered in this category.

Content Category 2A: Assemblies of molecules, cells, and groups of cells within singlecellular and multicellular organisms

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		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	Ch. 5 Structure and Function of Plasma Membranes	Ch. 4 Tissues	Ch. 9 Lipids and Biological Membranes, pp. 245-292 Ch. 10 Membrane Transport, pp. 293-321

*If a chapter is listed in this row, the abbreviations apply to all sections listed below.

(continued)

Content Category 2A: Assemblies of molecules, cells, and groups of cells within singlecellular and multicellular organisms (continued)

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		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	Ch. 4 Cell Structure		Ch. 9 Lipids and Biological Membranes, pp. 245-292 Ch.10 Membrane Transport, pp. 293-321 Ch. 11 Enzymatic Catalysis, pp. 322-360
		Cytoskeleton (BIO) • General function in cell support and movement • Microfilaments: composition and 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	Ch. 4 Cell Structure		Ch. 1 Introduction to the Chemistry of Life, pp. 1-22

*If a chapter is listed in this row, the abbreviations apply to all sections listed below.

(continued)

Content Category 2A: Assemblies of molecules, cells, and groups of cells within singlecellular and multicellular organisms (continued)

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		Tissues Formed From Eukaryotic Cells (BIO) • Epithelial cells • Connective tissue cells			Ch. 7 Protein Function: Myoglobin and Hemoglobin, Muscle Contraction, and Antibodies: Section 2, Muscle Contraction, pp. 200-201

Content Category 2B: The structure, growth, physiology, and genetics of prokaryotes and viruses

The highly-organized assembly of molecules that is the cell represents the fundamental unit of structure, function, and organization in all living organisms. In the hierarchy of biological organization, the cell is the simplest collection of matter capable of carrying out the processes that distinguish living organisms. As such, cells have the ability to undergo metabolism; maintain homeostasis, including ionic gradients; the capacity to grow; move in response to their local environments; respond to stimuli; reproduce; and adapt to their environment in successive generations.

Life at cellular levels arises from structural order, and its dynamic modulation. It does so in response to signals, thereby reflecting properties that result from individual and interactive features of molecular assemblies, their compartmentalization, and their interaction with environmental signals at many spatial and temporal scales.

The content in this category covers the classification, structure, growth, physiology, and genetics of prokaryotes, and the characteristics that distinguish them from eukaryotes. Viruses are also covered here.

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		Cell Theory (BIO) • History and development • Impact on biology	Ch. 4 Cell Structure		Ch. 1 Introduction to the Chemistry of Life, pp. 1-22
		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) • Lack of nuclear membrane and mitotic apparatus • Lack of typical eukaryotic organelles • Presence of cell wall in bacteria • Flagellar propulsion, mechanism	Ch. 4 Cell Structure		Ch. 1 Introduction to the Chemistry of Life, pp. 1-22

(continued)

Content Category 2B: The structure, growth, physiology, and genetics of prokaryotes and viruses (continued)

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		Growth and Physiology of Prokaryotic Cells (BIO) • Reproduction by fission • High degree of genetic adaptability, acquisition of antibiotic resistance • Exponential growth • Existence of anaerobic and aerobic variants • Parasitic and symbiotic • Chemotaxis	Ch. 22 Prokaryotes: Bacteria and Archaea		Ch. 22 Mammalian Fuel Metabolism: Integration and Regulation, p. 77
		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)	Ch. 22 Prokaryotes: Bacteria and Archaea		Ch. 1 Introduction to the Chemistry of Life, pp. 1-22
		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	Ch. 21 Viruses		
		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	Ch. 21 Viruses		

Content Category 2C: Processes of cell division, differentiation, and specialization

The ability of organisms to reproduce their own kind is the characteristic that best distinguishes living things. In sexually reproducing organisms, the continuity of life is based on the processes of cell division and meiosis.

The process of cell division is an integral part of the cell cycle. The progress of eukaryotic cells through the cell cycle is regulated by a complex molecular control system. Malfunctions in this system can result in unabated cellular division, and ultimately the development of cancer.

In the embryonic development of multicellular organisms, a fertilized egg gives rise to cells that differentiate into many different types of cells, each with a different structure, corresponding function, and location within the organism. During development, spatial-temporal gradients in the interactions between gene expression and various stimuli result in the structural and functional divergence of cells into specialized structure, organs, and tissues. The interaction of stimuli and genes is also explained by the progression of stem cells to terminal cells.

The content in this category covers the cell cycle; the causes, genetics, and basic properties of cancer; the processes of meiosis and gametogenesis; and the mechanisms governing cell specialization and differentiation.

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		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	Ch. 10 Cell Reproduction		
		Biosignalling (BC) • Oncogenes, apoptosis			Ch. 13 Biochemical Signaling, pp. 402-441

(continued)

Content Category 2C: Processes of cell division, differentiation, and specialization (continued)

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		Reproductive System (BIO) • Gametogenesis by meiosis • Ovum and sperm » Differences in formation » Differences in morphology » Relative contribution to next generation • Reproductive sequence: fertilization; implantation; development; birth	Ch. 43 Animal Reproduction and Development	Ch. 26 The Reproductive System	
		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	Ch. 43 Animal Reproduction and Development	Ch. 27 Human Development and Pregnancy	

Foundational Concept 3: Complex systems of tissues and organs sense the internal and external environments of multicellular organisms, and through integrated functioning, maintain a stable internal environment within an ever-changing external environment.

Content Category 3A: Structure and functions of the nervous and endocrine systems and ways these systems coordinate the organ systems

The nervous and endocrine systems work together to detect external and internal signals, transmit and integrate information, and maintain homeostasis. They do all of this by producing appropriate responses to internal and external cues and stressors. The integration of these systems both with one another, and with the other organ systems, ultimately results in the successful and adaptive behaviors that allow for the propagation of the species.

Animals have evolved a nervous system that senses and processes internal and external information that is used to facilitate and enhance survival, growth, and reproduction. The nervous system interfaces with sensory and internal body systems to coordinate physiological and behavioral responses ranging from simple movements and small metabolic changes to long-distance migrations and social interactions. The physiological processes for nerve signal generation and propagation involve specialized membranes with associated proteins that respond to ligands and/or electrical field changes, signaling molecules and, by extension, the establishment and replenishment of ionic electrochemical gradients requiring ATP.

The endocrine system of animals has evolved to produce chemical signals that function internally to regulate stress responses, reproduction, development, energy metabolism, growth, and various individual and interactive behaviors. The integrated contributions of the nervous and endocrine systems to bodily functions are exemplified by the process whereby the signaling of neurons regulates hormone release, and by the targeting of membrane or nuclear receptors on neurons by circulating hormones.

The content in this category covers the structure, function, and basic aspects of nervous and endocrine systems, and their integration. The structure and function of nerve cells is also included in this category.

Content Category 3A: Structure and functions of the nervous and endocrine systems and ways these systems coordinate the organ systems

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		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	Ch. 35 The Nervous System	Ch. 10 Nervous Tissue	
		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	Ch. 35 The Nervous System	Ch. 10 Nervous Tissue	

(continued)

Content Category 3A: Structure and functions of the nervous and endocrine systems and ways these systems coordinate the organ systems (continued)

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		Biosignalling (BC) • Gated ion channels » Voltage-gated » Ligand-gated • Receptor enzymes • G protein–coupled receptors	Ch. 35 The Nervous System	Ch. 10 Nervous Tissue	Ch. 13 Biochemical Signaling, pp. 402-441
		Lipids (BC, OC) • Description, structure » Steroids » Terpenes and terpenoids	Ch. 3 Biological Macromolecules		Ch. 9 Lipids and Biological Membranes, pp. 245-292
		Endocrine System: Hormones and Their Sources (BIO) • Function of endocrine system: specific chemical control at cell, tissue, and organ levels • Definitions of endocrine gland, hormone • Major endocrine glands: names, locations, products • Major types of hormones • Neuroendrocrinology–relation between neurons and hormonal systems	Ch. 37 The Endocrine System	Ch. 15 The Endocrine System	
		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	Ch. 37 The Endocrine System	Ch. 15 The Endocrine System	Ch. 22 Mammalian Fuel Metabolism: Integration and Regulation: Section 2, Hormonal Control of Fuel Metabolism, pp. 781-785

Content Category 3B: Structure and integrative functions of the main organ systems

Animals use a number of highly-organized and integrated organ systems to carry out the necessary functions associated with maintaining life processes. Within the body, no organ system is an island. Interactions and coordination between organ systems allow organisms to engage in the processes necessary to sustain life. For example, the organs and structures of the circulatory system carry out a number of functions, such as transporting:

- nutrients absorbed in the digestive system;
- gases absorbed from the respiratory system and muscle tissue;
- hormones secreted from the endocrine system; and
- blood cells produced in bone marrow to and from cells in the body to help fight disease.

The content in this category covers the structure and function of the major organ systems of the body including the respiratory, circulatory, lymphatic, immune, digestive, excretory, reproductive, muscle, skeletal, and skin systems. Also covered in this category is the integration of these systems and their control and coordination by the endocrine and nervous systems.

Category 3B: Structure and integrative functions of the main organ systems

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		Respiratory 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	Ch. 39 The Respiratory System	Ch. 21 The Respiratory System	

(continued)

Category 3B: Structure and integrative functions of the main organ systems (continued)

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		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 • Composition of blood » Plasma, chemicals, blood cells » Erythrocyte production and destruction; spleen, bone marrow » Regulation of plasma volume • Coagulation, clotting mechanisms • Oxygen transport by blood » Hemoglobin, hematocrit » Oxygen content » Oxygen affinity » Modification of oxygen affinity • Carbon dioxide transport and level in blood • Nervous and endocrine control	Ch. 40 The Circulatory System	Ch. 16 Blood Ch. 17 The Cardiovascular System Ch. 18 The Cardiovascular System: The Blood vessels	

(continued)

Category 3B: Structure and integrative functions of the main organ systems (continued)

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		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		Ch. 19 The Lymphatic System	
		Immune System (BIO) • Innate (nonspecific) v. adaptive (specific) immunity • Adaptive immune system cells » T-lymphocytes » B-lymphocytes • Innate immune system cells » Macrophages » Phagocytes • Tissue » Bone marrow » Spleen » Thymus » Lymph nodes • Concept of antigen and antibody • Antigen presentation • Clonal selection • Antigen-antibody recognition • Structure of antibody molecule • Recognition of self vs nonself, autoimmune diseases • Major histocompatibility complex	Ch. 42 The Immune System	Ch. 20 The Immune System	

(continued)

Category 3B: Structure and integrative functions of the main organ systems (continued)

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		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	Ch. 34 The Digestive System	Ch. 22 The Digestive System	

(continued)

Category 3B: Structure and integrative functions of the main organ systems (continued)

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		Excretory System (BIO) • Roles in homeostasis » Blood pressure » Osmoregulation » Acid-base balance » 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	Ch. 41 Osmotic Regulation and the Excretory System	Ch. 24 The Urinary 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 » Integration with nervous control	Ch. 43 Animal Reproduction and Development	Ch. 26 The Reproductive System	

(continued)

Category 3B: Structure and integrative functions of the main organ systems (continued)

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		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	Ch. 38 The Musculoskeletal System	Ch. 9 The Muscular System	
		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		Ch. 9 The Muscular System	

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Category 3B: Structure and integrative functions of the main organ systems (continued)

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		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	Ch. 38 The Musculoskeletal System	Ch. 7 The Skeletal System Ch. 8 Joints	
		Skin System (BIO) • Structure » Layer differentiation, cell types » 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, vasoconstriction		Ch. 5 The Integumentary System	

Foundational Concept 4: Complex living organisms transport materials, sense their environment, process signals, and respond to changes using processes that can be understood in terms of physical principles.

Content Category 4B: Importance of fluids for the circulation of blood, gas movement, and gas exchange

Fluids are featured in several physiologically important processes, including the circulation of blood, gas movement into and out of the lungs, and gas exchange into the blood. The energetic requirements of fluid dynamics can be modeled using physical equations. A thorough understanding of fluids is necessary to understand the origins of numerous forms of disease.

The content in this category covers hydrostatic pressure, fluid flow rates, viscosity, the Kinetic Molecular Theory of Gases, and the Ideal Gas Law.

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		Circulatory System (BIO) • Arterial and venous systems; pressure and flow characteristics	Ch. 40 The Circulatory System		

Foundational Concept 5: The principles that govern chemical interactions and reactions form the basis for a broader understanding of the molecular dynamics of living systems.

Content Category 5A: Unique nature of water and its solutions

In order to fully understand the complex and dynamic nature of living systems, it is first necessary to understand the unique nature of water and its solutions. The unique properties of water allow it to strongly interact with and mobilize many types of solutes, including ions. Water is also unique in its ability to absorb energy and buffer living systems from the chemical changes necessary to sustain life.

The content in this category covers the nature of solutions, solubility, acids, bases, and buffers.

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		Acid/Base Equilibria (GC, BC) • Bronsted-Lowry definition of acid, base • Ionization of water » K_w, its approximate value ($K_w = [H^+][OH^-] = 10^{-14}$ at 25°C, 1 atm) » Definition of pH: pH of pure water • Conjugate acids and bases (e.g., NH_4^+ and NH_3) • 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 K_a and K_b: pK_a, pK_b • Buffers » Definition and concepts (common buffer systems) » Influence on titration curves			Ch. 2 Water: Section 2, Chemical Properties of Water, pp. 31-40
		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			Ch. 2 Water: Section 2, Chemical Properties of Water, pp. 31-40

Content Category 5C: Separation and purification methods

Analysis of complex mixtures of substances—especially biologically relevant materials—typically requires separation of the components. Many methods have been developed to accomplish this task, and the method used is dependent on the types of substances which comprise the mixture. All of these methods rely on the magnification of potential differences in the strength of intermolecular interactions.

The content in this category covers separation and purification methods including: extraction, liquid and gas chromatography, and electrophoresis.

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		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-layer chromatography • Separation and purification of peptides and proteins (BC) » Electrophoresis » Quantitative analysis » Chromatography ▪ Size-exclusion ▪ Ion-exchange ▪ Affinity • Racemic mixtures, separation of enantiomers (OC)			Ch. 5 Proteins: Primary Structure: Section 2, Protein Purification and Analysis, pp. 99-108

*If a chapter is listed in this row, the abbreviations apply to all sections listed below.

Content Category 5D: Structure, function, and reactivity of biologically-relevant molecules

The structure of biological molecules forms the basis of their chemical reactions including oligomerization and polymerization. Unique aspects of each type of biological molecule dictate their role in living systems, whether providing structure or information storage, or serving as fuel and catalysts.

The content in this category covers the structure, function, and reactivity of biologically-relevant molecules including the mechanistic considerations that dictate their modes of reactivity.

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		Nucleotides and Nucleic Acids (OC, BC, BIO)* • Nucleotides and nucleosides: composition » Sugar phosphate backbone » Pyrimidine, purine residues • Deoxyribonucleic acid: DNA; double helix • Chemistry (OC, BC) • Other functions (OC, BC)	Ch. 3 Biological Macromolecules		Ch. 3 Nucleotides, Nucleic Acids, and Genetic Information, pp. 42-79
		Amino Acids, Peptides, Proteins (OC, BC)* • Amino acids: description » Absolute configuration at the α position » Dipolar ions » Classification ▪ Acidic or basic ▪ Hydrophilic or hydrophobic » Synthesis of α-amino acids (OC) ▪ Strecker Synthesis ▪ Gabriel Synthesis • Peptides and proteins: reactions » Sulfur linkage between a pair of cysteines » Peptide linkage: polypeptides and proteins » Hydrolysis • General Principles ▪ 1° structure of proteins ▪ 2° structure of proteins ▪ 3° structure of proteins ▪ Isoelectric point	Ch. 3 Biological Macromolecules		Ch. 4 Amino Acids, pp. 80-96

*If a chapter is listed in this row, the abbreviations apply to all sections listed below.

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Content Category 5D: Structure, function, and reactivity of biologically-relevant molecules (continued)

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		The Three-Dimensional Protein Structure (BC) • Conformational stability » Hydrophobic interactions » Solvation layer (entropy) • 4° structure • Denaturing and folding	Ch. 3 Biological Macromolecules		Ch. 6 Proteins: Three-Dimensional Structure, pp. 131-179
		Nonenzymatic Protein Function (BC) • Binding • Immune system • Motor	Ch. 3 Biological Macromolecules		Ch. 7 Protein Function: Myoglobin and Hemoglobin, Muscle Contraction and Antibodies, pp. 180-220
		Lipids (BC, OC)* • Types • Storage » Triacyl glycerols » Free fatty acids: saponification • Structural » Phospholipids and phosphatids » Sphingolipids » Waxes • Signals, cofactors » Fat-soluble vitamins » Steroids » Prostaglandins	Ch. 3 Biological Macromolecules		Ch. 9 Lipids and Biological Membranes, pp. 245-292

*If a chapter is listed in this row, the abbreviations apply to all sections listed below.

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Content Category 5D: Structure, function, and reactivity of biologically-relevant molecules (continued)

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		Carbohydrates (OC)* • Description » Nomenclature and classification, common names » Absolute configuration » Cyclic structure and conformations of hexoses » Epimers and anomers • Hydrolysis of the glycoside linkage • Keto-enol tautomerism of monosaccharides • Disaccharides (BC) • Polysaccharides (BC)	Ch. 3 Biological Macromolecules		Ch. 8 Carbohydrates, pp. 221-245
		Phenols (OC, BC) • Oxidation and reduction (e.g., hydroquinones), ubiquinones: biological 2e– redox centers			Ch.14 Introduction to Metabolism: Section 3, Oxidation–Reduction Reactions, pp. 461-466
		Polycyclic and Heterocyclic Aromatic Compounds (OC, BC) • Biological aromatic heterocycles			Ch. 3 Nucleotides, Nucleic Acids and Genetic Information: Section 1, Nucleotides, pp. 43

*If a chapter is listed in this row, the abbreviations apply to all sections listed below.

Content Category 5E: Principles of chemical thermodynamics and kinetics

The processes that occur in living systems are dynamic, and they follow the principles of chemical thermo-dynamics and kinetics. The position of chemical equilibrium is dictated by the relative energies of products and reactants. The rate at which chemical equilibrium is attained is dictated by a variety of factors: concentration of reactants, temperature, and the amount of catalyst (if any).

Biological systems have evolved to harness energy, and utilize it in very efficient ways to support all processes of life, including homeostasis and anabolism. Biological catalysts, known as enzymes, have evolved to allow all of the relevant chemical reactions required to sustain life to occur both rapidly and efficiently, and under the narrow set of conditions required.

The content in this category covers all principles of chemical thermodynamics and kinetics including enzymatic catalysis.

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		Enzymes (BC, BIO) • Classification by reaction type • Mechanism » Substrates and enzyme specificity » Active-site model » Induced-fit model » Cofactors, coenzymes, and vitamins • Kinetics » General (catalysis) » Michaelis-Menten » Cooperativity » Effects of local conditions on enzyme activity • Inhibition • Regulatory enzymes » Allosteric » Covalently modified	Ch. 6 Metabolism		Ch. 17 Enzyme Kinetics, Inhibition, and Control, pp. 346-401

(continued)

Content Category 5E: Principles of chemical thermodynamics and kinetics (continued)

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		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			Ch. 18 Electron Transport and Oxidative Phosphorylation, pp. 588-629

Foundational Concept 6: Biological, psychological, and socio-cultural factors influence the ways that individuals perceive, think about, and react to the world.

Content Category 6A: Sensing the environment

Psychological, socio-cultural, and biological factors affect sensation and perception of the world. All sensory processing begins with first detecting a stimulus in the environment through sensory cells, receptors, and biological pathways.

After collecting sensory information, we then interpret and make sense of it. Although sensation and perception are distinct functions, they are both influenced by psychological, social, and biological factors and therefore become almost indistinguishable in practice. This complexity is illuminated by examining human sight, hearing, touch, taste, and smell.

The content in this category covers sensation and perception across all five human senses.

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		Sensory Processing (PSY, BIO)* • Sensation » Thresholds » Weber's Law (PSY) » Signal-detection theory (PSY) » Sensory adaptation • Sensory receptors » Sensory pathways » Types of sensory receptors	Ch. 36 Sensory Systems		
		Vision (PSY, BIO)* • Structure and function of the eye • Visual processing » Visual pathways in the brain » Parallel processing (PSY) » Feature detection (PSY)	Ch. 36 Sensory Systems	Ch. 13 Special Senses	

*If a chapter is listed in this row, the abbreviations apply to all sections listed below.

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Content Category 6A: Sensing the environment (continued)

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		Hearing (PSY, BIO)* • Auditory processing » Auditory pathways in the brain • Sensory reception by hair cells (PSY)	Ch. 36 Sensory Systems	Ch. 13 Special Senses	
		Other Senses (PSY, BIO)* • Somatosensation » Pain perception (PSY) • Taste » 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	Ch. 36 Sensory Systems	Ch. 13 Special Senses	

*If a chapter is listed in this row, the abbreviations apply to all sections listed below.

Foundational Concept 7: Biological, psychological, and socio-cultural factors influence behavior and behavior change.

Content Category 7A: Individual influences on behavior

A complex interplay of psychological and biological factors shapes behavior. Biological structures and processes serve as the pathway by which bodies carry out activities. They also affect predispositions to behave in certain ways, shape personalities, and influence the likelihood of developing psychological disorders. Psychological factors also affect behavior, and consequently, health and well-being.

The content in this category covers biological bases of behavior, including the effect of genetics and how the nervous and endocrine systems affect behavior. It also addresses how personality, psychological disorders, motivation, and attitudes affect behavior. Some of these topics are learned in the context of non-human animal species.

Content Category 7A: Individual influences on behavior

Intro Bio	1st-Semester Biochem	Topic	*Boundless Biology*	*Boundless Physiology*	*Fundamentals of Biochemistry*
		Biological Bases of Behavior (PSY, BIO)* • The nervous system » Neurons ▪ ~~The~~ reflex arc » Neurotransmitters » Peripheral nervous system » Central nervous system ▪ The brain ‣ The brainstem ‣ The cerebellum ‣ The diencephalon (BIO) ‣ The cerebrum ‣ Control of voluntary movement in the cerebral cortex ‣ Information processing in the cerebral cortex ‣ Lateralization of cortical functions • Neurons communicate and influence behavior (PSY) • Influence of Neurotransmitters on behavior (PSY) • The endocrine system » Components of the endocrine system » Effects of the endocrine system on behavior • Behavioral genetics • Genes, temperament, heredity • Adaptive value of traits and behaviors • Interaction between heredity and environmental influences • Genetic and environmental factors contribute to the development of behaviors » Experience and behavior (PSY) » Regulatory genes and behavior (BIO) » Genetically based behavioral variation in natural populations • Human physiological development (PSY) » Prenatal development » Motor development » Developmental changes in adolescence	Ch. 35 The Nervous System		

*If a chapter is listed in this row, the abbreviations apply to all sections listed below.