Unit 1 | Foundations of Cell Biology: Molecules, Macromolecules, and Chemical Energy

Chapter 1 Entering the Fascinating World of Cells

Module 1.1 Preparing for an Adventure

Lesson 1. An Introduction to Interactive Cell Biology

Lesson 2. Understanding the Past to Understand the Present

Lesson 3. Perspective is Everything

Lesson 4. What's in a Name?

Lesson 5. Appreciating Scale. Entering the World of Cells and Macromolecules

Lesson 6. The Continuity between the Cellular and Molecular Worlds

Module 1.2 An Introduction to Cells

Lesson 1. Bacteria and Archaea

Lesson 2. The Prokaryotic/Eukaryotic Classification System

Lesson 3. Prokaryotic Characteristics

Lesson 4. Eukaryote Characteristics

Lesson 5. Single-Celled Eukaryotes

Lesson 6. Our Journey through a Model Cell

Module 1.3 How We Know: Techniques in Cell Biology

Lesson 1. Examining Cells with Light and Fluorescence Microscopy

Lesson 2. Examining Subcellular Structures with Electron Microscopy

Lesson 3. Solving Molecular Structures with X-Ray Crystallography

Lesson 4. Segregating Cell and Molecular Components: Electrophoresis, Western Blotting, Chromotography, and Centrifugation (TBD)

Lesson 5. Genetic Manipulation: PCR and Cloning (TBD)

Lesson 6. A Roadmap of Our Journey Ahead

THE HUMAN CONNECTION Seeing inside a Cell

Chapter 2 The Building Blocks of Cells: Molecules and Macromolecules

Module 2.1 Carbon Backbones and Functional Side Groups

Lesson 1. Carbon: The Molecular Backbone

Lesson 2. Functional Groups

Lesson 3. Biological Molecules

Module 2.2 The Four Categories of Biological Molecules

Lesson 1. Carbohydrates

Lesson 2. Nucleotides

Lesson 3. Amino Acids

Lesson 4. Lipids

Module 2.3 Macromolecules and Macromolecular-Like Structures

Lesson 1. Introduction to Macromolecules

Lesson 2. From Carbohydrates to Polysaccharides

Lesson 3. From Nucleotides to Nucleic Acids

Lesson 4. From Amino Acids to Proteins

Lesson 5. From Lipids to Lipid Membranes

THE HUMAN CONNECTION Essential Nutrients
Chapter 3 A Closer Look at DNA and Proteins
Module 3.1 DNA Structure
Lesson 1. DNA Is Polar and Antiparallel
Lesson 2. The Nitrogenous Bases
Lesson 3. Complementary Base Pairing
Lesson 4. The Double Helix
Lesson 5. DNA Major and Minor Grooves
Module 3.2 Protein Structure
Lesson 1. The Four Hierarchical Levels of Protein Structure
Lesson 2. Primary Structure
Lesson 3. Secondary Structure: α-Helices
Lesson 4. Secondary Structure: β-Sheets
Lesson 5. Motifs and Domains
Lesson 6. Tertiary Structure
Lesson 7. Quaternary Structure
Module 3.3 Protein Function
Lesson 1. Proteins Are Molecular Machines
Lesson 2. Proteins Function by Undergoing Conformational Changes
Lesson 3. Inducing Conformational Change
Lesson 4. Protein Binding Affinity
Lesson 5. Regulating Protein Activity with On/Off Switches

Lesson 6. Regulating Protein Activity with Timed Switches
THE HUMAN CONNECTION Huntington's Disease
Chapter 4 Lipid Membranes and Cell Compartmentalization
Module 4.1 Lipid Membrane Structure
Lesson 1. Lipid Membranes Compartmentalize Biological Solutions
Lesson 2. Phospholipid Structure
Lesson 3. Hydrophobic Interactions Explained
Lesson 4. Micelles and Liposomes
Lesson 5. A Hydrophobic Barrier
Module 4.2 Membrane Protein Structure
Lesson 1. Protein Control of Phospholipid Bilayers
Lesson 2. Integral and Peripheral Membrane Proteins
Lesson 3. Transmembrane Proteins
Lesson 4. Transmembrane Domains
Lesson 5. Examples of Transmembran Proteins
Lesson 6. Stuck in the Middle
Lesson 7. Membrane Proteins Can Shape Lipid Membranes
Module 4.3 The Fluid Mosiac Nature of Lipid Membranes
Lesson 1. The Two-Dimensional Fluidity of Lipid Membranes
Lesson 2. Regulating Membrane Fluidity
Lesson 3. Asymmentry in Lipid Membranes
Lesson 4. Lipid Rafts
Module 4.4 Protein-Based Compartmentalization
Lesson 1. Biomolecular Condensates
Lesson 2. Bacterial Microcompartments
THE HUMAN CONNECTION Lyme Disease Bacterium
Chapter 5 Cells Are Powered by Chemical Energy
Module 5.1 Chemical Energy Explained
Lesson 1. Follow the Energy: A Straight Path through the Macromolecular Web

Lesson 2. Electron Tug-of-War and Chemical Potential Energy
Lesson 3. Electronegativity: Who Wants It More?
Lesson 4. High-Energy and Low-Energy Covalent Bonds
Lesson 5. From Tug-of-War to Ball and Cliff
Lesson 6. From Potential to Kinetic and Back Again
Module 5.2 Releasing Chemical Energy with Enzyme Catalysts
Lesson 1. Activate before Use
Lesson 2. Sources of Activation Energy
Lesson 3. Enzymes Catalyze Chemical Reactions
Module 5.3 Using Chemical Energy: ATP Hydrolysis
Lesson 1. From Sunlight to Glucose to ATP
Lesson 2. ATPase Enzymes Are Powered by ATP Hydrolysis
Lesson 3. Setting the Stage for ATP Hydrolysis
Lesson 4. ATP Hydrolysis Powers Molecular Movement
Lesson 5. Most ATP Is Used to Build Proteins
Module 5.3 From ATP to Everything Else
Lesson 1. Webs of Energy Flow and Chemical Reactions
Lesson 2. From ATPases to Enzymes to All Cellular Proteins
THE HUMAN CONNECTION Leigh Syndrome
Unit 2 | The Functional Backbone: From the Nucleolus to the Endomembrane System
Chapter 6 Ancient Ribosomes: The Nucleolus, Nucleus, and Nucleic Acids (DNA and RNA)
Module 6.1 Looking through the Lens of Evolution
Lesson 1. Protein Production: The Functional Backbone of a Cell
Lesson 2. Getting to the Center of the Central Dogma
Lesson 3. Where to Begin, the Chicken or the Egg?
Lesson 4. Evolution Holds the Answer
Module 6.2 Life Began in the Heart of a Ribosome
Lesson 1. All Cellular Function Revolves Around Ribosomes
Lesson 2. Following the Evidence to the Ribosomal Core
Lesson 3. The rRNA Core: A Window into the Past
Lesson 4. The Evolution of the Ribosome

Lesson 5. Ancient RNA Relics Persist Today
Module 6.3 The Nucleolus: Our Starting Point
Lesson 1. Our Journey Begins!
Lesson 2. Clusters and Copies of rDNA
Lesson 3. rRNA Transcription and Processing
Lesson 4. Nucleolar Christmas Trees
Lesson 5. Nucleolar Subcompartments
Module 6.4 The Nucleus: DNA and Chromosomes
Lesson 1. The Nucleoplasm and Chromosomes
Lesson 2. Nucleosomes: The First Level of DNA Packaging
Lesson 3. Higher-Level DNA Packaging
Lesson 4. Histone Modifications Control DNA Packaging
Lesson 5. The Fully Condensed Chromosome
Lesson 6. The Nuclear Envelope
THE HUMAN CONNECTION Ribosomopahies and Diamond-Blackfan Anemia (DBA)
Chapter 7 From DNA to mRNA: Transcribing the Code of Life
Module 7.1 An Overview of Transcription
Lesson 1. Setting the Stage for Transcription and Translation
Lesson 2. RNA Polymerase Binding and Transcription Bubble Formation
Lesson 3. mRNA Polymerization
Lesson 4. The mRNA Product
Module 7.2 Transcription in Bacteria
Lesson 1. Transcription Initiation
Lesson 2. Open Complex Formation
Lesson 3. Transcription Elongation
Lesson 4. Intrinsic Termination
Lesson 5. Rho-Dependent Termination
Module 7.3 Differences between Bacterial, Archaeal, and Eukaryotic Transcription
Lesson 1. RNA Polymerases
Lesson 2. Initiation Factors
Lesson 3. DNA Packaging

Lesson 4. Polycistronic mRNA and Intron Splicing
Lesson 5. Termination and mRNA Processing
Module 7.4 Transcription in Eukaryotes
Lesson 1. Promoters Recruit General Transcription Factors
Lesson 2. TFIID, TFIIA, and TFIIB
Lesson 3. RNA Polymerase II, TFIIF, TFIIE, TFIIH, and Mediator
Lesson 4. Open Complex Formation and Phosphorylation of the C-Terminal Tail of RNA Polymerase II
Lesson 5. Polymerase Escape and the NELF/DSIF Checkpoint
Lesson 6. Releasing Checkpoint Inhibition
THE HUMAN CONNECTION Drug Inhibitors of RNA Polymerase II
Chapter 8 From mRNA to Protein: Processing and Translating the Code of Life
Module 8.1 Eukaryotic mRNA Processing
Lesson 1. From Nascent Pre-mRNA to mRNA
Lesson 2. The 5’ Cap
Lesson 3. Capping Is a Three-Step Process
Lesson 4. Splicing Out the Introns
Lesson 5. The Spliceosome in Action
Lesson 6. 3’ Polyadenylation and Transcription Termination
Lesson 7. Exporting the mRNA to the Cytosol
Module 8.2 Setting the Stage for Translation
Lesson 1. From Abstract Code to Tangible Machine
Lesson 2. The Genetic Code
Lesson 3. Ribosome Structure
Lesson 4. The Ribosome Central Chamber
Lesson 5. tRNA Adaptors: From Nucleotides to Amino Acids
Module 8.3 Translation Initiation, Elongation, and Termination
Lesson 1. Bacterial, Archaeal, and Eukaryotic Translation
Lesson 2. Bacterial Translation Initiation
Lesson 3. Bacterial vs. Eukaryotic Translation Initiation

Lesson 4. Eukaryotic Translation Initiation
Lesson 5. Translation Elongation: Entering the A-Site
Lesson 6. Translation Elongation: Polymerization and Ratcheting
Lesson 7. Translation Termination
Lesson 8. Putting It All Together
THE HUMAN CONNECTION IPEX Syndrome and Polyadenylation
Chapter 9 The Regulation of Protein Production
Module 9.1 Regulation Is Necessary
Lesson 1. Different Proteins through Space and Time
Lesson 2. Regulation Is Dynamic
Lesson 3. To Transcribe or Not to Transcribe
Lesson 4. Transcription Factors
Module 9.2 Regulation of Transcription in Bacteria: The *lac* Operon
Lesson 1. It's All about Efficiency
Lesson 2. The *lac* Operon
Lesson 3. Glucose and Lactose: Four Possible Combinations
Lesson 4. Lactose Detection: The Repressor and the Operators
Lesson 5. Glucose Detection: The Catabolite Activator Protein (CAP)
Lesson 6. Summary of *lac* Operon Regulation
Module 9.3 Regulation of Protein Production in Eukaryotes
Lesson 1. Unpackage before Use: Chromatin Remodeling for Transcriptional Regulation
Lesson 2: Regulation at a Distance
Lesson 3. All for One and One for All
Lesson 4. Regulation of Alternative Splicing
Lesson 5. Regulation of Translation Initiation
Module 9.4 Degradation of mRNA and Protein
Lesson 1. The Balance between Production and Degradation
Lesson 2. Degrading mRNA from the Ends: Poly(A) Tail and 5’ Cap Integrity
Lesson 3. Degrading mRNA from Within: RNA Interference (RNAi) via RISC
Lesson 4. miRNA and siRNA Processing
Lesson 5. Differences between miRNA and siRNA

Lesson 6. Protein Degradation: The Proteasome
THE HUMAN CONNECTION Treatment of hATTR Amyloidosis with Patisiran
Chapter 10 Protein Trafficking through the Cytosol
Module 10.1 Introduction to Protein Trafficking
Lesson 1. From Production to Destination
Lesson 2. Proteins Are Targeted by Signal Sequences
Lesson 3. Introduction to Cytosolic Trafficking
Module 10.2 Trafficking into the Nucleus: Nucleocytoplasmic Transport
Lesson 1. The Nuclear Pore Complex (NPC)
Lesson 2. Nucleocytoplasmic Transport
Lesson 3. Nuclear Import and the Ran-GTP Cycle
Lesson 4. Nuclear Export and the Ran-GTP Cycle
Module 10.3 Trafficking to Mitochondria, Chloroplasts, and Peroxisomes
Lesson 1. Mitochondria and Chloroplasts Are Different from Other Organelles
Lesson 2. Trafficking to Mitochondria
Lesson 3. Trafficking to Chloroplasts
Lesson 4. Trafficking to Peroxisomes
THE HUMAN CONNECTION Niemann-Pick Type C Disease
Chapter 11 Protein Trafficking into the Endoplasmic Reticulum
Module 11.1 Introduction to the Endomembrane System
Lesson 1. The Endomembrane Environment
Lesson 2. Movement through the Endomembrane System
Lesson 3. All Aboard Golgi Airlines
Module 11.2 Entering the Rough ER and Endomembrane System
Lesson 1. Rough ER and Smooth ER
Lesson 2. The ER Signal Sequence, the Signal Recognition Particle (SRP), and the SRP Receptor
Lesson 3. Translating Soluble Proteins into the Rough ER
Lesson 4. Translating Transmembrane Proteins into the Rough ER
Module 11.3 Covalent Modifications in the Rough ER

Lesson 1. First Steps in the Rough ER: Covalent Modifications
Lesson 2. Disulfide Bond Formation
Lesson 3. Glycosylation
Lesson 4. Glycosylation Continued: Attaching the First Oligosaccharide
Module 11.4 Preparing for a Journey through the Endomembrane System
Lesson 1. Leaving the Rough ER: The First Checkpoint
Lesson 2. Checkpoints 2 to 5: Get Fixed or Die Trying
Lesson 3. Endomembranes are Asymmetrical
THE HUMAN CONNECTION SLC6A1 Epileptic Encephalopathy
Chapter 12 Protein Trafficking through the Endomembrane System
Module 12.1 Vesicle Budding and Fusion
Lesson 1. The Roadmap Ahead through the Endomembrane Trafficking System
Lesson 2. An Introduction to Vesicle Budding and Fusion
Lesson 3. Vesicle Formation and Coat Assembly
Lesson 4. Vesicle Budding and Coat Disassembly
Lesson 5. Vesicle Docking and Fusion
Lesson 6. v-SNARE Recycling: Setting up for the Next Fusion
Module 12.2 Trafficking through the Golgi Apparatus
Lesson 1. A Snapshot of the Golgi
Lesson 2. Cisternal Maturation in Action
Lesson 3. Retrograde Vesicular Traffic
Lesson 4. Chemical Modification and Sorting in the Golgi
Lesson 5. Leaving the *trans*-Golgi Network with Clathrin
Module 12.3 Endosomes, Lysosomes, the Cell Membrane, and the Extracellular Solution
Lesson 1. Exocytosis: To the Cell Membrane and Extracellular Solution
Lesson 2. Endocytosis: From the Cell Membrane and Extracellular Solution
Lesson 3. Endosomes
Lesson 4. Lysosomes
Lesson 5. A Summary of the Endomembrane Trafficking System
THE HUMAN CONNECTION Botulinum Toxin Mechanism

Unit 3 | Energy and Structure: Chloroplasts, Mitochondria, the Cytoskeleton, and the Cell Membrane
Chapter 13 Chloroplasts and Photosynthesis: Producing Fuel for Everyone
Module 13.1 The Evolution of Cyanobacteria and Chloroplasts
Lesson 1. Capturing Sunlight Energy for All Life on Earth
Lesson 2. The Core of Photosynthesis: Porphyrin Rings and Magnesium Ions
Lesson 3. From Cyanobacteria to Giant Redwoods
Lesson 4. Cyanobacteria and Chloroplasts: Cut from the Same Cloth
Lesson 5. Anatomy of a Chloroplast
Module 13.2 Photosynthesis Stage 1: Converting Light to Chemical Energy
Lesson 1. An Overview of Photosynthesis
Lesson 2. Capturing Light with Chlorophyll
Lesson 3: Energy Transfer through Photosystems
Lesson 4. The Photosystem II Reaction Center: Stripping Electrons from Water
Lesson 5. Cytochrome B6F: Using Electrons to Pump Protons
Lesson 6. Photosystem I: Getting Excited Again
Lesson 7. The Thylakoid Membrane: A Charged Capacitor
Lesson 8. ATP Synthase: A Molecular Turbine
Lesson 9. ATP Synthase: Plugged into the Thylakoid Membrane
Module 13.3 Photosynthesis Stage 2: Using Chemical Energy to Make Glucose
Lesson 1. An Overview of Photosynthesis Stage 2
Lesson 2. The Calvin Cycle
Lesson 3. From G3P to Glucose to All Life on Earth
THE HUMAN CONNECTION Apicoplasts in Human Health
Chapter 14 Mitochondria and Aerobic Cellular Respiration: Refining the Fuel
Module 14.1 Getting to Know Your Mitochondria
Lesson 1. The Evolution of Mitochondria
Lesson 2. Mitochondria are a Relic of History
Lesson 3. The Outer Mitochondrial Membrane and the Intermembrane Space
Lesson 7. The Inner Mitochondrial Membrane and the Mitochondrial Matrix

Module 14.2 An Introduction to Aerobic Cellular Respiration
Lesson 1. Extracting Energy from Glucose
Lesson 2. Aerobic Cellular Respiration Stage 1: The Big Picture
Lesson 3. Aerobic Cellular Respiration Stage 2: The Big Picture
Lesson 4. Redox Potential: Moving Electrons from One Molecule to Another
Lesson 5. Aerobic vs. Anaerobic Cellular Respiration
Module 14.3 Aerobic Respiration Stage 1: Extracting Electrons
Lesson 1. Glycolysis Steps 1– 5: Preparing for Electron Extraction
Lesson 2. Glycolysis Steps 6–10: Extracting 4 Electrons
Lesson 3. Fermentation: Sacrificing Electrons for ATP
Lesson 4. From Pyruvate to Acetyl-CoA: Extracting 4 More Electrons
Lesson 5. From Lipids to Acetyl-CoA: Increased Energy Production
Lesson 6. The Krebs Cycle: Extracting 16 Electrons: Steps 1–4
Lesson 7. The Krebs Cycle: Extracting 16 Electrons: Steps 5–8
Module 14.4 Aerobic Respiration Stage 2: From Electrons to Protons to ATP
Lesson 1. The Electron Transport Chain (ETC)
Lesson 2. The ETC Redox Centers
Lesson 3. Pushing and Pulling Electrons through the ETC
Lesson 4. Using Electrons to Translocate Protons
Lesson 5. The Electron Path through the Four ETC Complexes
Lesson 6. The Charged Cristae Membrane Powers ATP Synthase
THE HUMAN CONNECTION Barth Syndrome
Chapter 15 The Cytoskeleton: Shape, Strength, Roadways, and Movement
Module 15.1 The Cytoskeleton
Lesson 1. Introduction to the Cytoskeleton
Lesson 2. Components of the Cytoskeleton
Lesson 3. Evolution of the Cytoskeleton
Module 15.2 Actin Filament Structure and Function
Lesson 1. From G-Actin Monomers to Actin Filament Polymers
Lesson 2. Actin Polymerization Requires ATP

Lesson 3. Treadmilling: Balancing the Plus and Minus End of Actin Filaments
Module 15.3 Actin-Binding Proteins
Lesson 1. Actin-Binding Proteins Shape the Actin Cytoskeleton
Lesson 2. The Motor Protein Myosin
Lesson 3. The Power Stroke Cycle of the Myosin II Motor
Lesson 4. Sarcomeres and Muscle Contraction
Lesson 5. Bringing It All Together: The Migrating Fibroblast
Module 15.4 Microtubule Structure and Function
Lesson 1. Microtubule Structure
Lesson 2. The Centrosome
Lesson 3. Microtubule Polymerization Requires GTP
Module 15.5 Microtubule Motor Proteins and Higher Order Structures
Lesson 1. Kinesin Structure and Function
Lesson 2. One Foot in Front of the Other
Lesson 3. Kinesins Move Vesicles and Position Organelles
Lesson 4. Dynein Structure and Function
Lesson 5. Cillia and Flagella
Module 15.6 Intermediate Filaments
Lesson 1. Intermediate Filament Structure
Lesson 2. Strengthening Cells against Stress
Lesson 3. Different Types of Intermediate Filaments
THE HUMAN CONNECTION Tau Protein
Chapter 16 The Cell Membrane: The Gatekeeper of Life
Module 16.1 Regulating the Boundary of Life
Lesson 1. Separating Life from Non-Life
Lesson 2. Maintaining Order in a Disordered World
Lesson 3. Selective Permeability
Lesson 4. Diffusion across the Cell Membrane
Lesson 5. Proteins Regulate Transport across the Cell Membrane
Module 16.2 Concentration and Charge: Electrochemical Gradients

Lesson 1. Gradients across the Cell Membrane
Lesson 2. Cell Membrane Potential
Lesson 3. Membrane Potential Exists at the Membrane
Lesson 4. Dynamic Equilibrium and Resting Membrane Potential
Module 16.3 Active and Passive Transporters
Lesson 1. Transport Proteins Control Intracellular Composition
Lesson 2. Active and Passive Transport Membrane Proteins
Lesson 3. Active Transporters
Lesson 4. Passive Transporters
Lesson 4. Gradient-Driven Transporters/Pumps
Module 16.4 Channels
Lesson 1. Channels Are Passive Pores
Lesson 2. Channel Specificity and Regulation
Lesson 3. Ion Channel Selectivity Filters
Lesson 4. Aquaporins and Osmotic Pressures
Lesson 5. Working Together for Cell Function
THE HUMAN CONNECTION Cystic Fibrosis
Unit 4 | The Working Cell: Cell Communication, the Cell Cycle, and Multicellularity
Chapter 17 Cell Communication, Signal Transduction, and Response
Module 17.1 All Cells Communicate
Lesson 1. Cell Communication: Detecting Extracellular Signals
Lesson 2. Signal Transduction: Intracellular Processing and Response
Lesson 3. Single-Celled vs. Multicellular Cell Communication, Signal Transduction, and Response
Lesson 4. Cellular and Organismal Communication, Signal Transduction, and Response
Lesson 5. Modes of Cell Communication in Multicellular Organisms
Module 17.2 Signal Transduction
Lesson 1. Receptors Detect Extracellular Signals
Lesson 2. Response Is Based on Cell Type
Lesson 3. Signal Transduction Pathways
Module 17.3 Common Signal Transduction Events

Lesson 1. Molecular Toggle Switches Using ATP
Lesson 2. Molecular Timed Switches Using GTP
Lesson 3. G-Protein Regulation
Lesson 4. Second Messengers and Signal Amplification
THE HUMAN CONNECTION Tofacitinib
Chapter 18 Signal Transduction Pathways: Messengers and Receptors
Module 18.1 Categories of Signal Receptors
Lesson 1. Gated Ion Channels
Lesson 2. G-Protein-Coupled Receptors (GPCRs)
Lesson 3. Enzyme-Coupled Receptors
Module 18.2 GPCRs and Heterotrimeric G-Proteins
Lesson 1. GPCR Activation
Lesson 2. Heterotrimeric G-Protein Activation
Lesson 3. Heterotrimeric G-Proteins Target Ion Channels
Lesson 4. Heterotrimeric G-Protein Target Membrane-Bound Enzymes
Module 18.3 GPCR Signaling Pathways
Lesson 1. The AC Signaling Pathway
Lesson 2. The PLC Signaling Pathway: PIP2, IP3, and DAG
Lesson 3. The PLC Signaling Pathway: Ca2+ and PKC
Lesson 4. Example GPCR Pathway: Regulation of Blood Glucose Concentration Part 1
Lesson 5. Example GPCR Pathway: Regulation of Blood Glucose Concentration Part 2
Module 18.4 RTK Signaling Pathways
Lesson 1. RTK Dimerization
Lesson 2. RTK Activation via Trans-Autophosphorylation
Lesson 3. Recruitment to the RTK C-Terminal Tails
Lesson 4. SH2 and PTB Domain-Containing Proteins
Lesson 5. Example RTK Pathway: MAPK
Module 18.5 Ca2+ Signaling Pathways
Lesson 1. Ca2+ and CaM
Lesson 2. CaMKII Structure and Function

Lesson 3. CaMKII Remembers
THE HUMAN CONNECTION GPCRs as Drug Targets
Chapter 19 The Cell Cycle and DNA Replication
Module 19.1 The Life Cycle of a Cell
Lesson 1. An Overview of the Cell Cycle
Lesson 2. Getting Ready to Divide
Lesson 3. Cell Division
Module 19.2 DNA Replication
Lesson 1. An Overview of DNA Replication
Lesson 2. Replication Bubbles and Forks
Lesson 3. Prokaryotic vs. Eukaryotic DNA Replication
Lesson 4. Replisome Assembly: Helicase, Primase, and Topoisomerase
Lesson 5. Replisome Assembly: The Clamp Loader, the Clamp, and DNA Polymerase III
Lesson 6. DNA Polymerization
Lesson 7. DNA Replication is Semi-Discontinuous
Lesson 8. DNA Polymerase I and Ligase
Lesson 9. Telomeres and Telomerase
Module 19.3 Mitosis and Cytokinesis
Lesson 1. An Orchestra of Chromosomes and Microtubules
Lesson 2. Prophase: Chromosome Condensation
Lesson 3. Prophase: Mitotic Spindle Formation
Lesson 4. Prometaphase
Lesson 5. Metaphase
Lesson 6. Anaphase and Telophase
Lesson 7. Cytokinesis
THE HUMAN CONNECTION TP53: Guardian of the Genome
Chapter 20 Cell Cycle Regulation
Module 20.1 Checkpoints, Cyclins, and Cyclin-Dependent Kinases
Lesson 1. Checkpoints Regulate Cell Cycle Progression

Lesson 2. The Three Cell Division Checkpoints
Lesson 3. Opting Out of the Cell Cycle: G0
Lesson 4. Cyclins and CDKs Control the Checkpoints
Lesson 5. Multi-Layered Regulation of CDKs: Cyclins, Phosphorylation, and Inhibitors
Module 20.2 The G1/S Checkpoint
Lesson 1. The Point of No Return
Lesson 2. Three Layers of Regulation Working Together
Lesson 3. Responding to DNA Damage
Lesson 4. Triggering DNA Replication Initiation
Module 20.3 The G2/M and Metaphase/Anaphase Checkpoints
Lesson 1. The Phosphorylation/Dephosphorylation Balance
Lesson 2. Triggering Entry into M Phase
Lesson 3. The Metaphase/Anaphase Checkpoint
Lesson 4. APC Activation Triggers the Onset of Anaphase
THE HUMAN CONNECTION CDKL5 Deficiency Disorder
Chapter 21 From Single Cell to Multicellular Organism
Module 21.1 Connecting Cells Together
Lesson 1. From Cells to Tissues
Lesson 2. Adherens Junctions
Lesson 3. Desmosomes and Hemidesmosomes
Lesson 4. Tight Junctions, Gap Junctions, and Plasmodesmata
Lesson 5. Epithelial Cells and Tissues
Lesson 6. Epithelial Cell Polarity Is Maintained by Tight Junctions
Lesson 7. Shaping Epithelial Tissue with Adhesion Belts
Module 21.2 Beyond the Cell: The Extracellular Matrix
Lesson 1. Introduction to the Extracellular Matrix
Lesson 2. Plant Cell Extracellular Matrix
Lesson 3. Synthesizing and Depositing Cellulose Microfibrils
Lesson 4. Animal Cell Extracellular Matrix
Lesson 5. Collagen

Lesson 6. Polysaccharide Gels
Lesson 7. Integrin and Fibronectin
Module 21.3 Apoptosis
Lesson 1. Programmed Cell Death
Lesson 2. Apoptotic Molecular Machinery
Lesson 3. Intrinsic and Extrinsic Apoptosis
Module 21.4 Cancer
Lesson 1. The Selfish Gene
Lesson 2. Cancer-Causing Mutations
Lesson 3. Tumor Suppressor Genes and Oncogenes
Lesson 4. Characteristics of Cancer Cells
THE HUMAN CONNECTION Epidermolysis Bullosa