**Instructor’s Manual**

***Advanced Nutrition and Human Metabolism*, Gropper, 7e**

Chapter 1 – The Cell: A Microcosm of Life

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Chapter Outline

1. Introduction
   * 1. This chapter provides a brief review of the basics of a cell, including cellular components, biological energy, and an overview of a cell’s natural life span.
     2. Key Terms
        1. Cells – basic living, structural, and functional units of the human body
        2. Eukaryotic cells – multicellular organisms
        3. Prokaryotic cells – primitive cells
        4. Plasma membrane – sheet-like structure that encapsulates and surrounds the cell, allowing it to exist as a distinct unit
     3. Figures and Tables
        1. Figure 1.1 – three-dimensional depiction of a typical mammalian liver cell
2. Components of Cells
   1. Plasma Membrane
      1. Sheet-like structure that encapsulates and surrounds the cell. It is asymmetrical and considered to be a fluid structure
      2. Key Terms
         1. Hydrophobic – molecule or part of molecule that repels water but has strong affinity for nonpolar substances
         2. Receptors – macromolecules that bind a signal molecule with a high degree of specificity that triggers intracellular events
         3. Enzymes – protein catalysts that increase the rate of a chemical reaction in the body
      3. Figures and tables
         1. Figure 1.2 – lipid bilayer structure of biological membranes
         2. Figure 1.3 – fluid model of cell membrane. Lipids and proteins are mobile and can move laterally in the membrane
   2. Cytoplasmic Matrix
      1. Consists of filaments or fibers and provides the cell with structural support, framework, network to direct movement, means of independent location, pathway for intercellular communication, and possible transfer of RNA and DNA
      2. Key Terms
         1. Microtubules – hollow, cylindrical cytoskeletal structures composed of the protein tubulin that act to support the cell structure
         2. Intermediate filaments – strong, ropelike cytoskeletal fibers that are made of protein and that function to provide mechanical stability to cells
         3. Microfilaments – solid cytoskeletal structures made of a double-helix polymer of the protein actin that play a role in cell motility
      3. Microtubules, intermediate filaments, and microfilaments – make up the cytoskeleton
      4. Structural arrangement
         1. Hexose monophosphate shunt – pentose phosphate pathway
      5. Figures and tables
         1. Figure 1.4 – the cytoskeleton provides a structure for cell organelles, microvilli, and large molecules
   3. Mitochondrion
      1. Cellular organelle that is the site of energy production by oxidative phosphorylation and the site of tricarboxylic acid cycle
      2. Key terms
         1. Mitochondria – primary sites of oxygen use and ATP production in cells
         2. Oxidative phosphorylation – pathway in the mitochondria that makes ATP from ADP and Pi
         3. Electron transport chain – sequential transfer of electrons from reduced coenzymes to oxygen that is coupled with ATP formation and occurs within the mitochondria
      3. Mitochondrial membrane – consists of a matrix or interior space surrounded by a double membrane
      4. Mitochondrial matrix – metabolic enzyme systems that function by catalyzing reactions of the tricarboxylic acid and fatty acid oxidation
      5. Figures and tables
         1. Figure 1.5 – the mitochondrion
         2. Figure 1.6 – overview of a cross section of a mitochondrion
   4. Nucleus
      1. Largest organelle within the cell, regulating most cellular activities
      2. Key terms
         1. Nuclear envelope – composed of an inner and an outer membrane; surrounds the cell nucleus
         2. Nucleolus – region of the nucleus containing condensed chromatin and sites for synthesizing ribosomal RNA
         3. Genes – section of chromosomal DNA that codes for a single protein
         4. Genome – sum of all the chromosomal genes of a cell
         5. Nucleotides – phosphate esters of the 5ʹ-phosphate of a purine or pyrimidine in N-glyosidic linkage with ribose or deoxyribose; occurs in nucleic acids
         6. Complementary base pairing – pairing of nucleotide bases in two strands of nucleic acids; A pairs with T or U, while G pairs with C
         7. Replication – synthesis of a daughter duplex DNA molecule identical to the parental duplex DNA
         8. Transcription factors – auxiliary proteins that bind to specific sites in the DNA and alter the transcription of nearby genes
         9. Sense strand – the strand of DNA that serves as a template for mRNA
         10. Introns – noncoding regions of a gene
         11. Exons – coding regions of a gene
         12. Anticodons – three-base sequences of nucleotides within transfer RNA molecules
         13. Elongation – (1) extension of the polypeptide chain of the protein product during protein synthesis, (2) the addition of carbons to a fatty acid chain
         14. MicroRNAs – small noncoding RNAs that silence gene expression by binding to mRNA to inhibit its translation and/or promote its degradation
      3. Nucleic acids – macromolecules of nucleotides; consist of a nitrogenous core, a pentose sugar, and a phosphate
      4. Cell replication – synthesis of daughter DNA identical to the parental DNA
      5. Transcription – taking genetic information in a single strand of DNA and making a specific sequence of bases in a messenger RNA chain
      6. Translation – process by which genetic information in an mRNA molecule is turned into the sequence of amino acids in the protein
      7. Control of gene expression – controlled through transcription, processing-level control mechanisms determine the path by which mRNA is translated into polypeptide and translation-level control mechanisms determine which mRNA is translated
      8. Figures and tables
         1. Figure 1.7 – steps of protein synthesis
         2. Figure 1.8 – DNA replication
   5. Endoplasmic Reticulum and Golgi Apparatus
      1. The organelles function together to create a mechanism for communication from the innermost part of the cell to its exterior
      2. Key terms
         1. Endoplasmic reticulum – network of membranous channels pervading the cytosol and providing continuity between the nuclear envelope, the Golgi apparatus, and the plasma membrane
         2. Sarcoplasmic reticulum – smooth endoplasmic reticulum that is found in muscle cells and is the site of the calcium pump
         3. Cytochromes – heme-containing proteins that serve as electron carriers
         4. Oxidation – enzymatic reaction in which oxygen is added to, or hydrogen and its electrons are removed from, the reactant
         5. Lipophilic – state of being attracted to lipids and thus repelled by water
         6. Hydrophilic – refers to a molecule or part of a molecule having a strong affinity for water and other polar substances
         7. Golgi apparatus – the part of the cell responsible for modifying macromolecules synthesized in the endoplasmic reticulum and packaging them to be transported to the cell surface or cytosol
   6. Lysosomes and Peroxisomes
      1. Aid in cell’s digestion and oxidative catabolic reactions
      2. Key terms
         1. Lysosomes – cell organelles that contain digestive enzymes
         2. Peroxisomes – cell organelles containing enzymes that perform oxidative catabolic reactions
         3. Catabolism – process by which organic molecules are broken down
3. Selected Cellular Proteins
   1. Receptors
      1. Highly specific proteins located in the plasma membrane and act as recognition markers
      2. Key terms
         1. Ligands – small molecules or minerals that bind to a larger molecule
      3. Receptors that generate internal chemical signals – an internal chemical signal is generated following interaction between some receptors and ligands
      4. Receptors that function as ion channels – in some cases, the binding of the ligand to its receptor causes a voltage change, which then becomes the signal for a cellular response
      5. Receptors that internalize stimuli – a stimulus is internalized through a stimulus
      6. Receptor’s role in homeostasis – receptors that respond to changes in the external conditions
      7. Figures and tables
         1. Figure 1.9 – example of an internal chemical signal by a second messenger
         2. Figure 1.10 – internalization of a stimulus into a cell via its receptor
   2. Catalytic Proteins (Enzymes)
      1. These are enzymes that are catalysts and take part in reactions but are not part of the final product of that reaction
      2. Key terms
         1. Oxidoreductases – enzymes that catalyze all reactions in which one compound is oxidized and another is reduced
         2. Transferases – enzymes that catalyze reactions not involving oxidation and reduction in which a functional group is transferred from one substrate to another
         3. Hydrolases – enzymes that catalyze cleavage of bonds between carbon atoms and some other kind of atom by the addition of water
         4. Lyases – enzymes that catalyze cleavage of carbon–carbon, carbon–sulfur, and certain carbon–nitrogen bonds without hydrolysis or oxidation–reduction
         5. Isomerases – enzymes that catalyze the interconversion of optical or geometric isomers
         6. Ligases – enzymes that catalyze the formation of bonds between carbon and other atoms
         7. Ischemia – deficiency of blood in a tissue
         8. Oncogenes – genes capable of causing a normal cell to convert to a cancerous cell
      3. Reversibility – the same enzyme catalyzes a reaction in both directions
      4. Regulation – anabolic and catabolic reactions are kept balanced
         1. Covalent modification – enzyme is inactive until a posttranslational modification is made
         2. Allosteric enzyme modulation – a secondary regulatory mechanism that is used by certain enzymes called allosteric enzymes. These enzymes possess another site besides the catalytic site
         3. Induction – creates changes in the concentration of certain inducible enzymes by increasing enzyme synthesis
      5. Examples of enzyme types – enzyme participation depends on where the enzyme is located through the cell
      6. Clinical applications of cellular enzymes – enzymes are synthesized intracellularly, and most function within the cell they are formed in. Enzymes must have high degree of organ or tissue specificity, steep concentration gradient of enzyme activity between the interior and exterior of cells, must function in the cytosol of the cell, and must be stable for a reasonable time period in the vascular compartment
4. Apoptosis
   * 1. Programmed cell death
     2. Key terms
        1. Apoptosis – programmed cell death
        2. Caspases – family of cysteine proteases involved in the degradative events during apoptosis
        3. Tumor necrosis factor – a cytokine released by immune cells and mast cells that causes destruction of tumors and migration of neutrophils toward the site of bacterial infections
        4. Cytokines – generic term for nonantibody protein messengers released from a macrophage or lymphocyte that is part of an intracellular immune response
        5. Oncosis – a prelethal pathway accompanied by cellular swelling, organelle swelling, and increased membrane permeability that lead to cell death
        6. Motility – movement
5. Biological Energy
   1. Energy Release and Consumption in Chemical Reactions
      1. Energy derived from macromolecules
      2. Key terms
         1. Macronutrients – dietary nutrients that supply energy, including fats, carbohydrates, and proteins
      3. Figures and tables
         1. Figure 1.11 – adenosine triphosphate
         2. Figure 1.12 – a comparison of the simple combustion and the metabolic oxidation of the fatty acid palmitate
   2. Expressions of Energy
      1. Key terms
         1. Free energy – the potential energy inherent in the chemical bonds of nutrients
         2. Exothermic – a reaction in which the reactants have more free energy than the products; it therefore gives off energy as heat
         3. Endothermic – a reaction in which the products have more free energy than the reactants; it therefore requires energy
         4. Transition state – energy level at which reactant molecules have been activated and can undergo an exothermic reaction
         5. Activation energy – energy introduced into the reactant molecules to activate them to the transition state so that an exothermic reaction can take place
      2. Units of energy – calories are the unit of energy used throughout this text. Kcal is used to represent 1,000 calories.
      3. Free energy – potential energy inherent in the chemical bonds of nutrients is released if the molecules undergo oxidation
      4. Exothermic and endothermic reactions – reactions either involving energy or releasing energy
      5. Activation energy – energy required for a reaction to occur. Exothermic reactions are favored since they do not require external energy input
      6. Cellular energy – how the cell derives its energy from a series of chemical reactions
      7. Reversibility of chemical reactions – most cellular reactions are reversible, meaning an enzyme can catalyze in both directions
      8. Standard free energy change – a temperature of 298 K, a pressure of 1.0 atm, and the presence of both the reactants and the products at their standard concentrations, namely 1.0 mol/L
      9. Equilibrium constant and standard free energy change – the equilibrium constant of a reaction determines the sign and magnitude of the standard free energy change
      10. Standard pH – 7.0 is the adopted standard pH value
      11. Nonstandard physiological conditions – physiological standard conditions do not often exist, which may explain why reactions proceed when the conditions are not standard
      12. Figures and tables
          1. Figure 1.13 – the uphill–downhill concept illustrating energy-releasing and energy-demanding processes
          2. Figure 1.14 – example of a shift in the equilibrium by changing from standard conditions to physiological conditions
   3. The Role of High-Energy Phosphate in Energy Storage
      1. ATP can be used as a universal source of energy through the hydrolysis of the phosphate bonds
      2. Figures and tables
         1. Figure 1.15 – examples of very high-energy phosphate compounds
         2. Figure 1.16 – an illustration of how ATP is generated from the coupling of ADP and phosphate through the oxidative catabolism of nutrients and in turn, is used for energy-requiring processes
   4. Coupled Reactions in the Transfer of Energy
      1. Reactions that require energy and reactions that yield energy
      2. Figures and tables
         1. Figure 1.17 – examples of high-energy phosphate bonds being transferred
         2. Figure 1.18 – exothermic reactions
   5. Reduction Potentials
      1. Ability of a compound to be reduced by accepting an electron/s
      2. Key terms
         1. Standard reduction potential – tendency of a molecule to donate or receive electrons
         2. Hydrogen atoms – chemical element of hydrogen containing one proton and one electron
6. Summary
   1. Plasma Membrane
      1. Ability to protect the cell while adjusting to the environment
   2. Communication of the Cell
      1. Cell’s ability to use the cytosol, microtrabecular network, and the endoplasmic reticulum and Golgi apparatus to communicate between the nucleus and plasma membrane
   3. Division of Labor among Cell Components
   4. Nucleus
      1. Ability to ensure all needed proteins are synthesized
   5. Apoptosis
      1. Programmed cell death

Resources

***In-Text Web Sites***

[All About the Human Genome Project (HGP)](https://www.genome.gov/10001772/)

***In-Text Suggested Readings***

* Bartel DP. MicroRNAs: genomics, biogenesis, mechanism, and function. Cell. 2004; 116:281–97.
* Remely M, Stefanska B, Lovrecic L, Magnet U, Haslberger AG. Nutriepigenomics: the role of nutrition in epigenetic control of human diseases. Curr Opin Clin Nutr Metab Care. 2015; 18:328–33.

***Additional Resource***

* Sebastián D, Acín-Pérez R, Morino K. Mitochondrial health in aging and age-related metabolic disease. Oxid Med Cell Longev. 2016, 5831538. [Article ID](http://doi.org/10.1155/2016/5831538)

[Mitochondrial Health in Aging and Age-Related Metabolic Disease](http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4961810/)

Perspectives – Classroom Discussion

You may pose these questions to your students when discussing the perspectives section of this chapter.

* The endoplasmic reticulum has multiple roles including translation and protein regulation. What are some disorders that the endoplasmic reticulum plays a role in?
  + Answer: cystic fibrosis, type I diabetes, neonatal diabetes.
* What serves as the electron acceptor and donor throughout the oxidation and reduction of glucose?
  + Answer: NADH; when NAD+, it is able to accept the hydrogen; when NADH, it is able to donate the hydrogen.

Assignment – Group Project

* You have learned about the organelles of the eukaryotic cell and how each has a vital function. Find a partner and draw a diagram or a process map showing how a cell takes the DNA and produces a protein. Describe which organelles are involved in the process and which processes are occurring throughout the cell.
  + Rubric: The diagram should highlight the DNA in the nucleus undergoing transcription to become RNA to messenger RNA. From there, it should show the mRNA leaving the nucleus and entering the cytoplasm to be translated by the ribosomes into proteins.

Answer Keys

**Case Study – Tumor Suppressors and Cancer**

1. d

2. b

3. a

4. e

5. c

6. a

**Worksheet 1: Responding to Research – Mitochondria and Aging**

1. b

2. d

3. reduces; reduction

4. Reduce risks of heart disease and diabetes by eating a healthy diet and being active.

**Worksheet 2: Labeling It – A Eukaryotic Cell**

A. Mitochondria – energy, ATP synthesis, cellular respiration

B. Golgi apparatus – packages proteins, lipid synthesis for protein packaging

C. Rough endoplasmic reticulum – contains ribosomes responsible for protein synthesis

D. Nucleolus – ribosomal RNA synthesis

Worksheet 1: Responding to Research – Mitochondria and Aging

Mitochondria are organelles present in both eukaryotic and prokaryotic cells. Their main function is energy production through many oxidation/reduction steps. They are also key elements in the aging process.

Read the following article and then respond to the questions.

* Sebastián D, Acín-Pérez R, Morino K. Mitochondrial health in aging and age-related metabolic disease. Oxid Med Cell Longev. 2016, 5831538. [Article ID](http://doi.org/10.1155/2016/5831538)

[Mitochondrial Health in Aging and Age-Related Metabolic Disease](http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4961810/)

1. When biogenesis is increased, mitochondrial function becomes more efficient.

1. True
2. False

\_\_\_\_\_\_\_\_\_\_

2. Maria has recently been informed that she has coronary heart disease and that this puts her at more risk for mitochondrial dysfunction. She wants to understand more about her condition. What is the best explanation to give to her?

a. It is a natural aging process that is not affected by coronary heart disease.

b. It is a natural aging process and because she does not have diabetes, she will be fine.

c. It involves oxidation damage that only affects peripheral neurons.

d. It is caused by oxidation damage that might be reduced through the use of antioxidants.

\_\_\_\_\_\_\_\_\_\_

3. Mitochondrial mass \_\_\_\_\_\_\_ as the body ages, leading to a(n) \_\_\_\_\_\_ in oxidation.

a. reduces; reduction

b. reduces; increase

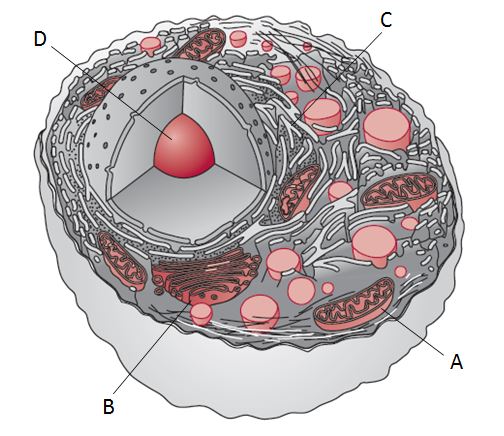
c. increases; reduction

\_\_\_\_\_\_\_\_\_\_

4. According to this article, what are two measures that can be taken for mitochondrial health?

Worksheet 2: Labeling It – A Eukaryotic Cell

Label the letters in the diagram below and describe the function of each of the organelles.



A. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

B. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

C. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

D. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_