CHAPTER 1
THEMES IN THE STUDY OF LIFE

Learning objectives

Inquiring about the World of Life

1. Briefly describe the unifying themes that characterize the biological sciences.
2. Diagram the hierarchy of structural levels in biological organization.
3. Describe the dilemma of reductionism.
4. Describe the two major dynamic processes of any ecosystem.
5. Name two characteristics shared by all cells.
6. Distinguish between prokaryotic and eukaryotic cells.
7. Describe the basic structure and function of DNA.
8. Explain the importance of regulatory mechanisms in living things. What is negative feedback.

Organizing the Diversity of Life

9. Distinguish among the three domains of life. List and distinguish among the various kingdoms of multicellular, eukaryotic life.
10. Explain the phrase: "life's dual nature of unity and diversity". Explain how evolution accounts for the unity and diversity of living things.
11. Describe the observations and inferences that led Charles Darwin to his theory of evolution by natural selection.
12. Explain why diagrams of evolutionary relationships have a treelike form.

The Process of Science

13. Distinguish between discovery science and hypothesis-based science. Explain why both types of exploration contribute to our understanding of nature.
14. Distinguish between quantitative and qualitative data.
15. Distinguish between inductive and deductive reasoning.

CHAPTER 2
THE CHEMICAL CONTEXT OF LIFE

Learning objectives

Elements and compounds

1. Distinguish between an element and a compound.
2. Identify the four elements that make up 96% of living matter.

Atoms and molecules

3. Draw and label a simplified model of an atom. Explain how this model misrepresents our understanding of atomic structure.
4. Distinguish between each of the following pairs of terms:
    a. Neutron and proton
    b. Atomic number and mass number
    c. Atomic weight and mass number
5. Explain how the atomic number and mass number of an atom can be used to determine the number of neutrons.
6. Define an isotope.

Electron distribution and chemical properties

7. Distinguish between nonpolar covalent, polar covalent and ionic bonds.
8. Explain why strong covalent bonds and weak bonds are both essential in living organisms.
9. Distinguish between hydrogen bonds and van der Waals interactions.
10. Give an example that illustrates how a molecule's shape can determine its biological function.
11. Explain what is meant by a chemical equilibrium.

CHAPTER 3
WATER AND THE FITNESS OF THE ENVIRONMENT

Learning objectives

The Properties of Water

1. With the use of a diagram or diagrams, explain why water molecules are:
    a. polar
    b. capable of hydrogen bonding with 4 neighboring water molecules
2. Define **cohesion** and **adhesion**. Explain how water's cohesion and adhesion contribute to the movement of water from the roots to the leaves of a tree.
3. Distinguish between **heat** and **temperature**, using examples to clarify your definitions.
4. Explain the following observations by referring to the properties of water:
    - Coastal areas have milder climates than adjacent inland areas.
    - Ocean temperatures fluctuate much less than temperatures on land.
    - Insects like water striders can walk on the surface of a pond without breaking the surface.
    - Ice floats on water.
    - Humans sweat and dogs pant to cool themselves on hot days.

The Solvent of Life

5. Distinguish between a **solute**, a **solvent** and a **solution**.
6. Distinguish between **hydrophobic** and **hydrophilic** substances.
7. Explain how you would make up a one molar (1M) solution of ethyl alcohol.

The Dissociation of Water Molecules

8. Name the products of the dissociation of water and give their concentration in pure water.
9. Define **acid**, **base**, and **pH**.
10. Explain how acids and bases may directly or indirectly alter the hydrogen ion concentration of a solution.
11. Using the bicarbonate buffer system as an example, explain how buffers work.
12. Briefly explain how the burning of fossil fuels may affect:

Acid precipitation

CHAPTER 4
1. CARBON AND THE MOLECULAR DIVERSITY OF LIFE

Learning objectives

The Importance of Carbon

1. Explain how carbon's electron configuration explains its ability to form large, complex and diverse organic molecules.
2. Describe how carbon skeletons may vary, and explain how this variation contributes to the diversity and complexity of organic molecules.
3. Describe the basic structure of a hydrocarbon and explain why these molecules are hydrophobic.
4. Distinguish among the three types of isomers: structural, geometric, and enantiomer.

Chemical Groups

5. Name the major chemical groups found in organic molecules. Describe the basic structure of each chemical group and outline the chemical properties of the organic molecules in which they occur.

ATP

6. Explain how ATP functions as the primary energy transfer molecule in living cells.

CHAPTER 5
THE STRUCTURE AND FUNCTION OF LARGE BIOLOGICAL MACROMOLECULES

Learning objectives

The Molecules of Life

1. List the four major classes of macromolecules.
2. Distinguish between monomers and polymers.
3. Draw diagrams to illustrate condensation and hydrolysis reactions.

Carbohydrates Serve as Fuel and Building Material

4. Distinguish between monosaccharides, disaccharides, and polysaccharides.
5. Describe the formation of a glycosidic linkage.
6. Distinguish between the two forms of glucose found in starch and cellulose. Explain why the difference is biologically important.

Lipids are a Diverse Group of Hydrophobic Molecules

7. Describe the building-block molecules, structure, and biological importance of fats, phospholipids, and steroids.
8. Name the principal energy storage molecules of

Proteins have Many Structures, Resulting in a Wide Range of Functions

9. Distinguish between a protein and a polypeptide.
10. Explain how a peptide bond forms between two amino acids.
11. List and describe the four major components of an amino acid. Explain how amino acids may be grouped according to the physical and chemical properties of the R group.
12. Explain what determines protein structure and why it is important.
13. Explain how the primary structure of a protein is determined.
14. Name two types of secondary protein structure. Explain the role of hydrogen bonds in maintaining secondary structure.
15. Explain how weak interactions and disulfide bridges contribute to tertiary protein structure.
16. List four conditions under which proteins may be denatured.

Nucleic Acids Store and Transmit Hereditary Information

17. List the major components of a nucleotide, and describe how these monomers are linked to form a nucleic acid.
18. Distinguish between:
    a. pyrimidine and purine
    b. nucleotide and nucleoside
    c. ribose and deoxyribose
    d. 5′ end and 3′ end of a nucleotide
19. Briefly describe the three-dimensional structure of DNA.
20. Explain how DNA or protein comparisons may allow us to assess evolutionary relationships between species.

CHAPTER 6
A TOUR OF THE CELL

Learning objectives

How We Study Cells

12. Distinguish between magnification and resolution.
13. Describe the principles, advantages, and limitations of the light microscope, transmission electron microscope, and scanning electron microscope.
14. Explain why cell fractionation is a useful technique.

A Panoramic View of the Cell

15. Distinguish between prokaryotic and eukaryotic cells.
16. Explain why there are both upper and lower limits to cell size.
17. Explain the advantages of compartmentalization in eukaryotic cells.

The Nucleus and Ribosomes

18. Describe the structure and function of the nuclear envelope, including the role of the pore complex.
19. Briefly explain how the nucleus controls protein synthesis in the cytoplasm.
20. Explain the role of the nucleolus in protein synthesis.
21. Distinguish between free and bound ribosomes in terms of location and function.

The Endomembrane System

22. List the components of the endomembrane system, and describe the structure and function of each component.
23. Compare the structure and functions of smooth and rough ER.
24. Explain the significance of the *cis* and *trans* sides of the Golgi apparatus.
25. Describe the cisternal maturation model of Golgi function.
26. Describe three examples of intracellular digestion by lysosomes.
27. Name three different kinds of vacuoles, giving the function of each kind.

Mitochondria and Plastids

28. Briefly describe the energy conversions carried out by mitochondria and chloroplasts.
29. Describe the structure of a mitochondrion and explain the importance of compartmentalization in mitochondrial function.
30. Distinguish among amyloplasts, chromoplasts, and chloroplasts.
31. Identify the three functional compartments of a chloroplast. Explain the importance of compartmentalization in chloroplast function.
32. Describe the evidence that mitochondria and chloroplasts are semiautonomous organelles.
33. Explain the roles of peroxisomes in eukaryotic cells.

The Cytoskeleton

34. Describe the functions of the cytoskeleton.
35. Compare the structure, monomers, and functions of microtubules, microfilaments, and intermediate filaments.
36. Explain the structure and role of centrioles and basal bodies.
37. Explain how the ultrastructure of cilia and flagella relate to their functions.

Cell Surfaces and Junctions

38. Describe the basic structure of a plant cell wall. Distinguish between the primary cell wall, middle lamella, and secondary cell wall.
39. Describe the structure and roles of the extracellular matrix in animal cells.
40. Understand the basic nature of the extracellular matrix.

CHAPTER 7

MEMBRANE STUCTURE AND FUNCTION

Learning objectives

Membrane Structure

1. Explain the meaning of the statement that phospholipids and most other membrane constituents are amphipathic molecules.
2. Explain how the fluid mosaic model of membrane structure explains each experimental finding:
    a. Actual membranes adhere more strongly to water than do artificial membranes composed only of phospholipids.
    b. Membranes with different functions may differ in type and number of membrane proteins.
    c. Membrane proteins are not very water-soluble.
    d. EMs of freeze-fracture membrane preparations show protein particles interspersed in a smooth matrix.
3. Describe the fluidity of the components of a cell membrane and explain how membrane fluidity is influenced by temperature and membrane composition.
4. Explain how cholesterol resists changes in membrane fluidity as temperatures change.
5. Distinguish between peripheral and integral membrane proteins.
6. List the major functions of membrane proteins

Traffic across Membranes

7. Explain how hydrophobic molecules cross cell membranes.
8. Distinguish between channel proteins and carrier proteins.
9. Explain how aquaporins facilitate the passage of water through membranes.
10. Define diffusion. Explain why diffusion is a passive and spontaneous process.
11. Distinguish between solutions that are hypertonic, hypotonic, and isotonic to cell contents.
12. Define osmosis and predict the direction of water movement based on differences in solute concentrations.
13. Describe how living cells with and without cell walls regulate water balance.
14. Explain how transport proteins facilitate diffusion.
15. Distinguish between osmosis, facilitated diffusion, and active transport.
16. Describe the two forces that combine to produce an electrochemical gradient.
17. Describe the process of cotransport.
18. Explain how large molecules are transported across a cell membrane.

CHAPTER 8
AN INTRODUCTION TO METABOLISM

Learning objectives

Metabolism, Energy, and Life

1. Explain the role of catabolic and anabolic pathways in cellular metabolism.
2. Distinguish between kinetic and potential energy.
3. Explain the first and second laws of thermodynamics in your own words.
4. Distinguish between exergonic and endergonic reactions in terms of free energy change.
5. List the three main kinds of cellular work. Explain in general terms how cells obtain the energy to do cellular work.
6. Describe the structure of ATP and identify the major class of macromolecules to which ATP belongs.
7. Explain how ATP performs cellular work.

Protein Enzymes Regulate Metabolic Pathways

8. Describe the function of enzymes in biological systems.
9. Explain why an investment of activation energy is necessary to initiate a spontaneous reaction.
10. Explain how enzyme structure determines enzyme specificity.
11. Explain the induced-fit model of enzyme function.
12. Describe the mechanisms by which enzymes lower activation energy.
13. temperature, pH, cofactors, and enzyme inhibitors can affect enzyme activity.

The Control of Metabolism

14. Describe how allosteric regulators may inhibit or stimulate the activity of an enzyme.
15. Describe how localization of enzymes within a cell may help order metabolism.

CHAPTER 9
CELLULAR RESPIRATION: HARVESTING CHEMICAL ENERGY

Learning objectives

The Principles of Energy Harvest

1. Write the summary equation for cellular respiration. Define oxidation and reduction.
2. Explain in general terms how redox reactions are involved in energy exchanges.
3. Describe the role of NAD^+ and FAD in cellular respiration.
4. Explain the role of the electron transport chain in cellular respiration and why it is so important.

The Process of Cellular Respiration

5. Name the three stages of cellular respiration and state the region of the eukaryotic cell where each stage occurs.
6. Explain why ATP is required for the preparatory steps of glycolysis.
7. Identify where substrate-level phosphorylation and the reduction of NAD^+ occur in glycolysis.
8. Describe where pyruvate is oxidized to acetyl CoA, what molecules are produced, and how this process links glycolysis to the citric acid cycle.
9. List the products of the citric acid cycle. Explain why it is called a cycle.
10. Describe the point at which glucose is completely oxidized during cellular respiration.
11. Distinguish between substrate level phosphorylation and oxidative phosphorylation.
12. In general terms, explain how the movement of electrons down the electron transport chain is coupled to the production of ATP(the process is called chemiosmosis).
13. Explain where and how the respiratory electron transport chain creates a proton gradient. Explain what this gradient is and how it contributes to the synthesis of ATP (This is one of the more confounding concepts to grasp).
14. Summarize the net ATP yield from the oxidation of a glucose molecule by constructing an ATP "ledger", showing the number of ATP synthesized in the various stages.

Related Metabolic Processes

15. Distinguish between fermentation and anaerobic respiration.
16. State the basic function of fermentation.
17. Describe the evidence that suggests that glycolysis is an ancient metabolic pathway.
18. Describe how food molecules other than glucose can be oxidized to make ATP.

CHAPTER 12
THE CELL CYCLE

Learning objectives

The Key Roles of Cell Division

1. Explain how cell division functions in reproduction, growth, and repair.
2. Describe the structural organization of a prokaryotic and eukaryotic genome.
3. Describe the major events of eukaryotic cell division that enable the genome of one cell to be passed on to two daughter cells.
4. Describe how the chromosome number changes throughout the human life cycle.

The Mitotic Cell Cycle

5. List the phases of the cell cycle and describe the sequence of events that occurs during each phase.
6. List the phases of mitosis and describe the events characteristic of each phase.
7. Recognize the phases of mitosis from diagrams and micrographs.
8. Draw or describe the mitotic spindle, including centrosomes, kinetochore microtubules, nonkinetochore microtubules, and the aster.
9. Compare cytokinesis in animals and plants.
10. Compare, in a general way, mitosis with meiosis (you may have to refer to the following chapter or handouts).

CHAPTER 16
THE MOLECULAR BASIS OF INHERITANCE

Learning objectives

DNA as the Genetic Material

1. Explain why researchers originally thought protein was the genetic material.
2. Explain how the experiments performed by the following scientists provided evidence that DNA is the genetic material:
    a. Frederick Griffith
    b. Oswald Avery, Maclyn McCarty, and Colin MacLeod
    c. Alfred Hershey and Martha Chase
    d. Erwin Chargaff
3. Explain how Watson and Crick deduced the structure of DNA and describe the evidence they used. Explain the significance of the research of Rosalind Franklin.
4. Describe the structure of DNA. Explain the base-pairing rule and describe its significance.

DNA Replication and Repair

5. Describe the semi-conservative model of replication and generally the significance of the experiments of Matthew Meselson and Franklin Stahl; just the basic idea.
6. Describe the process of DNA replication, including the role of the origins of replication and replication forks.
7. Explain the role of DNA polymerases in replication.
8. Explain what energy source drives the polymerization of DNA.
9. Distinguish between the leading strand and the lagging strand.
10. Explain how the lagging strand is synthesized even though DNA polymerase can add nucleotides only to the 3' end. Describe the significance of Okazaki fragments.
11. Explain the roles of DNA ligase, primer, primase, and helicase.
12. Define "antiparallel" and explain why continuous synthesis of both DNA strands is not possible.
13. Describe the structure and function of telomeres.

Bacterial and Eukaryotic Chromosomes

14. Compare—in a very general ways—a bacterial chromosome and a eukaryotic chromosome.

CHAPTER 17

FROM GENE TO PROTEIN

Learning Objectives

The Connection between Genes and Proteins

1. Explain how RNA differs from DNA.
2. Briefly explain how information flows from gene to protein. Distinguish between transcription and translation.
3. Compare where transcription and translation occur in bacteria and in eukaryotes.
4. Define “codon” and explain the relationship between the linear sequence of codons on mRNA and the linear sequence of amino acids in a polypeptide.
5. Explain what it means to say that the genetic code is redundant and unambiguous.
6. Explain the significance of the reading frame during translation.
7. Explain the evolutionary significance of a nearly universal genetic code.

The Synthesis and Processing of RNA

8. Explain the general process of transcription, including, generally, the three major steps of initiation, elongation, and termination.
9. Explain how RNA is modified after transcription in eukaryotic cells. Describe the functional and evolutionary significance of introns.
10. Explain why, due to alternative RNA splicing, the number of different protein products an organism can produce is much greater than its number of genes.

The Synthesis of Protein

11. Describe the structure and function of tRNA.
12. Explain how tRNA is joined to the appropriate amino acid.
13. Describe the structure and functions of ribosomes.
14. Generally, be able to describe the process of translation and explain which enzymes are needed for each stage.
15. Explain what determines the primary structure of a protein and describe how a polypeptide must be modified before it becomes fully functional.
16. Why is an insertion or deletion more likely to be deleterious than a substitution?

CHAPTER 22
DESCENT WITH MODIFICATION: A DARWINIAN VIEW OF LIFE

Learning objectives

The Historical Context for Evolutionary Theory

41. Explain the mechanism for evolutionary change proposed by Charles Darwin in *On the Origin of Species*.
42. Define **evolution** and **adaptation**.
43. Describe the theories of catastrophism, gradualism, and uniformitarianism.
44. Explain the mechanism for evolutionary change proposed by Jean Baptiste Lamarck. Explain why modern biology has rejected Lamarck's theories.

The Darwinian Revolution

45. Describe how Darwin's observations on the voyage of the HMS *Beagle* led him to formulate and support his theory of evolution.
46. Explain how the principle of gradualism and Charles Lyell's theory of uniformitarianism influenced Darwin's ideas about evolution.
47. Explain what Darwin meant by "descent with modification".
48. Explain what evidence convinced Darwin that species change over time.
49. Explain how Linnaeus's classification scheme fit Darwin's theory of evolution by natural selection.
50. Describe the four observations and two inferences that lead Darwin to propose natural selection as a mechanism for evolutionary change.
51. Distinguish between artificial selection and natural selection.
52. Explain why an individual organism cannot evolve.
53. Explain why natural selection can act only on heritable traits.

The Evidence for Evolution

54. Explain how the fossil record may be used to test our current understanding of evolutionary patterns.
55. Explain how the existence of homologous and vestigial structures can be explained by Darwin's theory of natural selection.
56. Explain how evidence from biogeography supports the theory of evolution by natural selection.

CHAPTER 23
THE EVOLUTION OF POPULATIONS

Learning objectives

Genetic Variation, the Substrate for Natural Selection

1. Explain the statement "It is the population, not the individual, that evolves."
2. Explain how Mendel's particulate hypothesis of inheritance provided necessary support for Darwin's theory of evolution by natural selection.

Mutation and Sexual Recombination

3. Explain why the majority of point mutations are harmless.
4. Explain how sexual recombination generates genetic variability.

The Hardy-Weinberg Principle

5. Define the terms **population**, **species**, and **gene pool**.

Natural Selection, Genetic Drift, and Gene Flow

6. Explain the following statement: "Only natural selection leads to the adaptation of organisms to their environment."
7. Explain the role of population size in genetic drift.
8. Distinguish between the bottleneck effect and the founder effect.
9. Describe how gene flow can act to reduce genetic differences between adjacent populations.
10. Define relative fitness.
11. Distinguish between intrasexual selection and intersexual selection.
12. Explain how diploidy can protect a rare recessive allele from elimination by natural selection.
13. List four reasons why natural selection cannot produce perfect organisms.

CHAPTER 24
THE ORIGIN OF SPECIES

Learning objectives

What Is a Species?

1. Define Ernst Mayr's biological species concept.
2. Distinguish between prezygotic and postzygotic reproductive barriers.
3. Describe five prezygotic reproductive barriers and give an example of each.
4. Explain a possible cause for hybrid breakdown.
5. Explain how hybrid breakdown maintains separate species even if fertilization occurs.
6. Describe some limitations of the biological species concept.
7. Be aware of differences in the following: ecological species concept, phylogenetic species concept, and morphological species concept.

Modes of Speciation

8. Distinguish between allopatric and sympatric speciation.
9. Define allopatric speciation. Describe the mechanisms that may lead to genetic divergence of isolated gene pools.
10. Explain how reproductive barriers evolve. Describe an example of the evolution of a prezygotic barrier and the evolution of a postzygotic barrier.
11. Define sympatric speciation and explain how polyploidy can cause reproductive isolation.