Chapter 1: The Science of Biology

In this chapter, you will review the definition of biology and the characteristics of living things. You will also learn how the study of science leads to an understanding of the natural world and see how science is done in the real-life. Finally, this chapter covers the themes that unify all of the concepts that you will learn in your study of biology. As you prepare for the AP Biology Exam, review the material in this book with these themes in mind, and be sure that you can apply what you are learning to *at le*ast one of these themes.

1.1 The Science of Life

Biology is the study of life. Though living things, or organisms, are quite diverse, there are some characteristics that they all share:

- Cellular organization: All organisms have one or more cells. All cells have DNA, cytoplasm, a plasma membrane, and ribosomes.
- Ordered complexity: Living things are organized and have complex structures. These structures directly dictate the functions that occur within an organism.
- Sensitivity: Organisms are sensitive to and can respond to stimuli in their environment.
- Growth, development, and reproduction: Organisms pass hereditary material, DNA, to offspring; DNA codes for proteins, which are used for cellular functions. All cells are produced from preexisting cells. Organisms have the capacity to grow (become larger) and develop (become more complex).
- Energy utilization: Organisms obtain energy from consuming organic molecules, and use this energy to perform work. Work includes many cellular functions such as movement, transport, growth, and reproduction.
- Homeostasis: Organisms maintain a constant internal environment. The internal environment of a cell is separated from the external environment by a plasma membrane.
- Evolutionary adaptation: Populations evolve over time as they adapt to changes in the environment. All organisms share many characteristics, such as DNA and cell membranes, but evolution has increased the diversity of organisms on the earth.

TAKE NOTE: *You should understand the characteristics of living things and be able to compare (describe similarities and differences) these characteristics between phyla or domains. You must be able to make the connection between form and function.*

There are many levels of organization within biological systems; each level builds upon the ones preceding it.

- *Cellular:* Atoms form molecules, which are used to build organelles and cells.
- *Organismal:* Cells are arranged in tissues, which are organized into organs, organ systems, and organisms.
- *Population:* Individual organisms of the same species are grouped into populations, which together with other kinds of species, form communities.
- *Ecosystem/Biosphere:* Communities live within an abiotic environment, forming an ecosystem. All of Earth's ecosystems make up the biosphere, the entire planet where life exists.

1.2 The Nature of Science

At its core, science is concerned with understanding the nature of the world by using observation and reasoning.

Deductive reasoning uses general principles to explain specific outcomes, while inductive reasoning uses specific observations to construct general principles. Most scientists use inductive reasoning to analyze results and explain observations.

Scientists study the world using hypothesis-driven processes that consist of several steps:

- Observation: You observe an event or an object.
- Question: You ask questions about the observation.
- Hypothesis: You formulate a statement that is a testable explanation of the question. A hypothesis is most useful when it makes a prediction.
- Experiment: You design an experiment that tests your hypothesis.
    - Variables: An independent variable is manipulated and the dependent variable changes in response. All other variables are kept constant.
    - Control: The control is not exposed to the independent variable so it can be compared to the treatment group(s); this helps verify that the results are due to the variable being tested rather than some other factor.
    - Controlled Variables: These are variables other than the independent variable; these variables (conditions) are held constant during the experiment.
- Results: You make measurements during the experiment which you analyze.
- Conclusion: You formulate a decision based upon the data analyses and either reject or not reject your hypothesis.

The word theory can be used in two ways: 1) an explanation of a natural phenomenon; or 2) an interrelated set of concepts in a particular area of study supported by much experimental evidence.

TAKE NOTE: The AP Biology examination will require you to design experiments and/or interpret experimental results. You may be asked to do this in either or both the multiple-choice and free-response sections.

- *Clearly state a hypothesis and explain its rationale.*
- *Propose a control group and explain its purpose.*
- *Include several samples for each group.*
- *Identify the dependent and independent variables.*
- *Indicate the variables that will be held constant; these are called the controlled variables. Examples include conditions such as temperature, pH, and volume.*
- *Clearly describe how you will run the experiment.*
- *Describe how the dependent variable changes in response to the independent variable.*
- *Describe how you will make measurements and/or collect data.*
- *Indicate that you will repeat the experiment several times; this will validate the data.*
- *Indicate how you will analyze your data. You may be asked to make a graph or do a Chi-square test. Graphs must have properly labeled axis with units, with the dependent variable on the y-axis and the independent variable on the x-axis.*
- *Clearly state a conclusion by indicating whether the results lead you to reject or not reject your hypothesis.*

1.3 An Example of Scientific Inquiry: Darwin and Evolution

Evolution is the overarching theme in biology. There is much evidence for natural selection as the mechanism for evolution. The evidence includes:

- Fossil record: The fossil lineage in rocks contains transitional forms of current organisms.
- Age of Earth: Earth is over 4.5 billion years old. This has provided ample time for organisms to evolve.
- Heredity mechanisms: DNA contains the genetic material. The DNA sequence mutates, giving rise to changes within organisms.
- Comparative anatomy: Many organisms have similar anatomical/morphological features; some of these features are homologous, which means that have the same evolutionary origin, but different structures and functions. Vertebrate limbs are examples of homologous structures. Analogous structures, such as the wings of butterflies and birds, have similar functions, but different evolutionary origins.
- Molecular Evidence: Comparison of DNA and amino acid sequences (proteins) indicate genetic change. Closely related organisms have fewer changes than more distantly related organisms.

Evolutionary relationships between organisms can be represented by a phylogenetic tree. The tree has as its root a common ancestor which gave rise to the particular lineage of interest. Organisms are classified into three domains: Bacteria, Archaea, and Eukarya. Domain Eukarya has four kingdoms: Plantae, Animalia, Fungi, and Protista.

TAKE NOTE: *Evolution is the change in populations over time. Natural selection is the process by which evolution occurs. You must understand that surviving organisms must reproduce and pass their genetic material (DNA) onto the next generation.*

1.4 Unifying Themes of Biology

Though your study of biology will involve many different topics, you will find that there are common themes that unify them:

- Cell theory describes the organization of living systems.
- The molecular basis of inheritance explains the continuity of life.
- The relationship between structure and function underlies living systems.
- The diversity of life arises by evolutionary change.
- Evolutionary conservation explains the unity of living systems.
- Cells are information-processing systems.
- Living systems exist in a nonequilibrium state.

TAKE NOTE: *You should be able to describe the unifying themes in biology. Look for these themes throughout your entire study of biology this year.*

Multiple-Choice Questions

1. Charles Darwin collected and analyzed much evidence in formulating his theory of natural selection and evolution. Which of the following was NOT used by Darwin?
   (A) structural changes in organisms produced by artificial selection
   (B) Malthus's ideas on human populations and food production
   (C) the fossil lineage which had gradual changes
   (D) creation of Earth 6,000 years ago
   (E) similarities between island and mainland species

2. The smallest unit of life is a(n)
   (A) atom.
   (B) molecule.
   (C) organelle.
   (D) cell.
   (E) tissue.

3. Darwin, based upon ideas developed by Maltus, observed that populations have the capacity to grow _____, but due to _____, population sizes grow more slowly and the nature of the population changes.
   (A) arithmetically; evolution
   (B) arithmetically; natural selection
   (C) arithmetically; mutation
   (D) exponentially; evolution
   (E) exponentially; natural selection

4. You decide to monitor the growth of roses in response to fertilizer application. The roses are in a sunny garden and you water the roses every day. What is the dependent variable in your experiment?
   (A) rose growth
   (B) amount of sunlight
   (C) fertilizer concentration
   (D) amount of water
   (E) rose variety

5. You react by pulling your finger away from a hot stove. You are demonstrating _____, which is a characteristic of all organisms.
   (A) development
   (B) complexity
   (C) homeostasis
   (D) adaptation
   (E) sensitivity

6. A tomato leaf is at the _____ level of hierarchical organization.
   (A) molecule
   (B) organelle
   (C) cellular
   (D) organ
   (E) organismal

7. The best definition of a hypothesis is a(n)
   (A) fact.
   (B) observation.
   (C) scientific theory.
   (D) possible explanation.
   (E) question.

8. Your heart, arteries, capillaries, and veins make up
   (A) an organism.
   (B) an organ.
   (C) an organ system.
   (D) tissues.
   (E) cells.

9. The plants, fungi, protests, bacteria, and animals in a temperate deciduous forest form a(n)
(A) biosphere.
(B) ecosystem.
(C) community.
(D) population.
(E) organism.

10. Comparisons of cytochrome c sequences (cytochrome c is a protein) between organisms showed the following differences.

Number of Amino Acid Differences in Cytochrome c

	Whale	Chicken	Snake	Yeast	Wheat
Whale	0	9	18	45	44
Chicken		0	18	46	46
Snake			0	46	46
Yeast				0	47
Wheat					0

Which organisms are the most closely related based upon the data provided?
(A) whale and chicken
(B) chicken and snake
(C) chicken and yeast
(D) yeast and wheat
(E) whale and wheat

Free-Response Question

1. A scientist wants to know how much carbon dioxide (CO_2) gas is produced by yeast in the presence various sugars in comparison to glucose. She mixed yeast with 2% sugar solutions in test tubes, incubated the test tubes at 37°C, and measured the volume of gas produced at 5 minute intervals for 30 minutes. There were five replicates for each treatment. Her results are below:

   Volume of gas produced, mL; average of five replicates

Time (minutes)	2% glucose	2 % fructose	2 % lactose
0	0	0	0
5	1	0.5	0
10	2	0.9	0
15	4	1.5	0.1
20	5	1.8	0.1
25	7	2.2	0.1
30	8	2.5	0.1

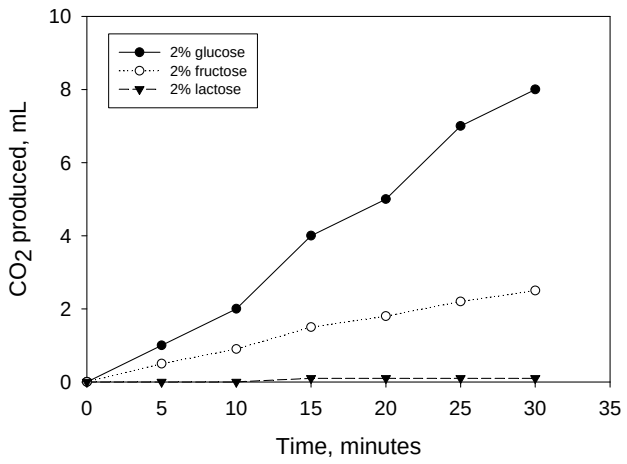
   (a) Plot the results on the graph paper provided.
   (b) What was the control for her experiment?
   (c) What are two factors that she held constant during the experiment?
   (d) Provide one explanation as to why the yeast produced little CO_2 when incubated with lactose.

Multiple-Choice Answers

1. (D) Darwin knew that the Earth was older than thousands of years.
2. (D) A cell has all of the characteristics of life.
3. (E) Malthus wrote that populations could increase exponentially, but Darwin realized that population size increases more slowly and that the population's characteristics change due to natural selection.
4. (A) The rose growth differs due to fertilizer concentration; fertilizer concentration is the independent variable. All the other conditions are held constant.
5. (E) You are reacting to an external stimulus.
6. (D) A plant leaf is an organ.
7. (D) A hypothesis is a question restated as a testable explanation.
8. (C) These organs and structures are parts of the vascular organ system.
9. (C) A community consists of the populations of different organisms living in the same place at the same time.
10. (A) The whale and the chicken have the fewest amino acid differences, and thus, are most closely related.

Free-Response Rubric

1. (a) Graph is worth 3 points:
   1 point of correct orientation of independent and dependent variables
   1 point for axis labels with proper units
   1 point for correct plotting (line and scatter plot, NOT a bar graph) with symbols for each sugar



   (b) 1 point for correctly identifying the 2% glucose as the control treatment

   (c) 1 point for each factor; only the first two are considered.
   - Temperature
   - Sugar concentration
   - Yeast concentration
   - Volume of solutions
   - pH
   - Type of tubes/apparatus for measuring gas production

   (d) 1 point for a possible explanation of no gas production with lactose
   - Yeast cannot metabolize (ferment) lactose
   - Yeast lack lactase
   - Lactose inhibits yeast