Chapter 1 Lecture Notes

Introduction A Big-Billed Bird Rebounds

A. Self-introduction.

B. Administrative details.

C. Introduction to class content and course organization.

D. Introductory comments about the science of biology.

E. Core themes in biology.

1. How do biologists organize their subject matter?

Biology is a broad collection of subdisciplines such as evolution, ecology, zoology, cell biology, and genetics.

2. Can we uncover some common concepts that underlie all biological study?

Evolution is the unifying theory of biology. All living organisms are composed of cells, which are the basic units of life. All life forms are related and use DNA and RNA. The genetic code is virtually universal. Biological study unifies the concepts of structure and function.

NOTE: As a preface to your review of the themes and characteristics of life, ask your students what they hope to get from the course, and discuss how the material to be covered in the course is relevant to their lives.

F. To begin, we start our study of biology by focusing on the relationship between the brown pelican, the fish they eat, and the humans with whom the brown pelican must compete for space and resources.

I. The Scope of Biology

Module 1.1 Life’s levels of organization define the scope of biology.

A. The levels at which life is organized are (from most to least inclusive): biosphere, ecosystem, community, population, organism, organ system, organs, tissues, cell, organelles, and molecules (Figure 1.1).

NOTE: Ask your students for examples, other than those in Figure 1.1, of each level of organization. Distinguish between unicellular and multicellular organisms.

B. These levels represent a hierarchy because each level is built of parts at successively lower levels of organization.

C. Biological researchers investigate the full spectrum of life, from the biosphere to the biochemical reactions within a cell.

Preview: The dynamics of higher levels of organization are discussed in Chapters 36 (populations) and 37 (communities and ecosystems).

Module 1.2 Living organisms and their environments form interconnecting webs.

A. Living things do not exist in isolation from their environment. An organism’s environment includes both living and nonliving components.

B. Plants, as well as certain prokaryotes and protists, use carbon dioxide, water, minerals, and the energy of sunlight to make food for themselves by the process of photosynthesis. Organisms that can make their own food are called producers.

Preview: The process of photosynthesis is discussed in detail in Chapter 7.

C. All animals are ultimately dependent upon plants for food and are called consumers. Animals use oxygen and give off carbon dioxide. Animals return minerals to the environment when they defecate or die.

D. Decomposers, such as prokaryotes, fungi, and small animals, are important for the recycling of complex organic matter and changing it into simple mineral nutrients that plants can use.

Preview: Nutrient cycles can be divided into separate chemical or molecular cycles. Nutrient cycles are discussed in Chapter 37 and Modules 37.15 through 37.19 and are important for understanding ecosystems.

E. Two major processes are at work in an ecosystem and are illustrated in Figure 1.2:

1. The recycling of chemical nutrient in an ecosystem.

2. The flow of energy through the ecosystem.

F. Chemicals or molecules that are recycled in an ecosystem include carbon dioxide, oxygen, water, and various other minerals. Energy is not recycled but passes through an ecosystem. It enters as sunlight and leaves as heat.

Module 1.3 Cells are the structural and functional units of life.

A. Cells are the basic unit of life that can perform all functions necessary for life. A cell can:

1. Regulate its internal environment.

2. Take in and use energy.

3. Respond to its local environment.

4. Develop and maintain its complex organization.

5. Divide to form new cells.

B. An important theme of biology is the emergent property that states life is dependent on the organizational levels of a cell. More aptly put, “the whole is greater than the sum of its parts.” The combination of the parts that form a more complex organization, regardless if it is a cell or a community, is called a system. The challenge to biologists is to understand the systems of biology.

C. All organisms are composed of cells. There are two basic types of cells: prokaryotes and eukaryotes (Figure 1.3). Prokaryotes are smaller and less complex than eukaryotes, and we commonly call them bacteria. Eukaryotes are generally larger and more complex than prokaryotes. The complexity arises from the use of organelles to compartmentalize functions within eukaryotic cells.

D. Irrespective of the differences between prokaryotes and eukaryotes, they do have common characteristics. For example, all cells use DNA as the genetic material.

Preview: An introduction to the cell and the differences between prokaryotic and eukaryotic cells is presented in Chapter 4.

II. Evolution, Unity, and Diversity

Module 1.4 The unity of life: All forms of life have common features.

A. Life is diverse, but there are common themes that all living things exhibit.

Preview: When viewed under a microscope, all cells look very similar (Chapter 4).

B. Genetic information within all cells is DNA (Figure 1.4A). Variations within the sequence of DNA determine the diversity we see among organisms. However, because all organisms use DNA, a gene from one species can be inserted into a different species, and the gene will still be functional. The insertion of the human gene for insulin into a bacterial cell is a perfect example.

Preview: DNA is composed of nucleotides that contain the genetic information of all cells (Chapter 3; Module 3.16).

C. Other common properties of organisms are presented below.

1. Order: All living things have complex organization (Figure 1.4B).

2. Regulation: Organisms regulate their internal environment (Figure 1.4C).

3. Growth and development: Genes control the pattern of growth and development.

4. Energy use: Energy is taken in and transformed to a stable, useable from.

5. Response to the environment: All organisms respond to their environment   
(Figure 1.4D).

6. Reproduction: Organisms reproduce their own kind (Figure 1.4E).

7. Evolution: Reproduction fosters change over time.

D. You might want to focus on one group of organisms to emphasize the point that at each level of biological organization, there is similarity and diversity. For example, have the students describe the characteristics of a bird, and then ask them to name as many birds as they can.

Module 1.5 The diversity of life can be arranged into three domains.

A. Biologists look at life both vertically, as in Figure 1.1, and horizontally. There is a stunning array of different species that inhabit or once inhabited the Earth. Species is the term used for one type of organism (e.g., Homo sapiens or Pelecanus occidentalis).

B. Making sense of the diverse life forms in the world, or even in a complex environment such as a tropical rain forest, can be overwhelming. To organize and simplify the process, we need a system for categorizing these living things. The process of placing organisms into groups and giving them names is called taxonomy.

C. A classification system used up until the past decade placed all organisms into five kingdoms. This taxonomic scheme has been replaced with the domain system of classification, which enables biologists to group organisms using classical and molecular taxonomy (structure and function, and DNA and RNA sequence analysis).

D. The three domains can be divided into two groups: cells without a nucleus (prokaryotes) and cells with a nucleus (eukaryotes). Taxonomists are still debating the number of kingdoms within the three domains.

Preview: The differences between prokaryotes and eukaryotes are discussed in greater detail in Chapter 4.

E. Domain Bacteria includes unicellular prokaryotes that lack a nucleus (Figure 1.5A).

F. Domain Archaea includes unicellular prokaryotes (Figure 1.5B). As will be discussed in Chapter 16, this domain has characteristics of both Eukarya and Bacteria.

Preview: Differences between the Bacteria and Archaea are highlighted in Module 16.8.

G. Domain Eukarya includes unicellular and multicellular eukaryotes. A group of organisms called protists are shown in Figure 1.5C. This group is extremely diverse and will be divided into several kingdoms (some day). This group includes algae and protozoa.

H. The other three kingdoms included in the domain Eukarya are kingdom Plantae (multicellular photosynthetic autotrophs with ridged cell walls made of cellulose; Figure 1.5C), kingdom Fungi (mostly decomposers: molds, yeast, and mushrooms; Figure 1.5C), and kingdom Animalia (multicellular heterotrophs, cells without a cell wall; Figure 1.5C).

Preview: The three-domain system is discussed further in Module 15.10.

Module 1.6 Evolution explains the unity and diversity of life.

Preview: This module previews Unit III, especially Chapter 13.

A. Darwin’s book on evolution presented two important concepts.

1. Species evolved from ancestors, and there was modification in the process or, as Darwin stated, “descent with modification.”

2. Natural selection occurs as heritable variations are exposed to environmental factors that favor the reproductive success of some individuals over others.

B. The synthesis of the idea for natural selection was inferred by Darwin from two observable features of life.

1. Individual variation: individuals in a population have variable inheritable traits.

2. Unequal reproductive success: a population of a species will overproduce offspring, and not all will survive and reproduce due to competition.

C. From these two observations, Darwin proposed the idea of “Unequal reproductive success.” Those individuals with the most suitable traits for the current environmental conditions will survive and reproduce, passing on those traits to their offspring.

D. The product of natural selection is adaptation, the collection of favorable modifications in a population over time.

E. A simplified example of natural selection is presented in Figure 1.6B. Light gray beetles are favored by birds and are eaten, removing them from the beetle population before they can reproduce, which leaves the dark beetles to pass their traits on to future generations.

F. Evolution explains why organisms are adapted to their environments. A pangolin and killer whale are good examples of animals with many visible adaptations to a particular environment (Figure 1.6C).

III. The Process of Science

Module 1.7 Scientists use two main approaches to learn about nature.

A. Science is a way of knowing. The word science is derived from the Latin word for “to know.” There are no absolute truths in science, and all that we understand about nature comes from our ability to observe the world around us. Scientists do not “believe” in something. Instead scientists have levels of confidence in explanations for natural phenomena.

B. Two approaches are commonly used by scientists to understand nature.

1. Discovery science is the process of gathering data by verifiable observations and measurements to explain natural phenomena. Pelicans diving into water to capture their prey or the sequence of human DNA are mere observations. From many careful observations, a process of inductive reasoning can lead to important conclusions such as the cell is the basic unit of life.

2. Hypothesis-driven science is conclusions drawn from the observations taken during “discovery science,” which lead the inquisitive scientist to ask more questions. Why do pelicans dive so fiercely into the water when seeking fish, or what is the function of the DNA sequence?

C. What is a hypothesis? A hypothesis is a tentative or educated guess at an answer to a problem or question that is being asked. A good hypothesis makes predictions that can be tested. Part of the process of hypothesis-based science uses deductive reasoning, which flows from a general premise to a specific premise. The important aspect of this process is that the deduction can be tested.

Module 1.8 With hypothesis-based science, we pose and test hypotheses.

A. The five steps of the scientific method are listed below with a brief explanation of each step.

1. Observations come from others or results of earlier tests.

2. Questions are asked about unclear aspects of the observations: How? Why? When?

3. Hypotheses are tentative explanations of a phenomenon phrased in such a way as to be testable.

4. Predictions are logical, testable outcomes of the hypotheses developed by the use of deductive reasoning. Predictions take the form of if (statement of hypothesis) is true, then (predictions).

5. Tests of prediction are performed to determine if the predictions are supported (fail to falsify) or falsified.

Preview: In addition to Module 1.8, other good examples of the application of the process of science to a problem can be found in, but are not limited to, Modules 36.7 (evolution shapes life histories), 37.20 (studies at Hubbard Brook), and Chapter 35 (Lorenz’s and Tinbergen’s studies on animal behavior).

B. Case studies illustrate the scientific process.

1. A Case Study from Everyday Life: The flashlight is a common household item that can be used to clearly demonstrate the scientific process. “How do you figure out how to fix it?” (Figure 1.8A).

2. A Case Study of Hypothesis-Based Science: The biological case study of the coral snake (Figure 1.8B) versus the king snake (Figure 1.8C) demonstrates the use of the scientific method. This experiment answers the question regarding the ring pattern of the king snake and the behavior of predators toward attacking coral snakes and king snakes (Figures 1.8D and E).

C. Two important qualities of the hypothesis-based science are illustrated in the flashlight example.

1. A hypothesis must be testable.

2. A hypothesis must be falsifiable.

A hypothesis becomes credible when repeated attempts to disprove it fail.

IV. Biology and Everyday Life

Module 1.9 Connection: Biology is connected to our lives in many ways.

A. Biology in the news has an enormous impact on our everyday lives (Figure 1.9). Some examples of biology in the news are endangered species, genetically modified crops, global warming, water and air pollution, cloning of embryos, nutrition controversies, emerging diseases, and medical advances.

Preview: These environmental concerns are discussed in more detail in Chapter 38.

B. Technology is the practical application of scientific knowledge and discovery. Scientists speak of discoveries, while engineers speak of inventions. Scientists and engineers benefit from the work and success of each other.