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invitation to biology

Chapter Outline

1.1 The Secret Life of EArth

1.2 LIFE IS MORE THAN THE SUM OF ITS PARTS

1.3 hOW lIVING THINGS ARE ALIKE

Organisms Require Energy and Nutrients

Organisms Sense and Respond to Change

Organisms Use DNA

1.4 How Living Things differ

1.5 Organizing information about species

A Rose by Any Other Name. . .

1.6 the science of nature

Thinking about Thinking

The Scientific Method

1.7 EXAMPLES OF EXPERIMENTS IN BIOLOGY

Potato Chips and Stomach Aches

Butterflies and Birds

1.8 analyzing experimental results

Sampling Error

Bias in Interpreting Results

1.9 the nature of science

The Limits of Science

1.10 THE SECRET LIKE OF EARTH (REVISITED)

SUMMARY

Self-Quiz

data analysis Exercise

Critical Thinking

Learning Objectives

1. Examine why it is important to understand our natural world.
2. List the eleven levels of life’s organization.
3. Outline the significance of energy and nutrients to organisms.
4. Examine how classification helps in understanding biodiversity using examples.
5. Examine the importance of taxonomy in the classification of different species.
6. Examine the importance of critical thinking in the application of the scientific method.
7. Recognize the importance of experimental research to the field of biology using an example.
8. Examine how sampling errors occur in scientific experiments and what methods researchers use to combat errors and bias.
9. Examine how science works.
10. Examine the limits of science.

Key Terms

animals

archaea

atoms

bacteria

biodiversity

biology

biosphere

cell

community

consumers

control group

critical thinking

data

deductive reasoning

dependent variable

development

DNA

ecosystem

emergent properties

energy

eukaryotes

experiment

experimental group

fungus, fungi

genus, genera

growth

homeostasis

science hypothesis

independent variable

inductive reasoning

inheritance

law of nature

model

molecules

nucleus

nutrient

organs

organ systems

organism

photosynthesis

plants

population

prediction

probability

producer

prokaryotes

protists

reproduction

sampling error

science

scientific method

scientific theory

species

specific epithet

statistically significant

taxon

taxonomy

tissues

traits

variable

Lecture Outline

1*.*1 The Secret Life of Earth

A. Are there any places left on Earth that have not been explored?

1. Yes: a 2005 trip to New Guinea discovered many new plant and animal species.

2. New species, mostly smaller organisms, continue to be discovered every day.

B. The more we learn about nature, the more we realize how much more there is to learn.

C. This text helps students discover “life,” that is, how organisms are constructed, how they live, etc.

1.2 Life Is More Than the Sum of Its Parts

A. Pattern in Life’s Organization

1. Biologists examine all aspects of life, from the smallest atom to global communities.

2. Cells are the fundamental building blocks of life.

3. The levels of organization grow in complexity: atoms 🡪 molecules 🡪 cells 🡪 organism.

4. Multicellular organisms have increasingly complex levels of organization that result in tissues 🡪 organs 🡪 organ systems 🡪 organisms 🡪 populations 🡪 communities 🡪 ecosystems 🡪 biosphere.

5. At each successive level of organization, emergent properties can be detected.

1.3 How Living Things Are Alike

A. Organisms Require Energy and Nutrients

1. Energy, the capacity to do work, moves through the universe in a series of transfers.

2. Higher levels of organization would cease without energy inputs from the environment.

3. Energy flows from the sun.

a. Producers (plants and other photosynthetic organisms) make their own food by converting sunlight to usable energy.

b. Consumers (animals and decomposers) cannot make food, but use other organisms to obtain their energy and molecular building blocks (carbohydrates, fats, and proteins).

4. Energy flows one way through producers, consumers, and back to the environment.

5. Energy flow is not 100 percent efficient, as heat (a form of energy) is lost at each transfer stage.

B. Organisms Sense and Respond to Change

1. Receptors and the stimuli they receive allow organisms to make controlled responses to heat and cold, harmful substances, and varying food supplies.

2. All organisms undergo homeostasis, a state in which the conditions of the “internal environment” are maintained within tolerable limits.

C. Organisms Use DNA

1. Deoxyribonucleic acid, or DNA, is considered the signature molecule of life.

a. DNA carries the hereditary instructions that allow organisms to grow and reproduce.

2. Inheritance is the acquisition of traits through the transmission of DNA from parents to offspring.

1.4 How Living Things Differ

A. Organisms may vary greatly, which we call Earth’s biodiversity.

B. One way animals can be classified is based on whether their DNA is contained in a nucleus.

1. Bacteria and archaea are single-celled organisms with DNA located outside the nucleus.

2. Eukaryotes are organisms with DNA housed inside the nucleus.

a. Protists are simple eukaryotes that are often single-celled organisms.

b. Fungi are eukaryotes that often act as decomposers.

c. Plants are photosynthetic eukaryotes that serve as food for many other organisms.

d. Animals are multicellular eukaryotes that act as consumers.

1.5 Organizing Information about Species

A. Taxonomy is a system of naming and classifying species.

1. Carolus Linnaeus developed the two-part naming system that is still in use today.

a. The first part of the name is the genus.

b. The second part of the name is known as the specific epithet.

2. Species are classified into taxa, which are groups of organisms that share a unique set of features.

B. A Rose by Any Other Name. . . .

1. Traits can vary and are used to classify organisms.

a. Traits may be based on morphology or processes, such as DNA analysis.

b. Ernst Mayr developed the biological species approach, which is based on the ability of organisms to produce fertile offspring.

1.6 The Science of Nature

A. Thinking about Thinking

1. All scientific research involves critical thinking—judging information before accepting it.

2. Students should avoid accepting information without question, or failing to consider recognized biases, when processing new scientific information.

B. How Science Works

1. Common research practices follow a step-by-step approach known as the scientific

method.

a. Observe an aspect of nature.

b. Ask a question or state a problem relating to the observation.

c. Develop hypotheses (testable explanations) of the observed phenomenon or process.

d. Make a prediction of what the outcome would be if the hypothesis were valid (deductive, “if-then” reasoning).

e. Test predictions by experiments, models, and observations.

f. Assess the results of such tests.

g. Report objectively on the tests and conclusions.

1.7 Examples of Experiments in Biology

A. Potato Chips and Stomach Aches

1. A Chicago theater was chosen as a “laboratory” to determine if the synthetic fat called Olestra® caused gastrointestinal cramps.

2. Both control and experimental groups were random samples of moviegoers who had no idea which fat-impregnated chips they were eating.

3. Later, the moviegoers were called at home to determine the extent of gastrointestinal

distress.

1. The results: 15.8 percent of people who consumed Olestra had discomfort vs. 17.5 percent that did not consume Olestra.
2. As a result of this study, it does not appear that Olestra causes abdominal distress.
3. Butterflies and Birds

1. Researchers of peacock butterflies observed two actions.

a. When a peacock butterfly rests, it folds its wings so only the dark underside shows.

b. When a butterfly sees a predator, it repeatedly flicks its paired forewings and

hindwings open and closed, a movement that both makes wingspots visible and

produces hissing and clicking sounds.

1. Noises when predators approach—may help peacock butterflies avoid predation.
2. The combination of both activities—camouflage at rest and owl-like eyes (wingspots); ion experiments, in which experimenters manipulated the presence of wingspots or the ability to make the clicking and hissing sounds, revealed that birds are indeed deterred

by peacock butterfly sounds, and even more so by wingspots.

1.8 Analyzing Experimental Results

A. Sampling Error

1. Sampling errors occur when conclusions inferred from the subset differ from results from the whole population.

a. Sampling errors occur most often when sample sizes are small.

b. Selecting a larger population subset or repeating the experiment many times may reduce sampling error.

B. Bias in Interpreting Results

1. It is often difficult to study the change in a single variable in human populations.

a. For example, the participants in the Olestra study also varied in age, gender, health

status, etc.

2. Researchers use critical thinking skills to remove bias from their studies.

1.9 The Nature of Science

A. When the hypothesis of an experiment is supported via years of collecting evidence, it is called a scientific theory.

1. A scientific theory can be rejected by a single finding or observation.

B. A law of nature is an observed phenomenon for which there is no current scientific explanation.

C. The Limits of Science

1. Science does not address moral, spiritual, supernatural events, or other intangibles.

1.10 The Secret of Life of Earth (Revisited)

1. Over 100 million species exist on Earth today.
2. New species are still being discovered and classified each year.

Suggestions for Presenting the Material

* Although Chapter 1 is a general introduction to biology and to this textbook, it will be viewed very differently by instructor and student. For the instructor, this chapter is a *review* rather than a *pre­view.* That means the instructor must take extra care not to “intimidate” the students during early lectures by offering more terms and definitions than the student can reasonably absorb.
* A casual glance at the chapter contents will reveal terms unfamiliar to most students. These might include *emergent properties, prokaryotic,* and *homeostasis.* In­dividual instruc­tors should decide if these terms need explanation now or are to be deferred until later. This decision may depend on the time available.
* Figure 1.2 (levels of organization) is an excellent “road map” and can be used throughout the course to guide the progres­sion along the organizational ladder. It can also be used in the exercise listed in the Enrichment section below.
* The diagram in Figure 1.3 (energy and nutrient movement in/around a system) also has relevance to future lectures. When introducing it here, you should stress the *flow* of *energy* through a system versus the *recycling* of nutrients and other *raw materials.*
* Sometimes students think the methods of scientific investigation in section 1.6 are used only by scientists. Show that this is not true by discussing the use of these meth­ods in a rou­tine investigation of “Why won’t the car start?” (See the Enrichment section below.)
* Some students may think that the scientific method is the only way scientists conduct experiments. Give examples of natural history-based observational studies, or even discuss “The Human Genome Project”—both types of studies are very useful in today’s world.
* Explain carefully the necessity for “control” groups in scientific investigations. Point out the dif­ficulty of determining which groups of human patients will *not* receive a valuable drug (the con­trols) and who will receive a possibly life-saving medication.

Classroom and Laboratory Enrichment

* Generate interest in “discovery” science by showing a slideshow of animals and plants that have been discovered by scientists in recent years. Examples may include: a horned toad (genus *Proceratophrys*) in Brazil (2008); a giant elephant-shrew called the gray-faced sengi (*Rhynchocyon udzungwensis*)in Tanzania (2008); the floral-banded wobbegong shark (Orectolobus floridus), discovered off the coast of Australia (2008); and the Togian white-eye bird (*Zosterops somadikartai*), discovered on a small Indonesian island (2008), the olinguito (*Bassaricyon neblina*) in the Amazon (2013), and the leaf-tailed gecko (*Saltuarius eximius*) in Australia (2013). A quick search of the internet for photos of these animals would provide much fodder for discussion.
* Bring several organisms into the classroom or lab and various nonliving things (e.g., rocks, candle with flame, even dirt). Ask your students to name characteristics that identify each item as living or nonliving (for some organisms, this may be difficult to do without specialized equipment, such as a microscope).

Ask the students to identify equipment or experi­ments that would help to determine if an item is a living organism. Challenge them to think about how they would classify dirt—living or nonliving—and why.

* Illustrate the levels of organization in nature with Figure 1.2. With the labels of the figure covered, ask your students to help you name each higher level from simple to complex.
* Show *Life on Earth* by David Attenborough as a general introduction to biological diversity.
* Take the time to discuss how scientific names were developed—with Latin as a basis—and present scientific names for local plants and animals that are well known to the students. Interpret the meaning of each Latin-specific epithet. An example would be the raccoon, *Procyon lotor*. The Latin translation means “early-dog” (*Procyon*: an ancestor of the dog) “swimming” (*lotor*: often found along waterways, often “plays” with its food in the water before eating it). A second example might be the house mouse, a common household pest. Its scientific name, *Mus musculus*, means “mouse tiny-mouse” or often translated as “thief tiny-thief,” likely related to its ability to steal food from homes!
* Show a phylogenetic tree of vertebrates (or any other group of organisms for which a phyloge­netic tree is available) to demonstrate the phylogenetic system of classification. Present students with a set of diverse organisms and ask them how they would classify these organisms. You can add as much detail in the classification as you prefer: grouped by domain, kingdom, phylum, or more. You may wish to hold off going to further levels of classification until students have gone through the diversity chapters and have a better feel for classification.
* Present fossil evidence showing how a group of related organisms or a single genus has evolved and changed through time (for example, the horse, *Equus*, and its ancestors show a complete fossil record).
* Briefly list the steps of the scientific method in the wrong order. Ask the class to place them, one by one, in the correct order.
* Show how we use the scientific method in everyday problem solving, as illustrated by this example:

*Event Method Step*

a. Auto will not start a. Observation

b. Battery dead b. Hypothesis

Ignition problem Hypothesis

Out of gas Hypothesis

c. Turn on headlights c. Experiment

Check spark plug Experiment

Check gas gauge Experiment

Dip long stick into gas tank Experiment

d. Headlights burn brightly (battery OK) d. Analyze results

Strong ignition spark Analyze results

Gauge says half tank, but no gas on stick Analyze results

e. Gas gauge is not accurate; car needs gas

to run e. Generalize; form principle

* Present an observation to the class. Divide students into groups of three or four, and give them 10 minutes to devise an experiment, making sure they address each step of the scientific method. Example observations might include: 1) My cell phone does not work; 2) My bread gets moldy faster if I leave it on the counter, as opposed to placing it in the refrigerator; 3) It has rained more this year than it has in the previous five years.
* Present a number of hypotheses to your class, and have students determine if they are scientifically testable. Examples might include: 1) Coke tastes better than Pepsi (not testable, an opinion question); 2) All bats carry rabies (testable); 3) Fish take up oxygen from water through their skin (testable); 4) It snows more at the North Pole than at the South Pole (testable); 5) It is wrong for humans to keep pets on leashes (not testable, a moral/ethical question).

Classroom Discussion Ideas

* Why is it important that we taxonomically catalog all organisms that are discovered?
* If we classify organisms based on different traits (e.g., DNA versus morphology) do we get the same result? How does this influence our understanding of the evolutionary history and relatedness of organisms?
* Where would you like to travel to search for new organisms, and why?
* Why is “discovery” science, which often lacks standard hypotheses, just as important to biology as true experimental studies?
* Are discoveries of insects and plants less important, as important, or more important than discoveries of more charismatic animals, like birds and mammals?
* A carnivorous sponge was recently discovered near Antarctica—how might natural selection have shaped the evolution of such an organism?

Additional Ideas for Classroom Discussion

* How does our modern definition of “life” differ from the definition of life that a seventeenth-century bi­ologist might have used? Ask students if they would consider viruses to be “alive.” Why or why not?
* What are some examples of homeostasis? Why must living organisms be able to maintain it?
* Human activities, like the use of tanning beds, can have direct effects on our DNA. For example, the concentrated UV rays from the tanning beds may cause mutations in our DNA. We know that mutations may lead to natural selection, the mechanism for evolution. So, is using a tanning bed good or bad for our species? Justify your answer.
* Can the plethora of shows about the supernatural or paranormal be considered scientific?
* In 2002, an Australian ecologist suggested that scientific bias toward the cute, unique, or spectacular may be helping condemn a substantial portion of the world's plants and animals to extinction. Do you agree with this statement? Why or why not? http://www.scienceagogo.com/news/20020011205947data\_trunc\_sys.shtml
* Have your students list 10 random organisms (you can also do this). Identify ways in which all of the organisms are similar, then ways in which all of the organisms are different. How would you classify these organisms (that is, place into meaningful groups)?
* Why is it important for a species to be able to change? Wouldn’t a species be more successful if it could be assured of remaining the same from one generation to the next? Can students relate this answer to current topics, like global warming or habitat fragmentation?
* Name some organisms you might find in a grassy area nearby. Using arrows, arrange the organ­isms in a diagram depicting energy flow and the cycling of materials (for help, see Figure XX). What are some organisms that may be invisible to the eye but are essential for the recycling of nu­trients during decomposition?
* An animal carcass infested with insect larvae is not an attractive sight. Yet it is a biological ne­ces­sity. Explore the role of these and other “recyclers.”
* Humans are able to manipulate certain aspects of nature for their own benefit. However, it is of­ten said that “humans are the only animals that engineer their own destruction.” Give examples to support this allegation.
* How is a theory different from a truth? Does the use of “theory” in biology mean the concept is in doubt? Explain using examples.
* Why is it difficult to obtain a control group when selecting volunteers to test a new anticancer drug?
* A recent study estimated that the percentage of fabricated experimental data in biomedical scientific literature is 5–10 percent. What can we do as scientists to decrease this percentage and to “catch” the frauds who are publishing this material?

*How Would You Vote?*

* Monitor the voting for the online question. Divide the room into halves and ask each portion to argue for or against the idea of protecting endangered species before all areas of Earth are surveyed.

Term Paper Topics, Library Activities, and Special Projects

* Discover more about how the first cells are thought to have evolved. How do biologists “draw the line” between that which is living and that which is nonliving?
* Have students choose five animals or plants that interest them. Ask them to look up each scientific name and discern its English-translated literal meaning. Does the translation still describe the organism as it fits into today’s world?
* Ask students to watch a drama such as *CSI* or a reality show such as *Forensic Files* this week. Have them keep track of every event in the show that depicts the scientific method being implemented.
* Tell students to watch 10 advertisements this week. Have them keep track of every claim made about the products for sale. How many claims can be tested, and therefore supported or refuted, scientifically? How many cannot?
* The field of taxonomy is constantly changing. Describe how any one of several modern scientific investigative tools (such as electron mi­croscopy, radioactive labeling, gas chromatography, gel electrophoresis, or polymerase chain reaction (PCR) techniques) has made it possible to discover similarities and differences among living organisms. Why can’t we base taxonomic status on “looks” alone? Furthermore, how do these technologies affect our categorization of fossil specimens?
* The origin of life on this planet has always fascinated humankind. Several explanations have been advanced. Search for the principal ones that are still in contention today.
* The supply of easily obtainable energy sources is a matter of debate today. Some persons see a bleak future; others are optimistic. What issues do each of these camps see?
* Have students think of other examples in history when individuals were punished due to their scientific beliefs.

Possible Responses to *Critical Thinking* Questions

1. The cells of a complex multicellular organism, such as a human, are specialized. This means that different cells develop functions that are unique to that cell type and contribute to the overall homeostasis of the organism. Therefore, if cells that relate to vital life-sustaining processes are destroyed, the organism may die.

1. In a single-celled organism, that one cell performs all of the functions necessary for the organism to successfully survive. This differs from an individual cell from a multicellular organism, because that cell may have a specialized function that depends highly on the functioning of other cells.

3. The specific epithet (species) is not unique, and gives no hint as to what type of organism is being described. This part of the scientific name is typically an adjective, perhaps describing where the organism was first discovered (e.g., *americanus* = America) or who discovered it (e.g., *Lepus townsendii*, the white-tailed jackrabbit, is named after a biologist named Townsend); but these names give no indication as to the type of organism or taxonomic status. (i.e., To whom is it most closely related? A bear? A fish? A sponge? A termite?)

4. Obviously, scientific research should not be eliminated. The “goodness” theory described by the turkey (?!?) appears to be a moral question, not one solely based on scientific observation—so it was never a true scientific theory from the start. Additionally, the evidence collected had a sample size equaling one turkey, certainly not representative of all turkeys (obvious sampling error) or of all organisms in the world.

5. It is disappointing to read about a peer-reviewed article that turns out to be a fraud. However, these cases appear very rarely. The positive side of this story is that, in science, experiments must be repeatable—and because no other labs could successfully repeat such an amazing feat, the fraud was quickly discovered.

Possible Responses to *Data Analysis Exercise* Questions

With all scientific experiments, it is necessary to run a control to insure the accuracy of your findings. In the experiment with the peacock butterflies, researchers were uncertain as to which characteristic frightened away birds: the large “eyes” on the wings, the noise made by fluttering the wings, or both. The butterflies in A had their wings painted so that no “eyes” were visible. The control population for this experiment was represented by D, in which the butterflies were painted but eyes were still visible. The butterflies in group B had wing “eyes,” but the parts of the wings that make sounds were removed. The control group in this case was group E, because their wings were cut but not silenced. Finally, we have group C, in which the spots were painted and the wings were silenced. The control for this group was represented by letter F, and the butterflies used as a control had their wings painted yet “eyes” were visible. In addition, their wings were cut but not silenced. By exposing these different groups to their primary predator, the blue tit bird, accurate conclusions could be drawn.