LECTURE OUTLINES

Chapter 1

An Introduction to the Science of Life

Learning Outcomes

In this chapter students will:

1.1 Describe the properties of life common to all living things. (Module 1.1)
1.2 Differentiate between the hierarchical levels of biological organization studied by biologists. (Module 1.2)
1.3 Outline the overall process used by scientists to study science, and how it differs from other ways of observing the world. (Modules 1.3–1.6)
1.4 Describe how scientists design controlled experiments to generate data, and how they visualize data to reach reliable conclusions. (Module 1.7)
1.5 Recognize the major themes that underlie the study of biology at all levels. (Modules 1.1, 1.2, 1.7)

Module Outlines

1.1 All living organisms share certain properties.

- **CORE IDEA:** Biology is the scientific study of life. All living things display a shared set of characteristics. Nonliving matter never displays all of these characteristics simultaneously.

A. Biology is the scientific study of life.
- **1.** Biologists recognize **life** through a series of characteristics shared by all living things.

B. Properties of life
- **1.** Reproduction
  - **a.** All organisms reproduce their own kind.
- **2.** Growth and development
  - **a.** Information carried by genes controls the pattern of growth in all organisms.
- **3.** Energy use
  - **a.** Every organism takes in energy, converts it to useful forms, and expels energy.
- **4.** Order
  - **a.** Each living thing has a complex but well-ordered structure.
- **5.** Cells
  - **a.** All living organisms consist of cells.
  - **b.** Some living organisms consist of a single cell, while others have trillions.
- **6.** Response to the environment
  - **a.** All organisms respond to changes in the environment.
- **7.** Evolution
  - **a.** Individuals with traits that help them survive and reproduce pass the genes for those traits to offspring.

C. A virus is not alive.
- **1.** Viruses do not display all the properties of life.

2. Viruses are not composed of cells.
3. Viruses cannot reproduce on their own.

1.2 Life can be studied at many levels.

- **CORE IDEA:** Life can be studied on a hierarchy of levels from the very large to the very small. Biologists study life at all levels.

A. Levels of biological organization
  1. Biosphere
    a. The **biosphere** consists of all life on Earth and all the environments that support life.
  2. Ecosystem
    a. An **ecosystem** includes all the living organisms in one particular area as well as the nonliving components that affect life.
  3. Community
    a. A **community** consists of all the interacting populations of organisms occupying an ecosystem.
  4. Population
    a. A **population** is a group of interacting individuals of one species.
  5. Organism
    a. An **organism** is an individual living being.
  6. Organ system
    a. An **organ system** is a group of organs that work together to perform a vital body function.
  7. Organ
    a. An **organ** consists of multiple tissues that cooperate to perform a specific task.
  8. Tissue
    a. A **tissue** is an integrated group of similar cells that work together to perform a specific function.
  9. Cell
    a. The **cell** is the fundamental unit of life.
    b. Nothing smaller than a cell is capable of having all life's properties.
  10. Organelle
    a. An **organelle** is a component of the cell that performs a specific function.
  11. Molecule
    a. A **molecule** is a group of atoms bonded together.
  12. Atom
    a. An **atom** is the fundamental unit of matter.
    b. It is the smallest unit of an element capable of displaying the properties of an element.
    c. Atoms are made up of even smaller units called subatomic particles.

1.3 Scientists use well-established methods to investigate the natural world.

- **CORE IDEA:** Scientific investigations always start with observations, which may lead to hypotheses, and experiments provide data on the validity of the hypothesis. Careful observation and experimentation allow scientists to investigate hypotheses and develop theories.

A. The Process of Science
  1. **Scientific method** is a rough "recipe" for discovery.
  2. Observation
  3. Question
  4. Hypothesis—proposed explanation
  5. Prediction

6. Experiment
7. Results
8. Conclusion—revise and repeat with new hypothesis if needed

B. **Discovery science**
1. Make verifiable observations, take careful measurements, and gather data.
2. Data gathered can prompt questions and guide the scientific method.

C. Science in Action
1. Scientific method is often presented as a series of linear steps.
2. Different paths may be taken through the steps.

D. Hypotheses and theories
1. **Hypothesis**—proposed explanation for an observation
   - **a.** Must be testable
   - **b.** Results support or refute a hypothesis.
2. **Theory**—well substantiated explanation
   - **a.** A theory is more comprehensive and broader in scope than a hypothesis.
   - **b.** Theories have not been shown to be false.
   - **c.** Theories explain a great many observations.

1.4 Scientists try to control for variables.

- **CORE IDEA:** To most clearly investigate hypotheses, scientists try to change just one variable per experiment. An independent variable is one that is changed to see its effect on a dependent variable. Performing experiments blind can reduce bias.

A. Controlled studies
1. **Controlled experiment** in which a test is run multiple times with one variable changing
   - **a.** Ideally, all others variables are held constant.
   - **b.** Allows scientist to draw a conclusion on the one variable that did change

B. Independent versus dependent variables
1. Independent variable—variable being manipulated
2. Dependent variable—response, output, or effect under investigation

C. Positive and **negative controls**
1. **Control group**—used to establish baseline for experiment
2. Negative control—group for which no change is expected
3. **Positive control**—group for which change is expected

D. Blind experiments
1. In a **blind experiment**, some information about the experiment is withheld from participants.
2. **Single-blind** experiment—test subject does not know which group they are in but the researcher does.
3. **Double-blind experiment**—neither the test subject nor the researcher knows which group a participant belongs to.
4. **Placebo—**a medically ineffective treatment used in the control group

1.5 Scientific thinking can be distinguished from other ways of viewing the world.

- **CORE IDEA:** Biology is limited to the study of life via recognized scientific approaches. Through peer review, outside authorities can help verify the validity of scientific results. Other ways of thinking, such as pseudoscience, are not considered part of biology.

A. Ways of viewing the world
1. Biology is the scientific study of life.
   - **a**. Learned through process of science

2. Other ways of thinking are also valid for investigating questions but are not science.
    - **a.** Examples are art, religion, meditation, fables, consultation with elders, etc.
    - **b.** Only accepted scientific principles should be employed to study biology.

B. Science versus pseudoscience

1. **Pseudoscience**—any field of study that is falsely presented as having a scientific basis
2. **Anecdotal evidence**—claim based on a single or a few examples that do not support a generalized conclusion
3. See chart on page 10 for indicators to separate science from pseudoscience.
4. Examples of pseudoscience
    - **a**. Fortune telling, useless gadgetry, skull measurements to predict personality, and ESP

C. Reliability of sources

1. Science depends on peer review.
    - **a**. **Peer review**—evaluation of work by impartial, qualified, often anonymous experts who are not involved in that work
2. No matter the source, reliable scientific information can be recognized by . . .
    - **a.** Being up to date
    - **b.** Drawing from known sources of information
    - **c.** Having been authored by a reputable expert
    - **d.** Being free of bias
    - **e.** See checklist on page 11.
3. A **primary source** is original material presented for the first time by the person who performed the research.
4. A **secondary source** is a description or review of primary sources, often containing commentary.

1.6 Scientists communicate data using tables and graphs.

- **CORE IDEA:** Scientists report data using tables and graphs. You can learn to properly interpret such data because tables and graphs follow standard conventions.

A. Data

1. Nearly every scientific investigation produces data.
    - **a. Data** are individual pieces of information that result from measurements.

B. Reading a scientific table

1. **Table**—efficient way to present a lot of data in a small amount of space
2. Notes on a specific table presented on page 12
    - **a.** Scientific tables and graphs usually have a descriptive title.
    - **b.** Notice the number of columns a heading spans.
    - **c.** Each column presents one category of data.
    - **d.** Each row presents one set of data.
    - **e.** One entry represents a discrete piece of data.
    - **f.** The source of the data is usually listed at the bottom of the table.
    - **g.** "N/A" in a table entry stands for "not available," which means that data were not collected or it does not make sense to include data for this entry.

C. Reading scientific graphs

1. **Graphs** are means of displaying data visually.
    - **a.** Can help to summarize and compare information
2. **Line graph**—often used to display data that changes continuously
    - **a.** Most graphs have a title.
    - **b. y-axis**—vertical axis

c. **x-axis**—horizontal axis

d. Key explains what line colors represent.

3. **Bar graph**—often used to compare categories of data

a. **Error bars**—may be used to represent the range of values that fall within the 95% confidence interval

i. If error bars overlap, then there is no significant difference.

ii. If error bars do not overlap, then there is a significant difference.

4. **Pie chart**—used to convey percentages

a. Entire pie adds up to 100%.

1.7 Several major themes run throughout the study of biology.

- **CORE IDEA:** Major themes—evolution, the relationship of structure and function, the flow of information, transformations of energy and matter, and connections between elements of biological systems—underlie the study of biology at all levels.

A. Evolution

1. **Evolution** is the descent with gradual modification of ancestral species to modern-day ones.

a. Theory of evolution by natural selection is the core theme that unifies all of biology.

b. Natural selection was first described by Charles Darwin.

B. Structure and function

1. Within biological systems, structure (the shape of something) and function (what it does) often provide insight into each other.

2. This relationship can be seen at every level of biological organization.

C. Energy and matter pathways

1. All activities in a cell require energy and matter to proceed.

2. Living organisms regulate the transformation of energy and matter.

D. Information flow

1. Information must be received, transmitted, and used.

2. Information flow is apparent at all levels of biological organization.

E. Interconnections

1. Different levels of biological organization

2. Many interconnections within and between levels

3. Emergent properties—emerge as complexity increases

a. "The whole is greater than the sum of its parts."

F. Applying the themes

1. Elephant example on page 15

Key Terms

1.1 All living organisms share certain properties.

Life

1.2 Life can be studied at many levels.

Atom	Ecosystem	Organelle
Biosphere	Molecule	Organism
Cell	Organ	Population
Community	Organ system	Tissue

1.3 Scientists use well-established methods to investigate the natural world.

Discovery science	Scientific method
Hypothesis	Theory

1.4 Scientists try to control for variables.

Blind experiment	Double-blind experiment	Positive control
Control group	Negative control	Single-blind experiment
Controlled experiment	Placebo	

1.5 Scientific thinking can be distinguished from other ways of viewing the world.

Anecdotal evidence	Primary source	Secondary source
Peer review	Pseudoscience	

1.6 Scientists communicate data using tables and graphs.

Bar graph	Graph	Table
Data	Line graph	x-axis
Error bars	Pie chart	y-axis

1.7 Several major themes run throughout the study of biology.

Evolution

Student Misconceptions and Teaching Tips

1.1 All living organisms share certain properties.

- Many people consider viruses to be alive because they hear the term used in that fashion. For example, many products claim to "kill" viruses.

1.2 Life can be studied at many levels.

- While the higher levels of classification may be more familiar to the nonmajor, the exact definitions are not. The differences between "community" and "population" are often overlooked.

1.3 Scientists use well-established methods to investigate the natural world.

- "Science" is often seen as something only scientists do. Use real-world examples to show that students use the scientific method every day to solve problems. For example, I observe my cookies don't taste as good as the ones my grandmother makes (observation). I wonder what's different? (question), and so on.
- Emphasize the difference between *hypothesis* and *theory*. In common language, they mean the same thing. In science, they have specific definitions.

1.4 Scientists try to control for variables.

- In a controlled study, only one variable changes. If my laptop doesn't turn on, I try several different things that might fix it, one after another. How will I know which specific thing fixed the problem?
- Independent and dependent sound much alike, yet the terms are very different. The dependent variable depends on the independent variable. My blood pressure (dependent) depends on which dose of the drug I took (independent).
- The purpose of the controls is to make sure the experimental protocol is working.
    - For example, a positive control contains what you are testing for with a reagent. If the reagent is working, you will see the presence of the substance in the positive control. If you don't, your reagent is not working. If you didn't do this and found

negative results in your tests, is that due to the substance being absent or your reagent being faulty?

    - In the same experiment, a negative control should show the substance being absent. If you get positive results indicating a substance is present on the negative control, you know that you have contamination in your tubes.

  - Single- or double-blind experiments prevent bias. Test subjects who know they are getting the test drug may be more positive that they feel changes even if they really don't. A researcher may be more encouraging to test subjects receiving the test substance (and more likely to get "desired" results) than to those not receiving the test substance.

1.5 Scientific thinking can be distinguished from other ways of viewing the world.

  - Nonmajors are more likely to be persuaded by pseudoscience than majors. It's important to emphasize what science is without denigrating other forms of inquiry for other subjects.
  - It is difficult for nonmajors to differentiate between reliable and unreliable sources of information on the Internet. Just because it's on the Internet (TV, magazine, newspaper, etc.) does not make it reliable.

1.6 Scientists communicate data using tables and graphs.

  - "Data" is plural, while "datum" is singular.
  - Unreliable information will not have the source of data cited.
  - The math behind error bars may be confusing for some, but the basic premise is still useable. A difference of one unit may or may not be significant depending on how much variability is in the data. How do you know unless error bars are given?

1.7 Several major themes run throughout the study of biology.

  - You will be coming back to these themes in almost every chapter.
  - Nonmajors are more likely to be uncomfortable with the "theory of evolution." It is an excellent idea to do some reading on how to address a student's concerns in a productive and respectful manner.

Class Activities

- Introduction to the Course
  - From the Instructor Exchange in MasteringBiology: *Creating a Community for Active Learning on the First Day of Class*. Posted on May 31, 2011, by Instructor Exchange, written by Kelly A. Hogan, University of North Carolina at Chapel Hill.
- Design of scientific studies
  - Modules 1.3–1.6 are about the principles behind scientific investigations.
  - A search of the Internet will yield collections of case studies that can be used to follow a particular experiment through analyzing design and evaluating data.

1.1 All living organisms share certain properties.

  - Student groups could choose or be given an organism. They would then decide how that organism meets all the properties of life. It would be interesting to give one group a virus.

1.2 Life can be studied at many levels.

  - Student groups could choose or be given an example organism. They would then follow the levels of organization up to biosphere and down to atom.

1.3 Scientists use well-established methods to investigate the natural world.

- ○ Student groups could choose or be given an example of an everyday problem to model the scientific method. Examples might include: My car does not start; I have a headache; My backpack feels unusually heavy today.
- ○ Student groups could choose or be given an everyday problem to analyze by a controlled experiment. Ask students to think about what specific variable they will change; what other variables must be held constant; and what sample size or number of repetitions would best support their hypothesis.
- ○ From the Instructor Exchange in MasteringBiology: *Practicing the Scientific Method: Are Girls Better than Boys at Some Tasks?* Posted on May 31, 2011, by Instructor Exchange, written by Kelly A Hogan, University of North Carolina at Chapel Hill.

1.4 Scientists try to control for variables.

- ○ Student groups receive a table similar to the one on page 9 but without answers. They are then given a list of answers to place in the right category. They should not use their books but rely on the knowledge gained by reading the chapter before class. Several students working together should be able to place most answers.
- ○ As an after-class activity, assign a comparison of the benefits and costs of GMO. A short list of two good points and two bad points should get students started. It would also be an excellent start to a discussion on good and bad sources of information. Undoubtedly, many students will look to Wikipedia or websites with a thinly veiled agenda.

1.5 Scientific thinking can be distinguished from other ways of viewing the world.

- ○ Student groups could devise an uncontrolled study. Then groups could exchange studies and turn them into controlled studies.
- ○ For the studies above, students should clearly indicate in their controlled study what the independent and dependent variables are.
- ○ For the studies above, students should devise positive and negative controls. This is difficult for people without a science background, so expect to help them.
- ○ Student groups could role-play different types of studies (not blind, single-, or double-blind) to discuss the pros and cons of the different types.
- ○ As an after-class activity, assign students to locate a study that does not follow these principles of good experiment design. Ask them to discuss the problems on a digital bulletin board or bring the problems to class for a discussion.
- ○ Nonmajors are more likely to use pseudoscience than majors. It is important to be respectful of students and use examples of pseudoscience being used as science as a teachable moment.
- ○ Ask students for examples of pseudoscience and discuss why they are in fact pseudoscience. Emphasize that they may be valid ways to think about our world but are not scientific. Be prepared to prevent a lengthy discussion of science and religion if that is not the purpose of the interaction.
- ○ Ask students to gather, or you can gather, examples of unreliable and reliable sources of information from the Internet. What items do you look for to differentiate? See the checklist on page 11. Is the article a primary or secondary source?

1.6 Scientists communicate data using tables and graphs.

- Reading graphs and tables is a skill no scientist can go without. Nonmajors are less likely to have this skill. It is crucial to practice reading graphs and tables for a person to become scientifically literate.
- Ask students to gather, or you can gather, examples of tables.
  - Discuss what features the gathered tables do or do not include.
  - Using the graph on page 12 as an example, ask how many males died from pancreatic cancer in 2014? You can also ask questions that the table does not address. How many people worldwide died of pancreatic cancer in 2014? How many males died of pancreatic cancer in 2012? Tables organize specific information.
- Ask students to gather, or you can gather, examples of graphs.
  - Discuss what features the graphs do or do not include.
    - For graphs with error bars, are the groups that are being compared significantly different?
      - Error bars do not overlap if groups are significantly different.
      - You might provide a reference for how to calculate error bars if a student is interested. The math is not integral to basic understanding.
    - For graphs without error bars, how can you tell if the difference between groups is significant?
      - You can't. What might someone be hiding (or at least deemphasizing) by not providing error bars?
  - Using the graph on page 13 as an example, ask how many American men died of lung cancer in 1951?

1.7 Several major themes run throughout the study of biology.

- The elephant image on page 15 is an excellent way to illustrate how these major themes can be applied to a specific case.
  - Ask students to gather, or you can gather, examples of applying themes to a specific case for in-class discussion or discussion on an electronic bulletin board.