# Active Learning Exercise 1: Themes in the Study of Life Reference: Chapter 1 (*Biology* by Campbell/Reece, 8<sup>th</sup> ed.)

# Introduction

The science of biology is enormous in scope—it spans unimaginable size scales, from the study of submicroscopic molecules to the global distribution of biological communities which contain an estimated 5 to 100 million different species of organisms. The field of biology encompasses life over incomprehensible stretches of time, from the present to nearly 4 billion years ago. With rapid information flow (via the Internet, books, magazines, scientific journals, etc.) and an explosion of discoveries in labs and field stations around the world each year, biology is in a continuous state of change making it impossible for any one individual to keep pace. Fortunately, there are several enduring themes that pervade the science of biology. This Active Learning Exercise, together with chapter 1 of your textbook, will introduce you to these unifying themes that you should keep in mind as you study biology in this course and in your future biological endeavors.

# Theme #1. New Properties Emerge at each level in the Biological Organization

1. Complete the diagram below of the levels of biological organization.



# Levels of Biological Organization

2. "The whole is greater than its parts" is a saying rings true when speaking of living things. As we move from the molecular level to the biosphere, novel **emergent properties** arise at each level that is not present at the preceding level. Emergent properties are created by new arrangements and interactions of parts as complexity increases. Provide two examples of properties that emerge for each of the following levels in the hierarchy of biological organization.

Level of Organization	Examples of properties that emerge
a. Molecules → organelle	
a. Organelles $\rightarrow$ cell	
b. Cells $\rightarrow$ Tissues	

3. Life is recognized by what living things do and defies a simple one-sentence definition. There are many key properties that emerge as a result of the arrangement and interactions between the molecules, organelles and the cells that makeup an organism and the interaction of organisms with their environment. *List and briefly describe* the **seven major properties** that living things have in common.

1.)			

• 、

ii.)			
iii.) <u> </u>			
iv.)			
v.)			
vi.)			
,			
vii.)			
)			

### Theme #2. Organisms interact with their environments, exchanging matter and energy.

Every organism interacts with its environment, including other organisms as well as nonliving factors. Both organism and environment are affected by the interactions between them. The dynamics of an ecosystem include two major processes: the cycling of nutrients and the *one-way flow of energy* from sunlight to producers to consumers. In most ecosystems, *producers* are plants and other photosynthetic organisms that convert *light energy* to *chemical energy*. *Consumers* are organisms that feed on producers and other consumers. All the activities of life require organisms to perform work, and *work* requires a source of energy. The exchange of energy between an organism and its environment often involves the transformation of energy from one form to another. In all energy transformations, some energy is lost to the surroundings as *heat*. In contrast to *chemical nutrients*, which *recycle* within an ecosystem, *energy flows through an ecosystem*, usually entering as *sunlight* and exiting as *heat*.

4. Complete labels a –g in the diagram below.



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## Theme 3. Structure and function are correlated at all levels of biological organization.

5. "*Form fits function,*" when applied to biology, is a guide to the anatomy of life at all its structural levels. Explain in your own words what is meant by "*form fits function*." Support your response with an *original* example that stems from *your* personal experience.

# Theme #4. Cells are an organism's basic units of structure and function

- 6. What is the lowest level of organization that can perform all the activities required for life?
- 7. There are three basic structures found in *all* cells. Name these three structures and briefly describe their major function. *Hint*: Trouble with the 3<sup>rd</sup> structure? See your response to #9!

Structure	Function
a.	
b.	
с.	

8. Distinguish between *prokaryotic* and *eukaryotic cells*, giving suitable examples of each. If necessary, see Chapter 6 and/or page 13 of the textbook for examples of pro- and eukaryotic cells.

9. Below are electron micrographs of a prokaryotic and a eukaryotic cell. Identify each cell type and then complete the labels for each cell.



#### Theme #5. The continuity of life is based on heritable information in the form of DNA.

10. Select from the following list of terms to complete the narrative below. Terms may be used once, more than once or not at all.

Amino acid(s)	Divide	Function	Nucleotide(s)	RNA
Carbohydrate(s)	DNA	Gene(s)	Nucleus	Transcription
Chromatin	Double helix	Genome	Prokaryotic	Translation
Chromosome(s)	Enzyme(s)	Lipid(s)	Protein(s)	
Cytoplasm	Eukaryotic	Nucleic Acid(s)	Replication	

At some point, all cells contain (a)	, the <i>heri</i>	table material that directs the cell's
activities. DNA is the substance of (b) _	, the	units of inheritance that transmit
information from parents to offspring. I	DNA in eukaryotic cells is	s organized into (c)
which have one ver	ry long DNA molecule w	ith hundreds or thousands of (d)
Each DNA molec	cule is made up of two lo	ng chains arranged in a (e)
Each link of a cha	ain is one of four (f)	, which encode the
cell's information in chemical letters. Th	he sequence of (g)	along a gene may code
for a specific (h) w	vith a unique shape and (i	) Almost all
cellular activities involve the action of o	one or more proteins. Hui	nan proteins include muscle cell
contraction proteins and defensive prote	eins called antibodies. All	cells also contain (j)
, crucial proteins th	nat <i>catalyze</i> (speed up) sp	ecific chemical reactions. DNA
provides the heritable blueprints, but (k)	.) are	the tools that actually build and
maintain the cell. DNA controls (1)	product	on indirectly, using a related kind of
molecule called (m)	_ as an intermediary. The	sequence of nucleotides along a gene
is <i>transcribed</i> into (n)	, which is then <i>transl</i>	<i>uted</i> into a specific (o)
with a unique shap	be and function.	_ ```

In the process of (p) \_\_\_\_\_\_, all forms of life employ essentially the same genetic code to

produce protein: a particular RNA sequence of (q) \_\_\_\_\_\_ says the same thing to one organism as it says to another. Recently, scientists have discovered whole new classes of (r) \_\_\_\_\_\_ that are <u>not</u> translated into protein. Some (s) \_\_\_\_\_\_ molecules regulate the functioning of protein-coding genes. The library of genetic instructions that an organism inherits is called its (t) \_\_\_\_\_\_.

### Theme #6. Feedback mechanisms regulate biological systems.

- 11. Chemical processes within cells are accelerated, or catalyzed, by specialized *protein catalyst* molecules called *enzymes*. Each type of enzyme catalyzes a specific chemical reaction. In many cases, reactions are linked into chemical pathways (metabolic pathways), with each step having its own enzyme. Many biological processes are self-regulating.
  - a.) Explain how *negative feedback* is used to regulate a metabolic pathway.

b.) Explain how *positive feedback* is used to regulate a metabolic pathway.

12. Illustrate using arrows and by circling the key regulatory enzymes in the hypothetical biosynthetic pathway below to show how *negative feedback* would work <u>most efficiently</u> to regulate the production of the amino acids C and D from precursor molecule A.



### Theme #7. The Core Theme: Evolution Accounts for the unity and diversity of life

(Note: We'll look at Darwin's theory of natural selection in more depth in ALE 2A.)

13. Organizing the Diversity of Life: Although there is no single correct way to classify the great diversity of life on our planet, the *three-domain approach* is most widely used by biologists. In the diagram, below, name the four kingdoms of domain Eukarya, giving examples of each, complete the "ovals" for the two prokaryotic domains and fill in the blanks next to the arrows. In addition to Chapter 1, you might find section 26.6 (pp. 551 – 552) handy as a reference.



14. Using the 3-domain approach of classification, into which domain would you place viruses? <u>*Explain*</u> <u>vour reasoning</u>. See Section 19.1 (pp. 381 – 383) a discussion of viruses.

15. Based on your response above, and the seven major properties associated with life, would you consider viruses living things? *Explain your reasoning*.

16. Explain why there is great unity yet at the same time tremendous diversity of life on earth.

#### Science as a process: the scientific Method

17. Put the following account of Edward Jenner into the steps of the scientific method. You may need to "read between the lines" to identify some of the steps.

"Edward Jenner first developed the technique of vaccination in 1795. This was the result of a 26-year study of two diseases, cowpox and smallpox. Cowpox was known as vaccinae. From this word evolved the present terms vaccination and vaccine. Jenner observed that milkmaids rarely became sick with smallpox, but they developed pock-like sores after milking cows infected with cowpox. This led him to perform an experiment in which he transferred puss-like material from the cowpox to human skin. Because the two disease organisms are so closely related, the person vaccinated with cowpox developed immunity (resistance) to the smallpox virus. The reaction to cowpox was minor in comparison to smallpox. Public reaction was mixed. Some people thought that vaccination was the work of the devil. Thomas Jefferson had his family vaccinated. In 1979, almost 200 years after Jenner developed his vaccination, the Center for Disease Control and the World Health Organization declared that smallpox was extinct."

Initial observation:

Question(s):

Hypothesis:

Experiment:

**Results**:

#### Communication of results:

- 18. Suppose a *controlled experiment* was performed to examine the effect that the age of a student at GRCC has on grade point average. Identify each of the following aspects of the experiment:
  - a. Independent variable:
  - b. Dependent variable:
  - c. Controlled variables (i.e. variables that need to be controlled and accounted for)

- 19. Six hypotheses are listed below. Some are suitable for scientific testing and some are not. Circle the letter of each hypothesis that is <u>not</u> testable by the scientific method. <u>Briefly explain your</u> <u>choice(s)</u>.
  - a. Increasing numbers of deformities such as the extra limbs that have been noted in many frog populations in North America are caused by infection by trematodes (parasitic flatworms).
  - b. People with strong religious beliefs live more meaningful lives.
  - c. People are more likely to survive cancer if they have a positive attitude.
  - d. Humans and chimpanzees diverged from a common ancestor that lived 5–7 million years ago.
  - e. Corn seedlings grow more quickly when people talk to them.
  - f. If you live a good life, you will be rewarded with an eternity in Heaven.
- 20. A philosopher once correctly stated that knowledge is "what's left after you have demonstrated what cannot be true." Explain what is meant by this statement considering what you know about the *scientific method* and *how a hypothesis becomes a theory*.

21. Darwin's *theory of natural selection* is occasionally criticized by the layperson as being "only a theory." Comment on the validity of this statement in light of what you know about the scientific method and how a hypothesis becomes a *scientific* theory. **Hint**: Think about how our society uses the term theory, versus the *scientific* meaning of a theory.

22. What is *pseudoscience*? Give an example or two—do not use the two examples below! Hint: Astrology and therapeutic touch are both considered pseudoscience. Pseudoscience is not discussed in the textbook, but there are pseudoscience links at the ALE section of the class website!

How is psuedoscience fundamentally different from science?

- 23. *Teleology* is a belief system that assigns an ultimate design or purpose to nature where natural processes and natural phenomena are believed to be directed towards an ultimate goal or shaped by a purpose. However, Darwin's theory of natural selection (to be studied in greater depth in ALE 2A), states that it is an ever changing *environment* that is the selecting force that directs the evolution of living things—"Adapt or Die." Hence, *teleological statements* are unproductive in explaining the cause for various biological phenomena.
  - a. Below are two *teleological statements*. Rephrase them so that they do not imply a goal or purpose and are therefore are scientific.
    - i. "Birds have wings so they can fly."
    - ii. "Ducks have developed webbed feet to swim more efficiently."
  - b. Why are teleological statements unscientific?
- 24. Circle the statement(s) below that are teleological. Suggest a refinement by rephrasing the sentence so that it is scientific and not teleological.
  - a. Hummingbirds often pollinate Red flowers.
  - b. Some birds engage in courtship behavior before mating.
  - c. Sexually mature salmon swim upstream in order to spawn.
  - d. Monarch butterflies migrate to coastal regions in California and Mexico to mate.

- 17. Science involves the construction of knowledge based on observation, testing, and measurement. Such knowledge is termed *empirical* or *scientific knowledge*. Nonscience may involve a different type of knowledge that is based in faith and cannot be tested using the scientific method. Identify each statement below as S if it can be tested scientifically or N if it is non-empirical knowledge. Be *prepared* to explain each of your responses in class.
  - a. Leonardo da Vinci is a better painter than Picasso is.
- b. Alcohol consumption by pregnant women may cause birth defects in their babies.
  - c. There is a God.
- d. The sun rises in the east every morning.
  - e. Four out of every five doctors recommend *Crest* toothpaste.
    - \_\_\_\_\_ f. People born between July 23 and August 22 should be concerned about things going wrong today.
- g. Fetal tissue transplanted into the brains of patients with Parkinson's disease causes improvement in brain function in these patients.
- h. It is unethical to use fetal tissue to treat Parkinson's patients.
  - \_\_\_\_\_i. Tylenol is a better pain reliever than aspirin.