Teacher's Guide

Notes on each lab and sample answers for the lab's questions are listed below. Students and teachers may generate more possible answers that are correct as well. The labs can be done in any order or in the order that works best for the season during which the lab is taught. For example, I like to run the Stream Lab when it is warmer. In the northern temperate zone this means the end of the spring term or the beginning of the fall term. Similarly, the forest ecology labs are probably easiest to run when the leaves are on the trees for identification purposes.

The labs approach the world from an ecological perspective and as a collection attempt to teach the student about many aspects of the environment, including soil health, stream health, forest health, clean air, as well as agricultural and development issues.

A set of four or five questions follows each lab. Sometimes these questions are asked progressively throughout the lab, as in the worm farming lab. Most can be done at the end of class and turned in that day or for homework and turned in the following week.

The teacher is also free to ask students to complete a scientific paper based on any of the labs. All of the labs except for the Sewage Treatment Plant and Organic Farm field trips are experimental in nature and a scientific paper could easily work for this.

1. Stream Ecology

This lab can be done at a local stream either on or near campus. The protocol is part of the protocol used in the Adopt-A-Stream program, and long term data could be gathered and the stream adopted by the class if it will be repeated.

Questions

1. The water quality rating will depend on the overall health of the stream and also the season in which sampling was conducted.

   Having an understanding of the upstream land uses (residential, agricultural, etc) will be helpful for understanding the results.

2. Macroinvertrates are likely found in leaf packs and under rocks because they have more shelter there. Leaf packs provide both food and shelter.

3. If a stream has a healthy riparian zone it may be quite healthy despite a great deal of fertilizer use in the watershed upstream. Farms are more likely to have some negative effects downstream if animals are able to access the stream.

4. Results may vary based on season due to different temperatures and degrees of land use. Late spring/early summer is likely to yield better results because the lower temperatures, compared to late summer early fall result in higher available oxygen for macroinvertebrates. Also, people are less likely to have started fertilizing their lawns by late spring to the same degree they will have in early fall.

A good hypothesis might incorporate the factors discussed above such as the season in which sampling occurred, upstream land uses in the watershed, and degree of riparian vegetation present.

2. Measuring Diversity

This lab is meant to be very flexible and can be conducted in the ecosystem of choice of the teacher. For example, a sampling of the leaf litter in a forest could be done, a stand of trees or even an aquatic ecosystem.

Calculations can be done in class if students bring a calculator, at home, or in the lab on an Excel

Questions

1. The answer to question one will depend on the data gathered in class.
2. The answer to question two will depend on the data gathered in class.
3. Simpson's Index of Diversity does take into account both richness and evenness because one needs to know the richness, or number of organisms, to calculate the evenness, measured by relative abundance. The relative abundance measure is used to calculate the Index of Diversity.
4. Students may answer that the highest diversity in the world is found in the rainforest or in coral reefs such as the Great Barrier Reef. Both are true in a way. For rainforests high diversity is attributed to the great deal of sunlight and rain that these types of forests receive, coupled with the tens of thousands of years, or longer, that these ecosystems have been evolving.

Cunningham 8e Answers to Practice Quizzes

Chapter 1

1. Global populations are rising, but in the future they should stabilize, although at what level and when depends on fertility changes. Fertility rates are falling everywhere, and the global average has declined from 5 to less than 2.5 children per woman.
2. Ecological services include many factors and resources we rely on. Often they're described in terms of provisioning, regulating, supporting, and cultural services. Climate regulation, water filtration, and food provision are a few examples.
3. A hypothesis is a testable, provisional explanation. A scientific theory is an explanation supported by a large body of empirical evidence and regarded by a majority of scientists as likely to be correct.
4. The scientific method involves 1) identifying a question, 2) forming a testable hypothesis, 3) collecting data, 4) interpreting results, 5) reporting results for peer review, 6) publishing findings. See figure 1.4.
5. Probability is a measure of how likely something is to occur. An example is flipping a coin. Each toss has a 50% probability of landing on a particular side.
6. Scientists try to reserve judgment because they know that better evidence could emerge from future tests or evidences. Thus they try to be skeptical of evidence and to look for solid, unbiased evidence. This is also why tests require replication: one test result could be an accident or an outlier. Many tests are better than a few.
7. The first step in critical thinking is to ask, "What is the purpose of my thinking?"
8. Utilitarian conservation is pragmatic, efficient resource use for the greatest good for the greatest number for the longest time. Gifford Pinchot and Teddy Roosevelt were leaders in this movement. Biocentric preservation emphasizes the right of other organisms—and nature as a whole—to exist regardless of their usefulness to us. John Muir was a leading proponent of this philosophy.
9. Water is a critical resource because 1.1 billion people lack access to clean water, 15 million people die annually from diseases linked to polluted water or inadequate sanitation, and by 2025, the U.N. warns, three-quarters of all humans may live in water-stressed countries.
10. In figure 1.5, the most dramatic warming occurs at high latitudes, especially northern Canada, Siberia, and parts of the Arctic Ocean.
11. The ratio of per capita income is about 52:35 (or a little less than 5:3) for North America: East Asia. For North America:South Asia, the ratio is about 52:2 (or about 25:1).
12. The poorest people are often both the victims and agents of environmental degradation. Forced to meet short-term survival needs at the cost of long-term sustainability, they suffer most from environmental damage because they have few other options.
13. Sustainability is a search for ecological stability and human progress that can last over the long term. Sustainable development is defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs."

Chapter 2

1. Two primary nutrients that cause eutrophication are nitrogen (N), and phosphorus (P).
2. Systems are networks of interactions among interdependent units or compartments as well as processes or flows that link those components. A positive feedback loop enhances or accelerates a process and a state variable. A negative feedback inhibits or reverses a process or reduces a state variable.
3. Carbon atoms, like all matter, are constantly cycled in living organisms. Given the huge number of carbon atoms in your body, it's almost certain that some of them were also part of some prehistoric organisms.
4. Water molecules are polar, which makes water a superb solvent. Water is the only inorganic liquid that exists at normal ambient temperatures. This provides a liquid medium for life processes. Water molecules are highly cohesive. This results in capillary action. Water expands when it crystallizes so that ice floats. Water has a high heat of vaporization, so we can remove a large amount of heat through evaporation. Water has a high specific heat, making it an ideal medium for storing heat and moderating the earth's temperature.
5. DNA (deoxyribonucleic acid) is an extremely complex, double helix-shaped molecule that contains the genetic material that defines an organism's traits. DNA exists in the nucleus of cells (for all cell-based organisms). It is made up of nucleotides linked together in long chains. The specific sequence of nucleotides in a DNA molecule carries the genetic information that codes for protein structure and gives each organism its unique inheritable characteristics.
6. Heat is stored energy, but if it is stored in a diffuse form, it is usually hard to convert from one form to another. We use the term "low-quality energy" to refer to diffused, dispersed, low temperature energy that is difficult to gather or use for productive work. "High-quality energy," in contrast, is intense, concentrated, high-temperature, and useful for work.
7. Materials cycle endlessly in the biosphere, or between biosphere, geosphere, hydrosphere, and atmosphere, because of the law of conservation of matter. Energy follows a linear path because it continually degrades to lower-quality forms as it is re-used, and ultimately energy dissipates to space as heat. This is the second law of thermodynamics—in every energy exchange, some of the energy is converted from higher quality to lower quality. Thus, to keep living processes going, there has to be a constant energy input and a sink to which surplus waste energy (such as heat) can dissipate.
8. Our eyes are sensitive only to visible light (0.4 to 0.7 um), which happens to be the most common wavelengths in solar radiation. Short ultraviolet wavelengths (microwaves (10 nm or 10×10^{-9} m) are 1 million (1×10^{6}) times shorter than microwaves (1 mm or 1×10^{-3} m).
9. Extremophiles live in extreme conditions at the bottom of the ocean, in hot springs, or deep in the earth's crust. They get the energy they need to live by chemosynthesis: reactions that use chemicals, such as hydrogen sulfide or hydrogen gas as an energy source.
10. For most organisms on the earth's surface, the ultimate source of energy is the sun, and the sink for waste energy is outer space.

11. Green plants capture solar energy through photosynthesis, a series of chemical reactions that occur in chloroplasts. The energy captured in this process is used to create chemical bonds in organic molecules. These molecules serve both as an energy source and building material for all plants and animals.
12. A species is made of all the organisms of the same kind that are able to breed under natural conditions and produce live, fertile offspring. A population consists of all the members of a species living in a given area at the same time. A biological community is made up of all the populations of different species living and interacting in a given area at a specific time.
13. Big, fierce animals (such as grizzly bears, tigers, and great white sharks) are usually the top carnivores in their ecosystem. They need to be large and fierce to catch their prey. Because they are at the top of the ecological pyramid, it takes many organisms at lower trophic levels (and therefore, large home ranges) to support these big carnivores. Thus, there are never very many of them in a given area. Their adaptations as top predators make them dangerous to humans. They also often compete with us for food, so we tend to eliminate them either directly by hunting, or indirectly by reducing their food supplies or eliminating their habitat.
14. An example of an inverted ecological numbers pyramid might be a single large tree supporting many herbivorous insects, or a single coyote supporting many parasites.
15. Humans release about 7 GT of carbon annually compared to 100 GT released by respiration from land-based plants, animals, and microbes.

Chapter 3

1. Tolerance limits restrict the distribution and abundance of species by forcing them to live in a specific environment. Saguaro cactus cannot withstand extended freezing temperatures, so their distribution is strictly limited by elevations at which freezing nights occur regularly. Similarly, young desert pupfish only live in hot water (20-36°C), forcing them to remain near hot springs in the desert. By contrast, at all ages the common carp and European starling survive in a broad range of temperatures, and through human introduction now occupy every continent in the world except Antarctica.
2. Allopatric speciation is the evolution of separate species in *different locations*. This occurs when an ancestor population has been separated. Sympatric speciation is the evolution of separate species in the *same location*. This might occur when subsets of a population come to occupy different niches or use different resources.
3. Selective pressure is the case in which certain traits, such as a heavy beak in a place with thick-coated seeds, allow some individuals somewhat greater reproductive success than other individuals. Eventually those traits become common in the population, while other traits become rare. Selective pressures in your locality could include temperature, water, wind, predation, food, fire, or a number of other environmental factors.
4. In the Type I curve, most individuals survive to a relatively mature age, then die at an old age. Type II describes a population that is equally likely to die at any age. Type III represents a population in which most individuals die very young, but a small proportion of individuals survive to reach maturity.
5. Symbiotic relationships involve two species living together. Mutualism refers to a relationship in which both species benefit, as in the case of algae or ox pickers on an

12 LABORATORY AND FIELD EXERCISES IN ENVIRONMENTAL STUDIES

by Jessica Seares, Ph.D.

TABLE OF CONTENTS

1. Stream Ecology: Biodiversity Sampling

Goal: To measure a local stream's health by looking for macroinvertebrates.

Background: The dominant animal life in small-order streams such as the one you will be working in are macroinvertebrates, which include insect larvae that will mature and leave the stream as adults (including caddisflies, springtails and mayflies).

Macroinvertebrates do not have a spinal cord, are big enough to see with the naked eye, and are important ecosystem players in small-order streams. In general, they are more likely to be found in leaf packs and under rocks in the riffles of streams rather than pools.

Because water moves so rapidly in streams, it can be difficult to monitor pollution in them. However, certain kinds of pollution can have long-term effects on the living organisms in streams. We will sample the stream for organisms and give the organisms that are least tolerant of pollution a greater weight in our biological analysis than organisms that are very tolerant of pollution. The organisms found will thus be a marker for the past presence of pollution – the presence of sensitive organisms indicates a healthy stream.

How Development in a Watershed Affects Streams:
A watershed is an area of land that drains into a creek or river. Impervious surfaces such as roads and rooftops accelerate runoff from rain, increasing the rate of soil erosion into local creeks. The physical effects of erosion on streams include steepening of banks, and increased sedimentation load in streams, resulting in a reduced number of breeding sites for stream wildlife, both macro and micro.

Fertilizers, farms, and leaking septic tanks or sewer lines negatively affect stream organisms. Streams are naturally oligotrophic (nutrient-poor) and increased levels of nutrients in the form of fertilizer or human waste may cause algal blooms, which in turn reduce oxygen levels, threatening fish and macroinvertebrates.

Deforestation for yards, construction sites, and farms can reduce the ability of streamside vegetation to buffer excess nutrients and sediments from entering streams. Streamside vegetation is called a riparian buffer because of the important ecological role it plays in slowing down runoff, sediment, and processing nutrients before they enter streams. Many state laws required a 25 foot riparian zone for small-order streams, but exemptions are frequently made for agricultural, lawn and garden use. Removing streamside vegetation can increase sediment load, erosion, fertilizers and other pollutants in streams. For this reason it is important to always maintain a buffer, in your own or parent's backyard, if it borders a creek. This means not mowing to the edge of the water. This will also reduce the threat of flooding downstream during storms.

Materials: Rubber boots, D-nets for stream sampling, plastic tubs, Petri dishes, forceps, magnifying lenses, stream macroinvertebrate keys

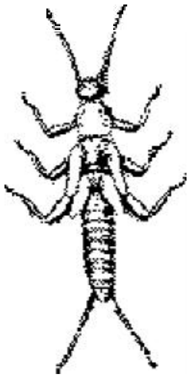
Method: In groups of at least two, find a riffle for sampling. : Have one person stand downstream holding the D-net so that its mouth faces upstream and the net touches the floor of the streambed. Another person standing two to four feet upstream should kick at the streambed for a few seconds to dislodge the leaf litter. This should cause organisms to drift into your net. After a couple of minutes, climb onto the bank and gently empty your net into a plastic tub that has a bit of water in it (add more if necessary). When you empty your nets into your trays your organisms it may take a while for your organisms to start moving. When they do, use the key to determine which species you have, and keep a tally on the attached sheet. When you are done gently return the water and organisms just upstream of the riffle where you sampled.

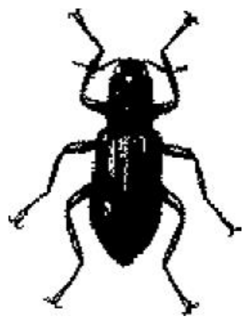
Identifying What You've Found:

Use the guide below to help you fill in the data table at the end of the lab. Click on the linked name of the organism for a description. Also please note, the organisms you find might not match those listed below exactly. Try to categorize the animals you find as closely as possible to the sketches. Using field lenses will help you to see definining features like tails, legs, and segmentation more clearly.

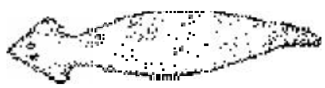
Macroinvertebrates That Are Sensitive to Pollution
Macroinvertebrate guide used with permission from Rick Webb and the Shenandoah Watershed Study

Found in Good Quality Water

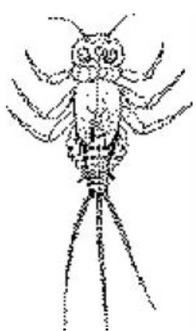


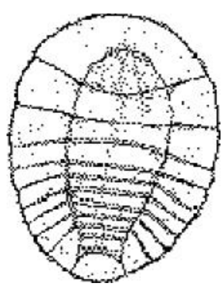


Stonefly **Riffle Beetle Adult**

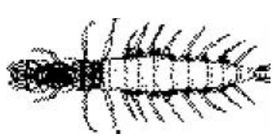


Gilled Snail **Planarian**





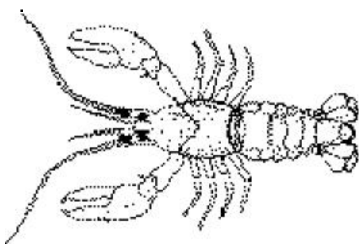
Mayfly – note three tails **Water Penny**



Caddisfly **Hellgramite**

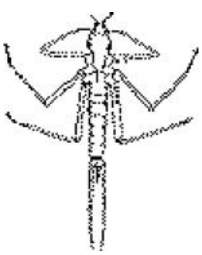
Macroinvertebrates That Are Somewhat Sensitive to Pollution

Found in Good or Fair Quality Water

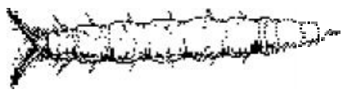


Crayfish **Alderfly**

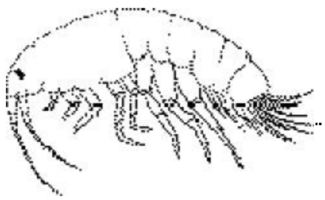
Crane Fly **Riffle Beetle Larva**



Damselfly **Sowbug**

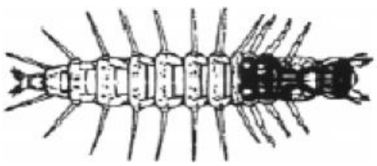


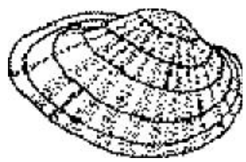
Dragonfly **Watersnipe Fly**



Scud

Whirligig Beetle Larva





Fishfly

Clam or Mussel

Cunningham 8e CRITICAL THINKING ANSWERS

Chapter 1

1. As girls gain an education, they have more income value for their family beyond child production, so there may be less pressure to marry young and have many children; they may also gain more ability to argue for their own employment priorities. .
2. There are many existential questions, such as, what is the meaning of life? Is there life after death? or Do we have a right to kill others? That science can't answer. Many of these are questions evaluated with empirical evidence, but rather have to do with values and life experience.
3. You can maintain objectivity in several ways. Keeping the identity of survey respondents secret from those who evaluate responses helps to maintain impartiality and objectivity. You can do blind or even double-blind experiments. You can carefully follow the ordered steps of the scientific method in order to be sure you are properly testing you hypothesis.
4. Whether there are there enough resources depends on our choices in patterns of production, consumption, and cooperation. It also depends on what you consider a decent, secure, happy life. As Paul Ehrlich points out, the carrying capacity for saints might easily be 10 billion, but the number of selfish, wasteful, greedy, destructive individuals the world can tolerate is far lower. Whether you think we have enough resources depends also on what kind of resource consumption we consider necessary. What level of resource consumption do you really need to be happy and healthy? Does your happiness depend on the size of your material goods or on the quality of your friendships?
5. In studying the environmental impacts of a rich versus poor country, you ought to examine not only the local environment of each country, but also evaluate the impacts of extracting, shipping, and using resources from remote locations. In other words, what are the environmental impacts of wealthy lifestyles and political/economic systems on the countries that produce the goods and services they use?

Chapter 2

1. The boundaries of an ecosystem are often defined in terms of the general characteristics of the plants and animals that live in an area—for example the boundaries of a desert ecosystem might be where moisture increases and vegetation becomes more abundant. All ecosystems are open with regard to energy source (usually the sun), but consider the sources of water, air, food, building material, and other resources. Where do they come from?
2. Entropy means disorder or disorganization or reduced structure. Entropy in everyday life includes death, decay, rusting metal, and water running down hill, or even disarray in your room the day after you have cleaned it. Does the principal of entropy explain why it's impossible to build a perpetual motion machine? Constant energy is needed to maintain order and cleanliness, in most cases.
3. If all chemical bonds were extremely strong, your cells would not be able to break them apart in order to release energy or form new compounds. Substances with strong bonds are solid, not moveable and fluid. If all chemical bonds were extremely week, no structures could exist, and your cells could not form stable structures or compounds to