Chapter 2 Frameworks for Understanding: Science, Systems, and Ethics

Key Terms

anthropocentric
biocentric
blind experiment
controlled experiment
deductive reasoning
dependent variable
disturbances
double blind experiment
ecofeminism
environmental justice
environmental racism
equilibrium
ethics
field investigation
frontier science
hypothesis
independent variable
inductive reasoning
instrumental value
intrinsic value
models
negative feedback loop
open system
paradigm shift
positive feedback loop
preservationist
resilience
scientific consensus
stewardship
systems
theory
toxic colonialism
utilitarian

Skills

1. Diagram the stages required to test a hypothesis.
2. Identify independent and dependent variables in a controlled experiment.
3. Conclude what criteria are necessary for a hypothesis to become a scientific theory.
4. Contrast deductive and inductive reasoning. Give an example of each.
5. Compare and contrast positive and negative feedback loops. List specific environmental examples of each type of loop.
6. Characterize the different philosophical viewpoints of anthropocentric, biocentric, utilitarian, and preservationist worldviews.
7. Examine the concepts of environmental justice and environmental racism.

The Nature of Science

Science is a method of producing knowledge in a systematic fashion based upon observation of natural phenomena. Scientists conduct experiments or field observations to explain their proposed explanations. Science qualifies all results of experiments as conditional because there is always the outside chance that additional research will demonstrate the results to be inaccurate. Scientists never "prove" anything, they "demonstrate," "show," "correlate," and "illustrate." For a scientist to publish his results, he must submit his research data to a peer-reviewed journal. Scientists must also do each experiment multiple times, known as replication. His or her work must be able to be repeated by other researchers, called reproducibility. For example, in 1989 two scientists claimed at a press conference to have carried out cold fusion in the laboratory. The energy and scientific communities were skeptical and tried to reproduce the data. They could not, nor was the experiment ever published in a peer-reviewed journal. Due to the lack of reproducible data, cold fusion was not determined to be possible at that time.

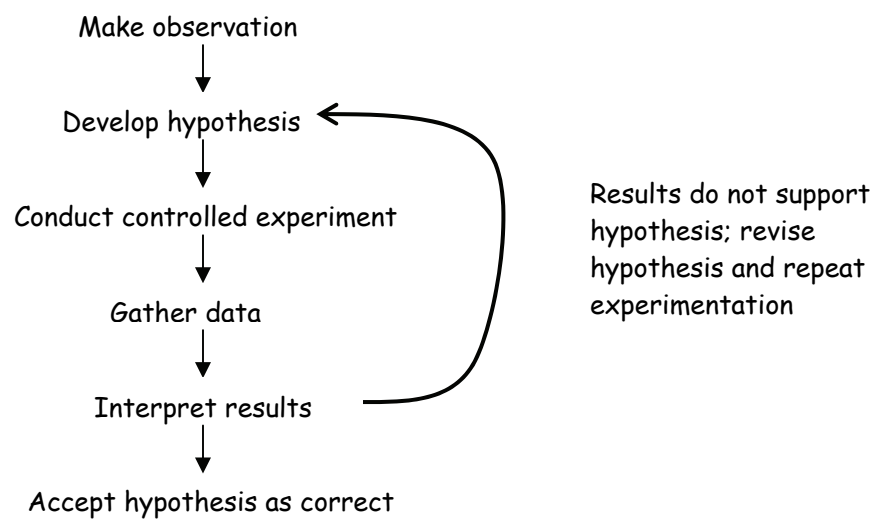
Reasoning

There are two types of reasoning, deductive and inductive. Deductive reasoning proceeds from the general to the specific. For example, if you know that venomous snakes typically have a triangular head and while hiking you find a snake with a triangular head in your path, deductive reasoning tells you that you should avoid the snake as it is likely venomous. Inductive reasoning is making a general rule from numerous observations. For example, it is well known that poison dart frogs are vibrantly colored. Other toxic species include the venomous sea slugs, the noxious tasting ladybug, and many species of caterpillars, all three brightly colored. Therefore, using inductive reasoning, brightly colored species tend to be toxic. This coloration is known as warning or aposematic coloration because the brightly colored animals are usually toxic.

Designing an Experiment

> **Take Note:** A "design an experiment" question is to be expected on each AP exam. You will be given a scenario and must develop a controlled experiment to test a hypothesis. You absolutely must be able to describe your hypothesis and experimental setup, including constants, controls, data, and interpretation, to answer such questions properly. See further information in the section on writing essays.

There are a series of steps in experimental design.



Once an explanation has been supported throughout the years with numerous studies, the explanation is deemed a scientific theory. This use of the word theory is as close to absolute as a scientist will come to stating something as fact. People not familiar with science tend to use the word theory as conjecture, but it means the opposite to a scientist. Theories include the theory of evolution and the theory of relativity, both substantiated by large amounts of scientific evidence

and accepted by the scientific community. Theories may be modified as additional data is collected.

When conducting experiments, you can conduct statistical analysis from available data. For example, you can count how many West Indian manatees are found dead in a given year and calculate the statistical relevance of the number by comparing it to the number found dead in prior years. This procedure is known as a natural experiment, because it analyzes previous observations.

Most frequently scientists must manipulate an experiment to derive the data in which they are interested. In that event, they must use a controlled, or manipulative, experiment, in which only one factor is changed and all the rest of the factors are constants. The factor that is changed is usually known as the variable. All other parameters of the experiment remain constant. This setup is known as a controlled experiment. For example, an observation is made that a species of frog is declining in an unpolluted area. Researchers cultured an unusual fungus from the bodies of the dead and dying frogs. To test whether the fungus was killing the frogs, a controlled experiment must be conducted. Two tanks with the same number of frogs of the same species would be set up. The tanks would have identical temperatures, water pH, water volume, light, and oxygen. The animals would be fed the same amount of food. In one of the tanks the fungus would be introduced. If the animals died, then the fungus could be killing the frogs, and the hypothesis would be accepted. The experimental or treatment group is the group exposed to the fungus. The control group of frogs would be the group not exposed to the fungus. The independent variable is the factor being changed and the dependent variable is the result that occurs in response to a change in the independent variable. The independent variable in this example is the fungus and the dependent variable is the death of the frogs.

To alleviate researcher bias, the experiment could be conducted as a blind study, where the researcher did not know which tank contained the fungus. Frequently a double blind study is conducted when testing new vaccines or medications. Neither the researcher nor the study participant knows if they have been given the medication. Then, if in the control group four people got headaches and in the experimental group three people got headaches, headaches are not likely to be a side effect of the medication. If the researcher or study participant knew which treatment they received, it might cause them to imagine or perceive a headache that did not exist.

Probability and Statistics

Probability is the likelihood that something will happen. The probability of two events occurring simultaneously is the product of their individual probabilities. For example, the likelihood of a tossed coin coming up head is one-half, because there are only heads and tails. The probability that two coins tossed together would both come up heads is one-fourth, or one-half x one-half. Statistics focus on calculating probabilities that the results of an experiment are accurate and do not arise as a result of chance. Statistics are frequently used to analyze experimental results.

Models

Models are representations. For example, a graph is a graphical model that illustrates relationships. Physical models are a miniature representation of an object. For example a model car or a model of the solar system would be physical models. Other models are mathematical. For example,
$N_t = rN_{(t-1)}$ is a formula used to predict population growth. Simulations can be complex mathematical models which are used to predict scenarios such as global climate change.

Consensus vs. Frontier Science

Frontier science is relatively new research that has not yet been supported by years of scientific evidence. For example, nearly ten years ago an article was published in a medical journal that established a link between autism and childhood immunization. The article has since been repudiated, as there has been no research that substantiated the researchers' claim of a link. The more current research seems to demonstrate that it is coincidence that autism appeared after immunization, rather than a cause-and-effect relationship. Unfortunately, many people with newborn children elected not to have their children vaccinated, which has led to an increase in easily prevented diseases such as measles and whooping cough. Consensus science is science supported by large amounts of data. For example, most scientists agree that the increasing levels of CO_2 in the earth's atmosphere are causing more heat to be retained in our atmosphere, resulting in global warming. Paradigm shifts are large changes in explanations as science uncovers more information. Plate tectonics not only greatly changed the science of geology but it also had a profound impact on paleontology and evolutionary biology.

Systems

A set of interacting components forms a system. For example, your stereo system has a receiver, CD player, and speakers. An ecological example of a system is a pond. The plants and algae present provide food for the numerous fish. Metabolic wastes and decay of dead fish and plants allow the nutrients to cycle in the system. If the system changes very little, it is said to be in equilibrium. A disturbance is an alteration in the equilibrium. For example, a drought might dry up the pond a bit. Periodic mild disturbances may help an ecosystem remain at equilibrium. If a system can recover quickly, it is said to be resilient. An open system receives input from the outside, but a closed system is not open to the outside for input. The earth is an open system for energy because it receives energy from the sun, but is a closed system for matter.

Feedback Loops

> **Take Note**: Students frequently confuse positive and negative feedback. Remember that positive feedback leads to exponential growth or decay, while negative feedback leads to homeostasis.

Feedback loops are found in systems that allow for correction of that system. A negative feedback loop is one in which the deviations from a normal set point are minimized. A good example is predator prey relationships. When the number of prey increases, the number of predators increases after a slight delay. When the predator increase causes the prey number to

drop, the predators die out, thus maintaining both populations around a standard set point. Negative feedback loops help maintain homeostasis, or the normal steady operating state of an organism or an ecosystem. A positive feedback loop is one in which the deviation from normal becomes greater and greater instead of correcting itself. In organisms, disease may result from positive feedback. A good ecological example of a positive feedback loop is eutrophication (eu—true; troph—feed) in a pond. In eutrophication, an increase in nutrients induces an algal bloom. The bloom blocks the sunlight from rooted vegetation and deeper algae, resulting in death. The subsequent decay of the dead plants and algae consumes the dissolved oxygen in the water, causing species with higher oxygen requirements to suffocate. Those dead organisms decay, further reducing the oxygen. The anoxic (an—without; oxy—oxygen) conditions eventually result in all living organisms dying out in the pond.

Ethics and Worldviews

Ethics is the branch of philosophy that deals with right and wrong. Environmental ethics asks us to examine the principles that guide us to do what is right in our actions toward the environment. Stewardship is managing and caring for the environment. A biocentric (bio—life; centr—center) worldview is that living things have a right to exist and should be respected. An anthropocentric (anthro—man; centr—center) worldview is that humans are above nature, not a part of nature. A utilitarian worldview believes that nature provides services and goods to humans for our use. Conservationists believe we should care for our environment so that it may provide for us for many years to come. Gifford Pinchot, the first head of the United States Forest Service (USFS), was appointed under Theodore Roosevelt because he was a noted conservationist. Preservationists feel that the environment should be protected in its natural state, but not used for the good of humans. John Muir, founder of the Sierra Club, was a preservationist.

Many people feel that because a living organism exists, it has value. This concept is called intrinsic or inherent value. If something has value because you can use it for a purpose, it has instrumental value. If something is considered to have value because it is beautiful, it is said to have aesthetic value.

Ecofeminism is the concept that males are more domineering and try to subjugate nature, while women are more nurturing and protective. Therefore, if women were not repressed in societies, nature would not be as exploited because women would have more of a voice in environmental issues.

Environmental justice is giving people of all socioeconomic, racial, ethnic, and religious affiliations equal rights with regard to environmental protection. For example, there are greater problems with lead poisoning in lower socioeconomic and ethnically diverse populations than in upper-income Caucasian populations. Environmental racism is the greater exposure to environmental pollutants based on race. Examples include the farm workers of color working on U.S. farms and being exposed to high levels of fertilizers and pesticides or dumping hazardous wastes on Native American reservations. Toxic colonialism is shipping toxins to reservations or undeveloped countries that welcome the income and disregard the damage that may result from the toxins. The U.S. Office of Environmental Justice was established by the Environmental Protection Agency (EPA) in 1992 to assist groups with fighting emissions or toxins in their area

when the groups do not have the resources to fight by themselves. It helps identify at-risk areas and the specific risks to the area.

Questions

Use the paragraph below for questions 1 and 2.

A scientist wished to test the impact of increased nitrates on plant growth. He placed 100 rye seeds in three different pots, making sure to use the same soil in each pot. He placed 100 ml of nitrate free fertilizer in pots 1 and 2 and nitrate containing fertilizer in pot 3. He also added clover seeds to pot 2 (clover is a legume). He placed the plants under a grow light and watered them daily with 50 ml of water for three weeks. His results are shown below.

Pot	Average ht rye (cm)	Increase in mass (g)
1	4.2	100.4
2	6.8	163.0
3	7.6	172.2

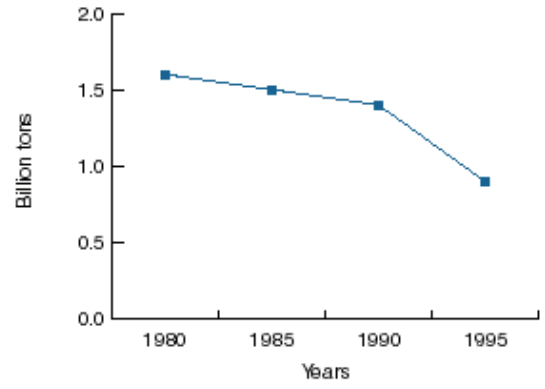
1. What is the independent variable in this experiment?
   a. soil
   b. height
   c. mass
   d. nitrates
   e. rye seeds

2. What statement best explains the use of pot 2 in the experiment?
   a. The nitrogen-free media only causes increased growth of the plants if other seeds are present.
   b. Clover seeds inhibit the growth of the rye grass.
   c. The clover must be fixing nitrogen from the atmosphere and enriching the soil thus enhancing the growth of the rye grass.
   d. The clover seeds crowd the rye grass and force it to grow better in their presence.
   e. The nitrogen-free media is toxic to the rye seeds but not the clover seeds.

3. Graph the above data as a bar graph. What conclusions can you draw from your graph?

4. Which of the following is an example of environmental racism?
   a. Sewage sludge from a sewage treatment plant is incinerated to generate electricity.
   b. Numerous hazardous waste sites are located on land owned by Native American tribes.
   c. Pesticide residues may be found on some fruits and vegetables.
   d. Lead can be removed from soil by using plants such as sunflowers that will take up the lead in their tissues.
   e. Dredging channels in rivers removes not only sediment but varying amounts of polychlorinated biphenyls and remnants of oil spills.

5. A hypothesis is
   a. a testable explanation for an observation.
   b. a theory devised after years of scientific study.
   c. proven true by general agreement of the scientific community.
   d. always demonstrated to be accurate after one experiment is conducted.
   e. rejected when the data support the premise.



6. The above graph shows U.S. sulfur dioxide emissions over a 15-year period. What can be inferred from the graph?
   a. The enforcement of the Clean Air Act passed in 1990 resulted in less sulfur dioxide emissions than in the previous decade.
   b. There was a 50 percent decline in sulfur dioxide emissions from 1980 to 1990.
   c. It can be determined from the graph trend that only 0.5 billion tons were released in 2000.
   d. Most of the sulfur dioxide was from natural rather than anthropogenic sources.
   e. Sulfur dioxide emissions are linked to increased global warming.

7. A scientist conducted a study to determine which wildflowers in an area attracted honey bees. She conducted visual observations in four different fields and recorded the number of visits by bees to each of the different colored flowers in the area. After statistically analyzing the data, it was demonstrated that the bees were attracted to the violet- and yellow-colored flowers and rarely visited the pink and red flowers. The scientist used:

   I. Inductive reasoning II. deductive reasoning III. the scientific method

   a. I only
   b. I and II
   c. I, II, and III
   d. I and III
   e. II and III

8. In the rainforest of Ecuador, oil and pollutants are dumped by oil companies into local rivers used by the indigenous people. This practice is an example of
   a. toxic colonialism.
   b. ecofeminism.
   c. environmental parity.
   d. anthropocentric worldview.
   e. environmental development.

9. Which of the following is an example of a controlled experiment?
   a. A botanist exposes three types of plants to varying levels of carbon dioxide to test growth.
   b. A zoologist watches the behavioral interactions of a group of monkeys.
   c. A researcher examines the toxicity of two pesticides by exposing one fish to both pesticides.
   d. A toxicologist treats one group of *Daphnia* with lead and compares the results to another group of *Daphnia* not exposed to lead.
   e. A scientist studies the combined impact of cigarette smoking and drinking alcohol by looking at the increase in liver and lung cancers in smokers that drink.

Explanations

1. d. Nitrates are the independent variables. The soil and rye seeds are constants of the experiment. The height and mass are the dependent variables because they are dependent upon the presence of the nitrates.
2. c. The clover must be fixing nitrogen from the atmosphere and enriching the soil thus enhancing the growth of the rye grass. Because the nitrates are lacking in the fertilizer, that pot 1 rye grass has nearly the same increase in height and mass as pot 2 indicates that the clover was fixing nitrogen for the rye seeds to use. The nitrogen-free media would not cause increased growth of the plants just because other seeds were present. Clearly the growth was better in pot 2 than pot 1, therefore the clover seeds could not be inhibiting the growth of the rye grass, nor would crowding enable plants to grow better. There was growth in pot 1, so the nitrogen-free media could not be toxic to the rye seeds.
3. Bar graph should plot experimental treatment along X axis, and both plant height and mass along Y axis. Conclusions could be that nitrogen-containing fertilizer produced the most growth in both height and weight. However, the clover plants in pot #2 are also increasing rye growth somewhat, and question #2 speculated that this is due to nitrogen fixation.
4. b. Environmental racism is subjecting people of color to hazards not present for the rest of the population. Therefore, the presence of hazardous waste sites on land owned by Native Americans is toxic colonialism.
5. a. The definition of hypothesis is a testable explanation for an observation.
6. a. The sulfur dioxide levels dropped since 1990. There was not a 50 percent decline in sulfur dioxide emissions from 1980 to 1990. You also cannot tell that the sulfur dioxide levels will continue to drop. The graph does not differentiate between natural and anthropogenic sources. On the contrary, sulfur dioxide emissions are not linked to global warming.
7. a. The scientist was using inductive reasoning by applying the scientific method. He gathered data based upon observation and repeated the experiment in four different fields for

replication. She came to the general conclusion that the violet and yellow flowers were favored, thus was using inductive reasoning.

8. a. Toxic colonialism is the release of toxins in undeveloped countries because they do not have the means to fight the injustice.

9. d. Because the toxicologist treats one group of *Daphnia* with lead and compares the results to another group of *Daphnia* not exposed to lead, this is a controlled experiment. The botanist did not have a control, nor did the zoologist. The toxicity of pesticides should have been tested on numerous fish, but separately. The increased lung and liver cancers may not demonstrate the impact of smoking and drinking unless the results are compared to the results from people with those cancers that did not drink or smoke.