

Chapter 2

Science as a Way of Knowing

2.1 UNDERSTANDING WHAT SCIENCE IS AND IS NOT

Case Study: Birds at Mono Lake: Applying Science to Solve an Environmental Problem

• This case study highlights the problems of Mono Lake in California where over a million birds use a lake that is drying up and becoming salty due to the diversion of water to the city of Los Angeles. The questions posed to a panel of scientists studying the lake were 1) without stream input how small would the lake become and 2) would it become too salty to support aquatic life and when? The answers were yes, too salty by 2003. What to do was a question of values, water for Los Angeles or water for the lake. In the end, the courts sided with the lake.

- Science is a process of discovery. Science starts with observations about the natural world followed by questions that boil down to what, how and why.
- Explanations are scientific only if they can be disproved.
- Science makes certain assumptions about the natural world:
 - The natural world can be understood by observation and analysis
 - The rules that explain the observations are universal
 - Generalizations are valid if they can be subjected to tests that can disprove them
 - Science can never provide absolute proof positive
- Science deals with ideas that, at least in principle, can be disproved.
- The nature of proof: If a conclusion follows logically from reason or from a **premise** (e.g. a straight line is the shortest distance between two points), the conclusion is said to be proven and the process is **deductive reasoning**. Deductive proof does not require that the premises be true, only that the reasoning is foolproof, but a deduction is only true if the premises are true. Science requires not only correct deductive reasoning, but also that the premises are correct, and the process is called **inductive reasoning**. Induction begins with specific observations about the natural world that lead to logical generalizations or explanations that are tested. If tests cannot be devised, then the explanation cannot be treated as science. For example, explanations for the creation of crop circles (see A

A Closer Look 2.1: A Brief History of Science

- Scientific observation began at least as early as Babylon and Egypt when climate and astrological records were kept. The Greeks developed a more theoretical approach to science with an interest in knowledge that had no immediate practical benefit. Modern science had its roots in the late 16th and early 17th centuries with the development of the scientific method by Gilbert (magnets), Galileo (physics of motion) and Harvey (circulation of blood).

Closer Look 2.2) that invoked supernatural forces or aliens are not

2.2 MEASUREMENTS AND UNCERTAINTY

- All measurements have error, only the degree of error differs. There are two types of error: **errors of precision** (the instrument is only capable of measuring to a certain precision) and **errors of accuracy** (when the instrument or observer are not accurate). A measurement may be very precise, but inaccurate. Conversely, a measurement may be accurate, but imprecise. Scientists estimate the accuracy of a measurement by calculating the differences between repeated measurements.

2.3 OBSERVATIONS, FACTS, INFERENCES AND HYPOTHESES

- When observations lead to a generality, the generality is known as an inference. When repeated observations support the generality, the inference becomes a hypothesis. Eventually, after much testing, if the hypothesis cannot be disproved then the hypothesis becomes fact or law. A typical hypothesis is a statement of how a **dependent variable** responds to one or more **independent variables**. Experiments are done by manipulating the independent variable and comparing the response of the dependent variable against a **control**.

- The scientific method can be described as a series of steps:
 1. Make observations and develop questions
 2. Develop tentative answers – a hypothesis
 3. Design experiments to test the hypotheses (or to disprove the null hypotheses).
 4. Collect data
 5. Analyze and draw conclusions from the data
 6. Compare the conclusions with the hypothesis
 7. Design additional experiments if conclusions are consistent with hypothesis or make additional observations and construct a new hypothesis.

2.4 A WORD ABOUT CREATIVITY AND THINKING

- Science is an intensely creative process. Scientists must have the creativity and inquisitiveness of a small child. Scientists often pose questions that seem silly or irrelevant to the layperson.

2.5 MISUNDERSTANDINGS ABOUT SCIENCE

- In common usage, the word theory conjures up an image of speculation. In fact, in scientific usage the term is the highest form of proof that is supported by an overwhelming body of evidence.
- Science is often confused with technology. Technology enables science, and science leads to technology, but technology is not science.
- Scientists aspire to be objective, but scientists are still human and subject to the same biases as all people, but there are methods designed to remove any observer bias such as the double blind study.
- Generalizations or hypotheses that have been disproved or that cannot be tested are termed **pseudoscience**. **Frontier science** is science on the cutting edge that has not been thoroughly tested.

A Closer Look 2.2: The Case of the Mysterious Crop Circles

- Crop circles that first appeared in grain fields in England were heralded as evidence of visits by extraterrestrials by many lay persons and even unscrupulous scientists eager to make a quick buck. They were deemed worthy of coverage by the national news media. Eventually the pranksters who created them confessed and the mystery was solved, but the sensation they created and the *belief* in a solution in the complete absence of scientific observation and testing is an interesting example of how easily the masses can be deceived.

2.6 ENVIRONMENTAL QUESTIONS AND THE SCIENTIFIC METHOD

- Environmental science deals with complex systems that present challenges to the traditional scientific method. Empirical scientific tests involving large complex systems are often not possible, and so alternative methods using microcosms and/or mathematical models are used. We often can test the premises, but not necessarily the final inference. Global warming due to rising CO₂ is a good example. We have tested the premise that CO₂ absorbs infrared radiation, and we have observed that the CO₂ concentration in the atmosphere is rising, but we will not know of the fact of global warming until the predictions either are or are not confirmed by long-term observation.
- Ecologists often make use of historical data to extend their range of observations, such as the CO₂ concentration in air bubbles trapped in ice cores, or the pollen concentrations contained in the sediment of a lake. Natural disturbances or accidents also are utilized when the disturbance results in what is in effect a natural experiment that could not or would not ever be purposely duplicated. The disaster at the Chernobyl nuclear reactor is an example of a tragic disaster that has provided a rich test bed for ecological research.

2.7 SCIENCE AND DECISION MAKING

- Scientific answers are often uncertain, and sometimes decisions must be made based on probabilities and uncertain estimates of costs and benefits. Global warming provides another good example. Many scientists (e.g. Wally Broecker) are convinced that it will be a disaster if the CO₂ concentrations in the atmosphere rise to 700 ppm, yet there are scientists (e.g. S. Idso) who raise the possibility that negative feedbacks from increased cloud cover and albedo will hold the temperature down. Environmental decisions are rarely easy, and the solution to one problem often creates a new problem (e.g. water treatment creates a solid waste disposal problem).

2.8 LEARNING AND SCIENCE

- Science is constantly evolving, particularly at the cutting edge. Learning science is not about memorizing facts, it is about using the facts or the understanding of how nature works to solve problems.

2.9 SCIENCE AND MEDIA COVERAGE

- Most media coverage involves new discoveries and pseudoscience. The media are quick to sensationalize a ‘new discovery’ before it has had time to mature.

Critical Thinking Issue.

- **How do we decide what to believe about environmental issues?**

Web Resources

http://www.npr.org/display_pages/features/feature_1893089.html Three views on global warming by scientists.