Data and interpretation: Knowing the difference

by Elaine Kennedy

Multiple, alternative interpretations of data are not only possible but probable.

Consider the following statements. **Statement 1**: A is a human being. B is a gorilla. Between and A and B are many similarities, but A has many superior attributes when compared with B.

Statement 2: The similarities show that both A and B had a common origin. The superiorities suggest that A evolved from B over millions of years.

Statement 3: The similarities show that both A and B had a common origin: the creator God. The superior attributes of A show that God chose to create human beings in His own image, and this was not the case with the creation of animals.

Statement 1 is data—observable, knowable, and open to experience. Statements 2 and 3 are interpretations of the facts, one by an evolutionist and the other by a creationist.

This simple illustration reveals that knowledge or information can be divided into two separate concepts: data and interpretation. Since data is subject to alternative interpretations, students and researchers must carefully distinguish between the information that constitutes the collected data and the "information" derived from the data that is presented as evidence in support of a hypothesis. Scientists endeavor to be as objective as is possible in this regard, but several factors (biases) influence the selection and interpretation of the data.

The distinction between data and interpretation is no less important in the science classroom than it is in the science laboratory. The greatest difficulty with the process of separating data from interpretation lies within the context of textbook assignments. Textbooks are the prime sources of information in any classroom; however, in the science classroom the information that is provided is often more interpretation than data. Students need early training with respect to identification of data in exercises using textbooks. The development of such exercises will require additional effort on the part of teachers, but should yield more analysis on the part of the students and less explanation on the part of the teacher as the class progresses.

Knowing the difference

What is data? What is the difference between data and interpretation? Data consist of measurements and observations used as a basis for reasoning, discussion, or calculation.[1] Observable data are usually regarded as unalterable facts, but may or may not be true. As technology and science progress, "facts" will be discarded, modified, or replaced with new data. For example, measurements may form a basis for identification, i.e., an interpretation, of an object or phenomenon. Fossils of extinct organisms are often identified, based on measurements of various structures on the body parts that have been preserved. The accuracy and precision of the measurements make correct identification difficult because with many of the extinct shelly fauna scientists do not know whether or not large organisms that have similar structure to small organisms represent different species, gender, or developmental stage. The actual identifications or calculations are not data; they are interpretations. Much of the controversy that exists in the scientific literature is generated by a rather significant problem: interpretations drawn from limited databases. This point needs to be emphasized in every unit that is studied in any science classroom.

The complexity of data and interpretations

As an illustration of the complex interplay between data and interpretations, consider two steps involved in the process of merely identifying rocks and minerals.

Step 1. Interpretations of light properties of minerals. Light properties of minerals are described from the microscopic examination of a very thin slice of rock (commonly referred to as a "thin section"). Polarized light (light waves that vibrate in only one particular plane) is used to conduct a series of tests on the light properties of each mineral in the thin section. The tests provide a visual database of light-transmission patterns. Mineralogists use these patterns to determine the mineral composition of the sample. The identification of the minerals is an interpretation based on the light property data.

Step 2. Determination of rock type. By examining the contact of one mineral with another and measuring how much of each mineral is present, the rock type can be determined. A geologist who identifies the rock considers the mineral identifications "data" even though the rock identification is actually an interpretation of an interpretation. (The mineralogical "data" were determined originally from the light property data.) The point is that the scope of what constitutes data is actually quite narrow.

Just how valid is identification? Identifications can be made using comparisons with standards. For example, three thin sections may have the same mineral composition but the mineral contacts may be very different. If the mineral grains are interlocking, the rock is an *igneous rock.* If the mineral grains are altered, distorted, elongated, and aligned, it is a *metamorphic rock.* The same minerals cemented together form *sedimentary rock.* When terms and procedures are well defined, identification is fairly easy and relatively reliable.

Since data is limited to what we can measure or directly observe, teachers need to foster their students' ability to interpret the data so that they can develop reliable conclusions. An interpretation is an explanation, a means of presenting information in understandable terms. Interpretations are limited by the availability of data and by the bias of the observer.

Multiple levels of interpretation

Several levels of interpretations exist. For example, the name, *oolite,* not only identifies a particular rock type but also implies an entire history of environmental requirements and depositional conditions for its formation. How can a name acquire that much interpretative information?

1. A thin section made of round, beadlike particles all cemented together must first be identified with respect to its mineralization. Therefore, the first level of interpretation is to identify the mineral composition of the little beads. For the purposes of this illustration, we will identify them as particles of calcium carbonate.
2. The identification of the structure of the round, bead-filled rock is based on recognition of a central object that may be a piece of some other kind of rock or perhaps a bit of shell material around which the calcium carbonate has precipitated. This structural information coupled with the roundness of the particles identifies the beads as oolites. At this point, one might think that the exercise is finished and the identification is as simple and straightforward as the mineral identifications. However, a third level of interpretation is introduced to explain how the oolites were formed.
3. The third level relies on observations in modern environments. Geologists know that oolites are typically formed near a shore by the agitation of warm, shallow, saline waters.
4. Researchers apply this knowledge to oolitic rocks found on a mountainside. In other words, geologists take what they know about the modern setting and interpret the ancient setting accordingly. They assume that the oolites on the mountain formed at that site sometime in the past in the same way that oolites form in the ocean or the Great Salt Lake in Utah. That interpretation implies that oolites do not form in any other way. The reasoning seems quite logical and the conclusion seems obvious; however, this association may not be true.

   The exercise is not over. This set of interpretations is now added to other data with multiple interpretations to bring us to the final description of a particular rock exposure. This process is duplicated at other exposures or outcrops of rock over a broader region to develop a model.
5. Geologists use other rock types and additional data to develop models to describe geologic events in Earth's history. For example, cemented quartz grains are called sandstones. Patterns in sandstone may be due to a process known as cross-bedding. Typically, cross-beds are formed as currents (wind and/or water) deposit sand and silt on the lee slope of dunes. By integrating a broad range of data and interpretations (the minerals, rocks, oolites, and cross-bedding) geologists can now develop that fifth level of interpretation: modeling. Models

provide scientists with a generalized framework for developing predictions and assessing events that may have occurred in the past.[2]

Thus the distinct difference between data and interpretation must be utilized when evaluating research. Data are actual measurements and observations. Interpretations try to identify or explain what is measured and observed. The validity of an interpretation is based on how well the interpretation accommodates the available data. Interpretations may change as the database changes. This interplay between data and interpretations is what make science so successful and progressive.

Bias during data acquisition

Scientists are aware that they are subject to error and misconception. Hence they try to maintain an attitude of objectivity in research.[3] This commitment to objectivity has created a sort of aura around scientists and, unfortunately, science has developed a popular image of "infallibility." People often prefer to believe that scientists are objective and deal with absolutes. Some even think that when a scientist draws a conclusion, all competing theories have been refuted and questions have been resolved. Thus a false sense of security in science develops. Some scientists do little to dispel this image. To complicate matters, the scientific community has adopted the position that any researcher having a religious bias is nonscientific; therefore, by definition, creation-science cannot be true science. Such an attitude fails to recognize its own bias.[4]

Here are some biases that influence science—some technical, some subtle and unconscious factors.

1. *Sampling constraints.* The first problem in gathering data is sampling bias. Every scientist has some preconceived ideas about the research that influences the selection of data. Random sampling helps minimize problems,[5] but even then there are choices made that favor a particular hypothesis.
2. *Systematic errors.* A scientist may have a "blind spot": a failure to recognize data. For example, it is common for a paleontologist who specializes in fossil snails to collect a wider variety of gastropods than anyone else on the mountainside. However, that same individual will have fewer clams and corals than other fossil collectors. These other fossils can have a significant impact on the interpretation of that site, but the bias of the researcher eliminates that input.

Can you find the data?

The article below is typical of the science news published in newspapers around the world. It contains a lot of information but not all of it is scientific data. Circle or underline the data as you read through the "news" and then check your answers on page 18. What can you conclude from just the data?

Rich Fossil Deposit Found

The New York Times, March 27, 1984. (Reprinted by permission.)

What is believed to be the richest deposit of early Ice Age fossils ever found in North America has been partly uncovered in a quarry near Apollo Beach, Fla. It is expected that the deposit will ultimately yield as many as 60 species.

However, only after the deposit has been fully excavated, and the specimens assembled and prepared for study, will it be possible to assess the full significance of the find, researchers say.

Those fossils found to date range from Ice Age elephants (mammoths and mastodons) to long necked camels and what appears to be a new species of llama. There are bones from large birds resembling the California condor, the Andean vulture, and a big extinct turkey vulture.

Although the site is now near the edge of Tampa Bay, Dr. S. David Webb of the Florida State Museum in Gainesville suspects, from the typical habitat of such birds, that the animals were all living far inland. The sea may have been "pretty far out in the Gulf," he said in a telephone interview on Monday.

Webb, a recognized authority on Ice Age animals, said the specimens all seemed to be of the primitive types that lived from 1.5 million to 1.9 million years ago.

The find was made by Frank Garcia, an amateur paleontologist, regarded by Webb as "one of our best in Florida." Last fall, Garcia found a few tantalizing specimens in the pit, from which seashells were being excavated for road surfacing. This encouraged him to dig deeper and, between two thick shell deposits, he found a highly concentrated bone deposit two feet thick.

The bones appear jumbled and disarticulated, rather than as intact skeletons lying where the animal died. Such deposits in Alaska have been attributed to water action that swept many animal remains into a single streambed. Webb believes the deposits should provide much information on faunal exchanges between North and South America soon after the Isthmus of Panama rose from the sea and provided a bridge between the continents.

Species found in the pit seem to display links to animals that evolved on both continents.

Besides the problems involved with obtaining data, the processing of data can introduce systematic technical bias.[6] An unrecognized faulty procedure or an incorrectly applied mathematical formula or statistical analysis in the processing of data introduces a systematic error or bias into the results.

3. *Technological constraints.* Scientists now have the ability to incorporate large quantities of data and interpretations into computer-generated models through analyses involving pattern recognition. However, gigantic databases do not necessarily mean that models adequately reflect complex systems and processes. The development of simplified models with computer-generated systems produces technological bias because the simplified parameters place limits on the application of the model to real systems.[7]
4. *Quality of data.* Analysis of data introduces bias due to the qualitative or subjective interpretations that are included. For example, in the analysis of potassium-argon data, the quantity of potassium and argon can be measured very accurately and precisely. However, it is difficult to know just what that data means, and the conclusions relative to age depend heavily on numerous assumptions and problems that arise within the context of the methodology.[8] Current technology does not measure the age of the rock directly, thus the conclusions are biased. Descriptive data are even more problematic.
5. *Financial constraints.* Scientific method requires rigorous testing before any theory can be accepted. However, time and monetary constraints limit the crucial testing process. New data are incorporated into current theory because it is easier to get material published if it is generally accepted by the scientific community. The funding process has an incredible influence on research today.[9] No papers published, no money for research. It's that simple. The rigorous testing proposed by the scientific method is not cost-effective; so ideas and concepts are rushed into print and cited in subsequent publications. Monetary pressures are increasing the technical bias by limiting the experimental process. Students should be aware that research funding has significant control over published research.

Implications for science and religion

When it comes to the interface between science and religion, several points need to be noted. First, not all data are accurately measured, and sometimes it is difficult to differentiate between data and interpretation. Certainly, multiple, alternative interpretations of any database are not only possible but probable. Interpreting data can be very complex; however, the simplest scenario is usually preferred to the more complex one in the development of theories. Second, bias is present in any interpretation because all scientific interpretations are at least partly subjective. Third, we need to understand the nature of science and how scientists work. People sometimes get discouraged because scientific interpretations are changing constantly, so they don't know what to believe. However, that is the nature of science; that is how it advances. Once one truly grasps this aspect of science, one is reluctant to base theological beliefs on specific data or scientific concepts. Fourth, while science may be useful and provide relevant information, it should not dictate anyone's theology. If science is allowed to dictate theology, then every time scientific interpretations change, theology must be altered, whether that alteration is consistent with one's belief system and experiences or not. At the same time, theology should not dictate anyone's science. Concepts such as "fixity of species," based on personal theology held by many in the 17th and 18th centuries,[10] and "flat earth" theory are some of the ideas that contributed to conflict between science and theology. The Bible can supply legitimate working hypotheses and constraints for science. In fact, Scripture as an information source suggests avenues of investigation that would not be considered by most non-Christian persons. Such research should acknowledge any scriptural bias that may be present and all the data must be fairly evaluated.

Conclusions

Scientists are fairly confident that they know what they are doing. However, especially in the area of origins, science alone cannot assess the complete database because the scientific approach does not consider the possibility of supernatural involvement in nature and in the history of our Earth. Most scientists believe there are irreconcilable conflicts between science and Scripture.[11] For example, Ayala states, "To claim that the statements of Genesis are scientific truth is to deny all the evidence."[12] The evidence does not prove either a long or short history for life. The evidence available provides very limited information.

Answers to page 17

The scientific data included in the news item are: (1) In a quarry near Apollo Beach, Florida, (2) disarticulated fossil bones were found, (3) some of which belonged to large birds. (4) The fossil bones were located between two shell deposits (5) that were two feet thick.

The data are not the primary problem in reconciling science and Scripture. It is the interpretation of the data that presents conflicts. It has also been said, "Not only is the present the key to the past, but the present is the key to the future."[13] Both the historical accounts of a worldwide Flood and the prophetic accounts of Christ's second advent proclaim the falsity of that concept.[14]

For Christians, the Bible provides a source of information that suggests there is a better way to approach science. From this perspective, some harmony between science and Scripture may be recognized. In fact, Christians expect harmony because they recognize God as the Creator of nature and its scientific "laws."

Elaine Kennedy (Ph.D., University of Southern California) is a geologist and a research scientist at the Geoscience Research Institute. Her mailing address: 11060 Campus Street; Loma Linda, California, 92350; U.S.A.

E-mail: ekennedy@univ.llu.edu

You may also consult the Institute's web site: www.grisda.org

Notes and references

1. *Webster's College Dictionary*, 1991.
2. Andrew D. Miall, *Principles of Sedimentary Basin Analysis* (New York: Springer-Verlag, 1984), p. 3.
3. Francisco Ayala, Robert McCormick Adams, Mary-Dell Chilton, Gerald Holton, Kumar Patel, Frank Press, Michael Ruse, and Philip Sharp, *On Being a Scientist* (Washington, D.C.: National Academy of Sciences Press, 1989), p. 1.
4. Del Ratzsch, *The Battle of Beginnings: Why Neither Side Is Winning the Creation–Evolution Debate* (Downers Grove, Illinois: InterVarsity Press, 1996), pp. 158-179. See also Philip E. Johnson, *Darwin on Trial* (Downers Grove, Illinois: InterVarsity Press, 1991), pp. 6-12.
5. Ayala *et al*, p. 5.
6. *Ibid* p. 5, 6.
7. *Ibid*, p. 6.
8. C M. R. Fowler, *the Solid Earth: An Introduction to Global Geophysics* (Cambridge University Press, 1998), p. 192.
9 Francisco J. Ayala and Bert Black, "Science and the Courts," *American Scientist* 81 (1998): 230-239.
10. J. Browne, *The Secular Ark* (New Haven, Conn.: Yale University Press, 1983), pp. 21-23.
11. Colin Norman, "Nobelists Unite Against 'Creation Science,'" *Science* 233 (1986): 935.
12. *Ibid*, p. 935.
13. Alan Baharlou, 1978. Personal communication that echoes sentiment of James Hutton in 1788, "The results, therefore, of our present inquiry is, that we find no vestige of a beginning—no prospect of an end" (from *Transactions of the Royal Society of Edinburgh).*
14. 2 Peter 3:3-10.