

Data and Interpretation:

Knowing the Difference

Consider the following statements:

Statement 1: A is a human being. B is a chimpanzee. A and B share many similarities, but A and B each have numerous different attributes.

Statement 2: The similarities show that both A and B descended from a common origin, i.e., a common ancestor. The differences suggest that A and B did not follow the same evolutionary path.

Statement 3: The similarities show that both A and B had a common origin—i.e., a Creator, God. The reason for the differences is that the Creator chose to make each species unique and distinctive.

The initial statement is data—observable, knowable, and open to experimentation. Statements 2 and 3 are not data—

they are conclusions drawn from assumptions about the meaning of the initial statement: the first by an evolutionist, the second by a creationist.

This illustration reveals that knowledge/information can be divided into two separate concepts—data and interpretation. Since data are subject to alternative interpretations, students and researchers must carefully distinguish between the information actually included in the collected data and the “information” *derived* from the data, which is presented as evidence for a hypothesis. Scientists endeavor to be as objective as possible in this regard, but several factors (biases) can influence their selection and interpretation of the data.

The distinction between data and interpretation is no less important in the science classroom than in the science laboratory. Students often see interpretation parading as data—at museums, on television science shows, in nature books and magazines, and in the newspaper. Teachers have a responsibility to help students understand what is data and what is speculation.

For teachers, the greatest difficulty in separating data from interpretation occurs with the use of textbooks, a prime source of classroom information. In the science classroom, the textbooks often include more interpretation than data. Students need early training to help them distinguish between the

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By Elaine Kennedy



Cross-section of sandstone.



Identification of minerals like this metamorphic rock is based on analysis of light patterns they form when thin sections of the substance are tested with polarized light.

two. This will require additional effort on the part of teachers, but it should have positive results. With practice, students will become more analytic and require fewer explanations from the teacher.

Knowing the Difference

What is data? How can anybody tell 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, although they may or may not be true. As technology and science progress, “facts” are discarded, modified, or replaced with new data. For example, measurements may form the basis for identifying an object or phenomenon. However, the identification may actually be an interpretation.

For instance, fossils of extinct organisms are often classified through measurements of various body parts that have been preserved. Despite the accuracy and precision of the measurements, correct identification is difficult because, with many of the extinct shelly fauna, scientists do not know whether large organisms whose structures are similar to those of small organisms represent different species, genders, or developmental stages. Identifications and comparisons are, therefore, not data; they are interpretations. Science, of necessity, must use identifications and comparisons as data.

Much controversy 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.

Complexity of Data and Interpretations

As an illustration of the complex interplay between data

and interpretation, consider two steps involved in the process of identifying rocks and minerals:

Step 1. Interpreting light properties. The researchers’ description of a rock’s properties is based on their 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 each mineral in the thin section. Mineralogists use the resulting patterns to determine the mineral composition of the sample. Therefore, the identification of the minerals is an interpretation based on the light property descriptions.

Step 2. Identifying rocks. To identify rock samples, scientists examine the contact between two types of mineral and measure how much of each is present. A geologist studying the rock considers the mineral identifications “data,” even though they are actually an interpretation of an interpretation. (The mineralogical “data” were derived from the light property descriptions.) Once the rock is identified, that information is used as data as well.

Just how valid is mineral or rock identification? It depends on the methods used. Conclusions can be drawn by comparing the sample with standards. For example, three thin sections may have the same mineral composition, but their mineral contacts may be very different. If the mineral grains are interlocking, the sample is said to be 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 are defined as only what can be measured or directly observed, teachers need to help their students learn to interpret what they read in order to arrive at reliable conclusions (and evaluate other people’s conclusions!). They need to understand that an interpretation is an explanation, a

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means of presenting information in understandable terms. The accuracy of interpretations is limited by the availability of data and 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 a history of environmental and depositional conditions involved in its formation. How can a name acquire that much interpretative information?

1. The researcher finds a rock with round, beadlike particles cemented together. The particles surround a larger object in the sample, which consists of a different substance. A thin section of the sample is selected and analyzed with respect to its mineralization. The first level of interpretation is identification of the mineral composition of the little beads. For the purposes of this illustration, we will say that they are particles of calcium carbonate.

2. Identification of the structure of the round, bead-filled rock is based on an analysis of the relationship of a small piece of rock or shell material to the calcium carbonate that has precipitated around it. This structural information, coupled with the shape (roundness) of the particles, causes the observer to identify the beads as oolites.

At this point, one might think that the exercise is complete and that identification of the sample is as simple and straightforward as identifying the mineral and its structure. However, a third level of interpretation is introduced to explain how the oolites were formed.

3. The third level relies on observations of modern environments. Geologists know that oolites are typically formed near a shore by the agitation of warm, shallow saline waters. Researchers apply this knowledge to the oolitic rocks found on a mountainside. In other words, geologists use what they know about the modern setting to interpret the earlier environment. They assume that the ancient oolites on the mountain formed there in the same way that modern oolites form in the ocean or the Great Salt Lake in Utah. That interpreta-

tion seems quite logical, and the conclusions appear obvious. However, the associations may not be correct.

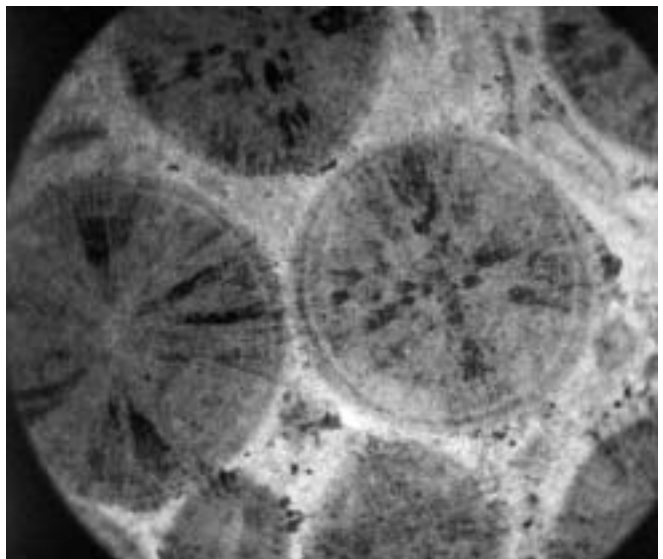
The exercise is not over. This set of interpretations is now added to other data (which also have multiple interpretations) to arrive at a final description of a particular rock exposure. The process is duplicated at other exposures or outcrops of rock over a broader region in developing a model.

4. Geologists use other rock types and additional data to develop models of geologic events in Earth's history. For example, cemented quartz grains are called sandstones. Patterns in sandstone may occur as the result of a process known as cross-bedding. Typically, cross-beds are formed as currents (wind and/or water) deposit sand and silt on the slope of dunes sheltered from the wind. By integrating a broad range of data and interpretations (the minerals, rocks, oolites, and cross-bedding), geologists develop a fifth level of interpretation: modeling. Models provide scientists with a generalized framework for developing predictions and drawing conclusions about events that may have occurred in the past.²

Why is it necessary to clearly distinguish between data and interpretation when evaluating research? Data are actual measurements and observations. Interpretations are an attempt to identify or explain what is measured and observed. An interpretation's validity depends on how well it accommodates the available data. Interpretations may change as the database changes. This interplay between data and interpretation is what makes science so successful and progressive.

Bias During Data Acquisition

Scientists realize that they are prone to errors and misconceptions. Hence, they try to maintain an attitude of objectivity in research.³ This commitment to objectivity has created an aura of infallibility around science and scientists. Reports in the popular press and on television oversimplify the work of scientists, implying that when a scientist draws a conclusion, all competing theories have been refuted and all ques-



Conclusions about how ancient rocks, such as the oolite above, were formed are based on observations of modern environments.

tions have been resolved. This encourages a false sense of security and confidence in science. 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 biases.⁴

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

1. *Sampling constraints.* The first problem in gathering data is sampling bias. Every scientist has some preconceived ideas that influence his or her selection of data. Random sampling helps minimize these problems,⁵ but even so, sampling choices often favor a particular hypothesis.

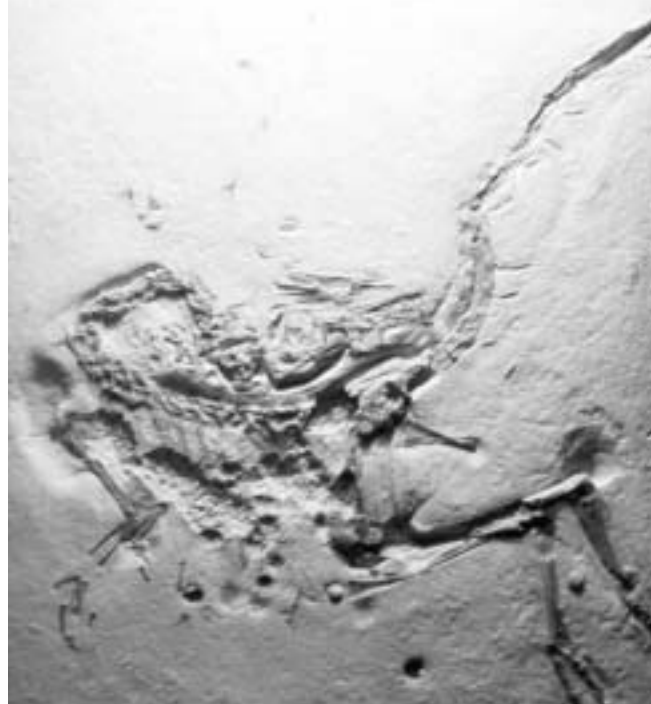
2. *Systematic errors.* A scientist may have a “blind spot,” a failure to recognize data. For example, it is common for a paleontologist who specializes in fossil snails to collect a wider variety of gastropods than other people searching a mountainside. However, that same individual will discover fewer clams and corals than other fossil collectors do at the site. An accurate tally of the types of fossils can have a significant impact on the interpretation of that site, but the bias of the researcher may affect the accuracy of the count.

The processing of data can also introduce systematic technical bias.⁶ An unrecognized faulty procedure or an incorrectly applied mathematical formula or statistical analysis during data processing introduces a systematic

Helping Students Separate Data From Interpretation

This exercise can work in various disciplines. Science teachers can use a chapter from a science textbook or an article from a newspaper or a popular science magazine that presents conclusions as facts. Use several examples and use at least one that presents conclusions without any data. History teachers may use several paragraphs from a history textbook or articles from a newspaper or magazine. Teachers in other disciplines such as Bible, English, and health can use a textbook or magazine article to create a helpful exercise for their students.

Before class, select a paragraph or section from the source, make copies to share with students, or write it on the chalkboard. Highlight or underline those items in the paragraph that can be measured or observed directly. Highlight or underline (in a different color) conclusions, speculations, and other statements that tell the reader what to believe. For additional assistance on this project, teachers may contact the author by E-mail at ekennedy@univ.llu.edu or consult the Geoscience Research Institute at <http://www.grisda.org/>.



Fossils, like that of *archaopteryx* above, are measured for identification purposes.

error or bias into the results.

3. *Technological constraints.* Scientists can incorporate large quantities of data and interpretations into computer-generated models to do analyses involving pattern recognition. However, the use of gigantic databases does not necessarily ensure that models adequately reflect complex systems and processes. The models created by computer-generated software produce technological biases because their simplified parameters limit the model's applications to real systems.⁷

4. *Quality of data.* Data analysis introduces bias because qualitative or subjective interpretations are embedded in the conclusions. For example: In using potassium-argon dating techniques, the quantity of these elements in a given sample can be measured very accurately and precisely. However, it is difficult to know just what the data mean. Conclusions about the age of the sample depend heavily on numerous assumptions and are affected by problems in the methodology, including human error.⁸ Current technology cannot measure the age of the fossiliferous sedimentary rock directly; thus, the conclusions are biased because they are based on an analysis of associated igneous material, which may or may not provide valid ages. Descriptive data (information that is not quantifiable) are even more problematic.

5. *Financial constraints.* The scientific method requires rigorous testing before theories 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 one's conclusions are widely 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 demanded by the scientific method is not cost-effective, so ideas and concepts are frequently rushed into print and then cited in subsequent publications.

Monetary pressures increase the technical bias by limiting the experimental process. Students should be aware that research funding exerts significant control over what gets into print.

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 it is sometimes difficult to differentiate between data and interpretation. Multiple interpretations of any database are not only possible but also plausible. Although data interpretation can be very complex, the simplest scenario is usually preferred to more complex ones in theory development.

Second, bias is present in every interpretation because all scientific interpretations are at least partly subjective.

Third, the public needs to understand how science works. People sometimes get alarmed because scientific interpreta-



Scientific theories are based on the interpretation of observed data.

Can You Find the Data?

The fictional article below is typical of the science news appearing in newspapers around the world. It contains a lot of information, but not all of it is scientific data. Much of it is actually interpretation of the data. Certain choices have been made that favor a particular hypothesis.

Circle or underline the data as you read the “news article” and then check your answers on page 39. What can you conclude from just the data?

Science News Notes: Unicorn Fossils Found

SoCal Times

HMMAHA, EUROPE, JULY 23, 2002. A stunning display of fossils dated to about 400 A.D. were found in a newly opened quarry near Glwddenston, Hmhaha, Western Europe. Researchers suspect that the deposit may yield approximately 35 unicorns.

The discovery was made by Dr. I. M. Looking, senior fellow and vertebrate paleontologist at Hmhaha University, a small school near the dig site. U. R. O’Kay, development supervisor at the Wee R. Rich Quarry, invited Dr. Looking to do an assessment before the company opened a new section of the quarry. According to Dr. Looking, unicorns were thought to be imaginary creatures, part of the fairy-tale world of knights in shining armor, magical castles, and dragons. “No one really believed they existed until now,” said Dr. Looking.

Although the site is located near Lake Tsestegee, the sand and gravel quarry was at one time part of a river that wound its way through a forest. This supports the notion that unicorns lived in wooded areas. Snail shells found in the gravel also support this conclusion. A full assessment of the significance of the find will require several years of excavation and research.

Numerous fully intact skeletons were found in the upper gravel deposit, indicating that the animals were buried very quickly after death. To date, three complete skeletons have been recovered from a gravel deposit three meters thick. Channel sands underlie and overlie the gravel, which was probably a point bar located at a bend in the river.

According to Dr. Looking, unicorns ate berries and plant shoots and are related to the ancestor of the modern horse, though unicorns are somewhat larger than the earliest member of the horse family, Eohippus (*Hydracotherium*), which was only nine inches tall at the shoulder. This means that the line of descent for unicorns and horses branched some 45 million years ago.

For centuries, folklore has attributed special healing qualities to unicorns’ horns, but Dr. Looking refused to comment on this possibility, saying that it would require further research.



tions are changing constantly, making it hard for them to know what to believe. However, that is the nature of science—that is how it advances.

Fourth, although science provides relevant information about the world around us and scientific discoveries have often been a blessing to humankind, Christians should not base their theological beliefs on specific scientific concepts. If science is allowed to dictate theology, then every time scientific interpretations change, theology will have to change, whether or not the alterations are consistent with one's belief system and experiences.

At the same time, theology must not dictate how scientists do their work or the conclusions they form. Concepts such as "fixity of species," based on theology taught by church leaders in the 17th and 18th centuries,¹⁰ and geocentric theory are some of the ideas that contributed to conflict between science and theology.

The Bible can provide both legitimate working hypotheses and constraints for science. In fact, Scripture often suggests avenues for investigation that would not be considered by most non-Christians. Such research should acknowledge any scriptural bias that may be present. As in all good science, the data must be carefully evaluated.

Conclusions

Scientists are fully aware of many of these issues. 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 or in Earth history. Furthermore, neither creation nor evolution scientists observed the events that occurred long ago in the universe, nor can they replicate them. Both processes are needed in order to draw reliable scientific conclusions from the data.

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 truths is to deny all the evidence. To teach such statements in the schools as if they were science would do untold harm."¹² In fact, scientific evidence does not prove either a long or short history for life. The available evidence provides very limited information.

Data are not the primary problem in reconciling science

Answers

The only data enclosed in the "news note" on page 38 are the following items: (1) site in a sand and gravel quarry; (2) near Lake Tsestegee, 15 miles north of Glwdenston in Hmaha, Western Europe; (3) snail shells, (4) three complete skeletons (though the fact that Dr. Looking had nothing with which to compare them introduces an element of speculation here), (5) upper gravel has fossils, (6) gravel bed with fossils is three meters thick; (7) gravel bed is overlain and underlain by sand deposits.

and Scripture. It is the *interpretation* of the data that creates conflicts. It has 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 philosophical basis for belief as well as a source of information that suggests an additional way to approach the study of nature. Using this perspective, some harmony between science and Scripture may be achieved. In fact, Christians may be the ones most likely to find harmony because they recognize God as the Creator of nature and its scientific laws. ✍



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NOTES AND REFERENCES

1. *Webster's College Dictionary* (New York: Random House, 1991).
2. Andrew D. Miall, *Principles of Sedimentary Basin Analysis* (New York: Springer-Verlag, 1984), p. 5.
3. Francisco Ayala, Robert McCormick Adams, Mary-Dell Chilton, Gerald Holton, Kumar Patel, Frank Press, Michael Ruse, and Phillip 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, Ill.: InterVarsity Press, 1996), pp. 158-179. See also Phillip E. Johnson, *Darwin on Trial* (Downers Grove: InterVarsity Press, 1991), pp. 6-12.
5. Ayala, et al., p. 5.
6. *Ibid.*, pp. 5, 6.
7. *Ibid.*, p. 6.
8. C. M. R. Fowler, *The Solid Earth: An Introduction to Global Geophysics* (Cambridge: Cambridge University Press, 1998), p. 192.
9. Francisco J. Ayala and Bert Black, "Science and the Courts," *American Scientist* 81:3 (May/June 1993), pp. 230-239.
10. E. Janet Browne, *The Secular Ark: Studies in the History of Biogeography* (New Haven, Conn.: Yale University Press, 1983), pp. 21-23.
11. Colin Norman, "Nobelists Unite Against 'Creation Science,'" *Science* 233:4767 (August 29, 1986), p. 935.
12. *Ibid.*
13. Alan Baharlou, 1978. Personal communication that echoes the 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.