The Similarity of Theory Testing in the Historical and "Hard" Sciences

Frequent claims appear in the Christian science/faith literature, and in popular discussions of science, that the historical sciences (cosmology, astronomy, geology, evolutionary biology, anthropology, archaeology) are fundamentally different from the "hard" sciences, and that their scientific conclusions are less rigorous and less testable.[1] It is argued that the historical sciences deal with unrepeatable events and are therefore not experimental.[2] Furthermore, because past events and processes are not directly observable, theories of origins are deemed inferior or less certain than studies of present processes. This view commonly finds expression in statements like: "No one was there so we can never know what really happened."[3] Scientific claims about Earth and biological history are then dismissed as untestable speculation. These various perceptions of historical science represent serious misunderstandings of both the nature of experiment and theory testing, and the character of scientific "proof." It is my hope that this brief essay will serve both to expose widely held misconceptions about the nature of science and to demonstrate that historical science is rigorously testable.

Science does not employ a simple inductive reasoning strategy as assumed by many who dismiss the claims of historical science. The inductive method was proposed by Francis Bacon at the beginning of the seventeenth century. The "Baconian method" argues that scientists should gather and combine all relevant facts, and from these facts derive general laws.[4] However, since the middle of this century, philosophers of science have recognized that science actually proceeds by the "hypothetico-deductive method."[5] Observations are made, and a hypothesis is proposed to explain those observations. A new set of observations not yet made is inferred deductively from the hypothesis. The hypothesis can then be tested against these new observations, and modified or rejected if necessary. Although hypotheses can be rejected by the methodology of science, they cannot be positively proved. No scientific theory can be proven in the sense of a mathematical or logical proof. Any accepted scientific theory is simply the best existing unfalsified explanation for the observations already made. This is as true for physics as it is for evolutionary biology.

The historical sciences follow the same methods and rules as the "hard sciences" and are no less scientific. The historical sciences follow the hypothetico-deductive method in the same manner as does chemistry or physics. Predictions made by hypotheses in these fields are continually being tested by new observations. If the predictions deduced from a hypothesis are not supported by new observations, then that hypothesis is modified or rejected. Scientific research proceeds by an almost continual process of hypothesis creation and testing. Many past theories in the historical sciences have been discarded with the accumulation of new observations and the development of new theories of greater explanatory power.

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being studied are rarely directly observable. The process of formation of atomic bonds during a chemical reaction, for example, is rarely directly observed; it must be reconstructed from the data collected during the reaction as interpreted by present theory. Likewise, subatomic events are reconstructed from the data obtained from instruments designed to record those signals which current theory predicts. What is available for analysis are the products or results of experimental events, not the events themselves—whether those events occurred in a test tube or a high-energy accelerator. The chemist or physicist examines the records of past events to infer unobservable processes. In addition, only a limited amount of data can be collected from those events. The investigator must select the data to be recorded. The recorded data thus will be constrained by existing theory, the specific objectives of the experimenter, the limitations of measurement technology, and the practical limitations of time and money. As a result, critical conditions or factors may remain unknown and unrecorded. This unrecorded data is lost irretrievably with each experimental event. Unless the products of an experiment can be retained for future analyses (as in chemical products or cell and tissue cultures), the only preserved record is the data collected—and this data is incomplete and subject to bias.

In the historical sciences, the records of past events are also examined to infer causal processes not directly observable. But, in this case, the preserved record is controlled, not by the investigator, but by nature. What is preserved are the products (e.g., minerals, fossils, rocks, faults) of past processes and events. The available record of past events is determined not on the basis of human bias, but by the preservational processes of nature that produce their own bias. The investigator then must select from this preserved record those data deemed significant for the problems being addressed. Data collected from the available record of ancient events by one scientist can be confirmed by the analyses of others. Scientists can return to this same record repeatedly and look at it in new ways—utilizing new technologies or simply focusing on previously ignored or unrecognized aspects of the record. Nature also commonly provides multiple records of the same or similar events. The geologist or paleontologist thus has "natural experiments" that provide multiple repeated trials. There are, of course, some historical events that are singularities, such as the origin of the universe, for which there is only one trial.

Other areas of research in the historical sciences in which the direct observation of past events occurs routinely are in the fields of astronomy and cosmology. Because of the finite speed of light, we are able to directly observe astronomical events dating back to very early in the history of the universe. We can observe the actual birth and death of stars that occurred millions to billions of years ago. The blackbody curve of the cosmic microwave background radiation, dating from about 300,000 years after the Big Bang, is one of the most thoroughly documented of physical observations.

Experiments in the nonhistorical sciences can be repeated under closely similar, though rarely identical, conditions. The more complicated the system, the less all conditions with possible impacts on the experimental outcome can be controlled. This is particularly true when designing experiments to study living systems—whether single organisms, populations, or ecosystems. Events and processes occurring in such systems are not strictly repeatable, yet scientists can make useful predictions of future behavior by studying them. Although unique, each new event or experimental outcome in a complex system increases the understanding of the causal processes involved. Strict repeatability is thus not a criterion for the testing and revision of hypotheses. The repeated occurrence of very similar, though not identical, events in Earth's history likewise provides the basis for the testing of theories and the prediction of future observations.

Historical sciences are just as predictive, and testable, as the "hard" sciences.[6] Like all scientific disciplines, geology and paleontology proceed by testing the predictions of existing models and theories. Predictions are tested against each new observation or analysis. Obtaining data from a newly analyzed sample or newly described locality is no different methodologically than obtaining data from a new experimental trial. In both cases, the new observations can be tested against expectations based on previous experience and theoretical predictions. In stratigraphy or sedimentology, for example, the measurement and description of each new rock

outcrop or subsurface core is a test of working hypotheses based on present understanding. If a specific rock unit is interpreted to be part of a coastal barrier island complex, then specific predictions can be made concerning the geometry of this rock body and the characteristics and distribution of associated sedimentary rocks. In modern barrier islands, a whole complex of environments are present—shoreface sands, beach deposits, coastal sand dunes, backbarrier lagoons, tidal inlets with ebb and flood deltas, tidal channels, and so forth. Each of these environments has its characteristic spatial relationships, sediment types, depositional features, and associated biota. If the original hypothesis of a barrier island was correct, then further exploration and sampling of the area should reveal the predicted geologic features and their predicted spatial and temporal relationships. If the new observations are contrary to these predictions, then the hypothesis must be modified, or if necessary, abandoned.

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Geological theories rise and fall based on their ability to explain previous data and to predict new observations. All practical applications of geological research (mineral and oil exploration, groundwater management, pollution control and abatement, assessment of human impacts on global change, etc.) are contingent on the ability to predict future observations based on theoretical models. These models are based on the observation of current geological processes, and on the reconstruction of past geological events and processes from the geological record.

Another testing methodology used by both the "hard" and historical sciences is the reconstruction of inferred conditions to see if they produce the predicted result. This may be done through actual experimentation or by numerical or computer modeling. The conditions may be highly simplified in order to understand the components of a naturally complex system, or they may be more or less realistic. Geologists thus construct flume or watertable experiments to model hydrologic systems, use pressure and temperature "bombs" to reproduce conditions in the Earth's interior, and construct geophysical computer models of the mantle and core to understand plate tectonics. The results of these models can then be compared to theoretical predictions and to real world observations. Similarly the physicist, chemist, and biologist commonly use simplified models to test the behavior of causal factors predicted to underlie much more complex real-world situations. Experiments may be constructed and data collected to test predictions of proposed models or theories, or to gather information on a system that is not well understood. The relationship between theory, data collection, and data interpretation is complex. Present theory and available technology affect what data are collected and how they are interpreted. The doing of science is always constrained by its historical context and the biases of its practitioners. There is no such thing as a pure objective Baconian science of unbiased observation.[7] This is true of both the "hard" and historical sciences. Biased data are not wrong, just incomplete, and as the body of accumulating data increases, scientific theories must be modified to be useful as explanatory and predictive tools. As a Christian scientist, I have confidence in the advancement of scientific understanding because I believe that our data, however incomplete, reflect an objective physical reality.

All theories are accepted based on their predictive and explanatory power, for their ability to make diverse observations intelligible. The validation of a scientific theory is not like a legal proof in which truth must be established beyond a reasonable doubt. No scientific theory will be without unresolved problems, inconsistent evidence, or unexplained phenomena. Comprehensive theoretical constructs or paradigms, such as macroevolution or plate tectonics, not only provide broad explanatory power but also serve to highlight those observations not easily accommodated, thus providing direction for further research. Some theories are ahead of the evidence and others struggle to accommodate the data already assembled. However, it is the generation of new questions that is the foundation of scientific research. Both the "hard" and historical sciences are on equal ground here. Scientists are driven to construct better and better models of the universe, of how physical reality really is. Thus science pursues truth, but never claims to have it fully within its grasp. ✻

Acknowledgment

Thanks are due to three anonymous reviewers who provided useful suggestions and helped me clarify my arguments.

Notes

[1]This dichotomy appears in its most extreme form in young Earth creationist literature as the distinction between "origins science" and "operational science." Duane Gish has stated: "Thus, for a theory to qualify as a scientific theory, it must be supported by events or processes that can be observed to occur, and the theory must be useful in predicting the outcome of future natural phenomena or laboratory experiments. An additional limitation usually imposed is that the theory must be capable of falsification; that is, one must be able to conceive some experiment the failure of which would disprove the theory. It is on the basis of such criteria that most evolutionists insist that creation be refused consideration as a possible explanation of origins. Creation has not been witnessed by human observers, it cannot be tested scientifically, and as a theory it is

nonfalsifiable. The general theory of evolution (molecules-to-man theory) also fails to meet all three of these criteria, however" (D. T. Gish, "Creation, Evolution, and the Historical Evidence," *The American Biology Teacher* 132 [1973]: 40. Reprinted in Michael Ruse, ed., *But is it Science?* [New York: Prometheus Books, 1996], 266–82).

[2]The view that the historical sciences are neither testable or experimental was expressed by many of those opposed to inclusion of macroevolution and Earth history in the Kansas science standards. "As to the specific editing of evolution related content in the Science Standards by our BOE, evolution-related concepts having precise, testable definitions were retained. Thus, Mendelian genetics, DNA structure and variability, mutations in DNA, natural selection and genetic drift were all retained. Evolution related content in the domain of historical reconstruction rather than experimental testing was generally removed, however. Historical science questions such as the age of the earth or whether dinosaurs evolved into birds cannot be experimentally tested in the manner of, say, whether a particular vaccine will prevent a disease. Such historical issues need to be treated more in the manner of a jury trial. Evidence is accumulated and alternative reasoned interpretations of the evidence explored" Paul Ackerman (ICR news release, Aug 20, 1999).

[3]The "no one was there" argument was frequently used during the debates over the Kansas science standards. "'I can't understand what they're squealing about,' Bacon said of scientists who oppose the board's action. Millions or billions of years ago, Bacon said, 'I wasn't here, and neither were they. Based on that, whatever explanation they may arrive at is a theory and it should be taught that way'" ("Science vs. the Bible: Debate Moves to the Cosmos," *New York Times* [October 9, 1999]).

This argument also figured prominently in the textbook disclaimer that was considered but ultimately rejected by the state of Oklahoma. The text of that disclaimer read in part: "No one was present when life first appeared on earth. Therefore, any statement about life's origins should be considered as theory, not fact. The word evolution may refer to many types of change. Evolution describes changes that occur within a species. (White moths, for example, may evolve into gray moths.) This process is microevolution, which can be observed and described as fact. Evolution may also refer to the change of one living thing into another, such as reptiles into birds. This process, called macroevolution, has never been observed and should be considered a theory" (Quoted in Kenneth R. Miller, "Dissecting the Disclaimer," *Reports of the National Center for Science Education* 20, no. 3 [2000]: 30–3).

Note that these arguments also presuppose the commonly held fallacy that "theory" means untestable speculation.

[4]It is interesting to note that a "Baconian" approach was extended to Scripture by the leaders of fundamentalism in the late 1800s. See George M. Marsden, *Fundamentalism and American Culture* (New York: Oxford University Press, 1980).

[5]See discussion of scientific methodology in Ian Barbour, *Religion in an Age of Science* (San Francisco, CA: HarperCollins Publishers, 1990) and in Nancey Murphy, *Reconciling Theology and Science: A Radical Reformation Perspective* (Kitchener, Ontario: Pandora Press, 1997).

[6]A recent article making the point that historical sciences are not inferior to experimental science in testing hypotheses is Carol E. Cleland, "Historical Science, Experimental Science, and the Scientific Method," *Geology* 29 (2001): 987–90.

[7]An interesting discussion of the nature of science is given by Henry H. Bauer, *Scientific Literacy and the Myth of the Scientific Method* (Urbana, IL: University of Illinois Press, 1994).

Books Received and Available for Review

This is a partial list of the books available for review. Please contact the book review editor if you would like to review one of them or receive a copy of the complete list. Richard Ruble, Book Review Editor, *Perspectives on Science and Christian Faith*, 212 Western Hills Dr., Siloam Springs, AR 72761. richard@tcainternet.com

Joe Ator, *Darwinism and the Creation Science Movement*, Star Bible Publications, 88 pages, 2000

Connie Barlow, *The Ghosts of Evolution: Nonsensical Fruit, Missing Partners, and Other Ecological Anachronisms*, Basic Books, 220 pages, 2001

Wendell Berry, *The Art of the Common Place: The Agrarian Essays*, Counterpoint, 325 pages, 2002

S. Bonting, *Chaos Theology: A Revised Creation Theology*, Novalis, 104 pages, 2002

Joseph Campbell, *The Inner Reaches of Outer Space: Metaphor As Myth and As Religion*, New World Library, 150 pages, 2002

G. S. Cootsona, *Creation and Last Things: At the Intersection of Theology and Science*, Presbyterian Publishing Corp., 110 pages, 2002

J. Davis & H. Poe, *Designer Universe: Intelligent Design and the Existence of God*, Broadman & Holman Publishers, 252 pages, 2002

Jim Denney, *Answers to Satisfy the Soul: Clear, Straight Answers to 20 of Life's Most Perplexing Questions*, Quill Driver Books, 275 pages, 2001

David Downing, *The Most Reluctant Convert: C. S. Lewis's Journey to Faith*, IVP, 192 pages, 2002

Robert C. Fuller, *Spiritual But Not Religious*, Oxford Univ. Press, 210 pages, 2001

Norman Geisler, *The Battle for God: Responding to the Challenge of Neotheism*, Kregel, 336 pages, 2001

Adrian Gilbert, *Signs in the Sky: The Astrological and Archaeological Evidence for the Birth of a New Age*, Three Rivers Press, 328 pages, 2001

M. L. Greenhut & J. G. Greenhut, *Science and God: Our Amazing Physical and Economic Universe … Accidental or God Created*, University Press of America, 180 pages, 2002

J. A. Hobson & J. A. Leonard, *Out of its Mind: Psychiatry in Crisis*, Perseus Publishing, 290 pages, 2001

James E. Huchingson, *Pandemonium Tremendum: Chaos and Mystery in the Life of God*, The Pilgrim Press, 230 pages, 2001

Stephen Kellert & Timothy Farnham, *The Good in Nature and Humanity: Connecting Science, Religion, and Spirituality with the Natural World*, Island Press, 280 pages, 2002

John Mason, *The Human Family and the Creator–God*, Vantage Press, 250 pages, 2000

Ric MacHuga, *In Defense of the Soul: What It Means to be Human*, Baker Book House, 204 pages, 2002

Clif Matthews, *When Worlds Converge: What Science and Religion Tell Us*, Open Court, 400 pages, 2002

Susan Quinn, *Human Trials: Scientists, Investors, and Patients in the Quest for a Cure*, Perseus Publishing, 295 pages, 2001

Jim Schicatano, *The Theory of Creation: A Scientific and Translational Analysis of the Biblical Creation Story*, Writers Club Press, 278 pages, 2001

Richard Schlagel, *The Vanquished Gods: Science, Religion, and the Nature of Belief*, Prometheus Books, 349 pages, 2001

Trent Stephens, *Evolution and Mormonism: A Quest for Understanding*, Signature Books, 240 pages, 2001