EDITORIAL

AXIOMS

For those of us who do science, it is sometimes distressing to realize that our work ultimately rests upon one or more unprovable assumptions. One would like to present a package of ideas that is based on totally testable concepts. Unfortunately, the major theories in science are founded on untestable axioms that arise from common-sense interpretations of observation and experience. Newton's First Law (read axiom) of Motion is intuitive and not provable. When an object moves from its path of motion, no one ever suspects that it did so without cause. Unfortunately there is no way that one could ever prove that deviations in the path of motion could not happen spontaneously and without cause, but experience and common sense say it will not. Geometry has its axioms, as do the sciences which do not rely on other disciplines for their basic premises.

Axioms are useful because they describe the world about us in very broad terms. But one must ever be aware that basic axioms may not always define Truth. In Euclidian geometry, parallel lines never join no matter how far they are extended, but in non-Euclidian geometry they may. Does this mean that Euclidian geometry has no functional significance and contains no truth? Obviously not. However, one should be cautious about building intellectual towers (and making pronouncements therefrom) on axioms intended for other structures.

Axioms in the biological sciences seem harder to come by than those in the physical or mathematical sciences, because living systems are a combination of a large number of physical and chemical processes. The cell theory, which proposes that all cells come from other cells, is an example. The statement is based on experience in the natural world, and is intuitive and not provable. Still it may have value in predicting the results of future experiments.

It should also be pointed out that the more limited the data on which the axiom is based, the more limited will be the axiom's usefulness. In addition, an axiom cannot predict phenomena in areas wider than the data base from which it was formed.

Unfortunately, a basic problem with axioms exists. Axioms can be tautologies, i.e., they may be circular in their reasoning. For example: lines in a plane that do not meet are parallel, and parallel lines in a plane don't meet. Most scientists recoil from tautologies, because they are considered to be self-fulfilling predictions. Karl Popper implied that if there is a tautology in a scientific menu, predictions cannot be falsified and therefore the work cannot be science.

Charles Darwin presented to the world a statement that would say (in simple words) only the fittest would survive. For a while, Popper criticized

this statement as untestable and suggested that the general theory of evolution was unscientific. But what Darwin presented was not a truth to be tested, but a self-evident axiom. The fittest *do* survive. What else would you call those who live? This axiom or Darwin's Law has value because experiments derived from the concept have provided useful descriptions of Nature.

For a Christian creationist, "survival of the fittest" does not accurately describe Nature and existence, especially with respect to human experience. The creationist rebels when concepts he holds most dear, i.e., freedom of choice, love as expressed in family relations, fidelity, self-sacrifice, and creativity, are all defined in a context of survival — all predetermined by one's genetic composition and acted upon by an environment. The weak often do survive at the expense of the more fit — "Greater love has no man than this, that a man lay down his life for his friends" (John 15:13, RSV). From this perspective survival of the fittest is not an evident truth. Something more than Darwin's Law is needed for a good foundation in creationist science.

But here lies the dilemma. Because an axiom does not totally describe the observed, must it be abandoned? If survival of the fittest applies to most plants and animals but does not fully apply to man, has it no value? It is my opinion that the present conflict between the creationist and evolutionist is due to each holding different fundamental axioms. Is there a resolution to the dilemma as to which system is better suited to provide the best postulates and experiments? The evolutionist limits his base for axiom building to the natural laws that surround him. The creationist develops what he considers better axioms by including both natural laws and experiences derived from human and divine relationships. He believes that truth about the world also can come from sources as yet unexplainable by known natural laws. Since creationists use this wider base of data to develop their models of the natural world, they are accused of being non-scientific. This is true if science is defined as studying phenomena using only natural laws. But if science is the pursuit of Truth, then the creationist does better science because he has more information with which to solve problems. Because of this wider area from which creationist axioms are formed, the experiments done and the predictions made will be different from that of the evolutionist. It would seem that the broader the data base from which axioms are taken, the firmer is the foundation for intellectual towers that are subsequently built.

Richard D. Tkachuck

REACTIONS

Readers are invited to submit their reactions to the articles in our journal. Please address contributions to: ORIGINS, Geoscience Research Institute, 11060 Campus St., Loma Linda, California 92350 USA.

RE: CHADWICK: PRECAMBRIAN POLLEN IN THE GRAND CANYON — A REEXAMINATION (ORIGINS 8:7-12)

[Chadwick's article] is largely devoted to questioning the accuracy of our joint work on pollen and spores from the Grand Canyon, besides the work I performed in conjunction with Dr. Gerhard Kremp, a German palynologist who was head of the Botany Department at the University of Arizona at the time I was taking work there in geology.

As I see it most of the Chadwick criticism is invalid, and shows a misunderstanding of the work I did at the University of Arizona under the guidance of one of the world's leading palynologists. Perhaps the general public was unaware of the reason I was chosen by Dr. Kremp to help in this Grand Canyon study. I was taking a class in botany from him. He needed someone to help him in a study of the Petrified Forest. Dr. Kremp had many students to choose from for that project. He selected me. On the basis of the work I did in the Petrified Forest, I was selected to aid in a similar study in the Grand Canyon. The point is if this work was done in a sloppy manner, as the article in *Origins* infers, then equal blame would rest on the shoulders of Dr. Kremp, and incidentally would cast doubt on the value of most published work in palynology.

Dr. Kremp took his class to the Canyon to take rock samples to process in the University specially equipped laboratory, where contamination is nothing to worry about. The inference in the *Origins* article was that the sampling was done in a careless manner. Actually Dr. Kremp did the sampling himself by cutting back into fresh, unfractured rock. The rock samples were sealed in sterile plastic bags. Dr. Kremp took them in person to the laboratory, where they were thoroughly washed before grinding and being placed in sterile tubes for processing. We used an improved technique that Dr. Kremp invented, which in part explains why I was able to get results where others failed who used less efficient techniques. The *Origins* article infers that in the main our results came from presently growing plants. The University has a library of spore samples from presently growing plant life, and our results don't match. Furthermore the red stain comes from having been embedded so long in red rocks. All air entering the laboratory was filtered.

The Loma Linda scientists gathered rock samples with one of Walter Lang's trips to the canyon. As I recall, I helped them in taking samples which they took to Loma Linda. I waited for months to hear from them, but finally they called to come over and help them set up a laboratory for processing the samples. I spent a week there. Finally they sent me slides of the spores they collected. Their results pretty much paralleled mine. I felt happy that we were working together, for the job was too big for one or two.

Then something happened to send the whole deal in reverse, as indicated in [Chadwick's] article. We do get plenty of backlash but in the main it comes from evolutionists or those who employ long ages. The fact that in the main the Tucson results show about the same type of angiosperms and gymnosperms from top to bottom of the Canyon suggest creation rather than evolution. The top Kaibab rocks contain the same type of brachiopods as the bottom Cambrian rocks; also, we find angiosperms

and gymnosperms most of the way through the canyon, suggesting a fast deposition at the time of the flood, rather than a slow evolutionary deposition, as my book "CANYONS OF CANYONS" explains in detail.

Morgan, et al., tried to duplicate my work at the University laboratory, but without success. After I examined his slides, the reason was self-evident. He had used an obsolete technique, and the slides were so clouded with silica that nothing was visible.

The charge of the poor quality of the photos in my paper is a new one to me. My coworkers in the Tucson laboratory thought my photos were good. The mention of some 10,000 feet of Proterozoic rock below the Cambrian emphasizes the long ages concept. Strange indeed that a few miles to the west, where the main trail descends, this Proterozoic formation does not show up.

Reference is made in *Origins* to the Salt Range of Punjab, India where a similar stratigraphic anomaly exists. This is taken at face value without first-hand study, while the attempt in *Origins* is to demolish the University of Arizona work in the Grand Canyon.

> *In passing we might mention a similar anomaly to that of the Grand Canyon. I had a personal letter from the scientist who did a similar piece of work in Venezuela some years ago. His work was challenged by three groups of scientists, but were unable to make their challenge stick. And if the Grand Canyon work is to stand, why are there no more cases coming to light with similar results? The answer is plain, too few creationists available for this type of study, and evolutionists are not the least bit interested. If they were, why have not the University of Arizona tried to either corroborate or defuse my work?*

How could we find 10,000 feet of Precambrian sedimentary rock strata a mere ten or twelve miles east of the Bright Angel trail where we find no outcrop at all of Precambrian sediments? Actually my spore samples from the Cambrian and Precambrian pretty well matched. And why do evolutionists ridicule any mention of a biblical flood? Just because the flood would so mix the fossils that any semblance of evolutionary order would be impossible. That is why we find so many jumbled stratigraphic sequences, such as in Glacier Park, etc.

Clifford L. Burdick
Tucson, Arizona

I have read with great interest and little enthusiasm the article by Dr. Chadwick on the matter of the Precambrian pollen grains and Mr. Burdick. I say with little enthusiasm, because of the facts which made the *Origins* article necessary.

I became a bit involved in this matter of pollen grains being present in too early a strata some years ago. At the time, a Mr. Waisgerber (Feb. 1973 *Geotimes*) had challenged geologists to check out the material in a *CRSQ* [*Creation Research Society Quarterly*] article in 1966 3(1) entitled "Microflora in the Grand Canyon." Drs. Allen Solomon and Ralph Morgan took up the challenge and reported their findings in the June 1973 *Geotimes*. The pertinent quotes from the report were as follows:

> *Burdick asked one of us to accompany him to the canyon, collect at Burdick's direction, and to extract those collections, in order to prove or disprove his thesis. The trip could not be made at that time, so Burdick found someone else to do the collecting and upon his return asked to have the samples extracted for pollen with safeguards against contamination. The extractions were done as requested. The results were total palynological sterility; i.e., no pollen grains or land plant spores of any kind were seen.*

The implication was that the spurious results were due to contamination, and the reported pollen grains were current ones. I felt that this matter called for an answer at least of some sort. Hence I addressed the following letter to the *Geotimes* editors:

> *Having taken due note of the letter entitled "Challenge Taken Up" in* Geotimes *of June 1973, pp. 9-10, I find it necessary to draw some items to your attention. The matter under discussion is the thesis that some plant forms are far too modern for the strata in which they are found. It follows that this can be interpreted as evidence favoring a creation origin over against an evolutionary origin of life. This was the thrust of Burdick's article, the evidence of which was questioned.*
>
> *However, Burdick's information is not needed for support of the thesis since Axelrod (*Evolution*, 13:264-275) and Leclerq* (Evolution*, 10:109-113) over 15 years ago had already reported the finding in Cambrian rhx of the microspores of vascular plants as well as tracheids possessing bordered pits. Neither are these isolated instances, since several workers in India, Australia, and the U.S.S.R. have reported these findings. At this point I would ask, "How is it that after more than 15 years this information is still buried?"*
>
> *Was it this information along with others that caused E. J. Corner to state in his essay entitled "Evolution" (which appeared as chapter 3 in MacLeod and Cobley,* Contemporary Botanical Thought*), "Much evidence can be adduced in favor of evolution ... from biology, biogeography, and paleontology, but I still think that to the unprejudiced, the fossil record of the plants is in favor of special creation."*
>
> *For discussion and references, see Rusch, W. H., "The Revelation of Palynology," CRSQ 5(3):103-105.*

I addressed carbon copies of my *Geotimes* letter to the two gentlemen, Solomon and Morgan, who had questioned Burdick's evidence. Interestingly enough, neither ever replied in any way. At the time, I wondered why *Geotimes* editors saw fit to eliminate the last two paragraphs of my letter when they printed it in *Geotimes*, September 1973! At that same time, I also sent copies to Mr. Burdick of all the material, both the original letters as well as all the responses, without ever receiving any response as I recall.

I suspect that since this Burdick pollen grain material has been used in "creation vs evolution" lectures and articles in recent times, the Chadwick article became really a necessity. It is unfortunate that poor technique apparently invalidated Burdick's findings. But certainly the findings of Axelrod and Leclerq leave the major thesis intact. Of recent times, the use of this material as it appeared in my article, has caused evolutionists to raise the question of contamination in the findings of both Axelrod and Leclerq in an attempt to minimize the effect. It would seem a reasonable question, particularly on the basis of the Burdick experience if it were just a matter of pollen grains. But it certainly would seem to be the height of naivete for any reputable scientist to seriously question the evidence of the tracheids on the basis that they are contaminants. Do those individuals seriously wish to postulate that tracheids with bordered pits are flying around loose in the atmosphere as possible contaminants? Oh come now.

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ARTICLES

PERCEPTIONS OF THE NATURE OF SCIENCE AND CHRISTIAN STRATEGIES FOR A SCIENCE OF NATURE

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WHAT THIS ARTICLE IS ABOUT

Attempts to resolve perceived conflicts between scientific theories and theology often rely heavily upon certain assumed characteristics of science. The author surveys several philosophies of science, noting attractive features as well as limitations.

Baconianism entails the common-sense notion that a methodical collection of facts will eventually lead to the laws of nature. Logical Positivism claims that experience is the basis of all legitimate knowledge, excluding metaphysics and theology. Karl Popper advocates falsification as the crucial means of eliminating error and insuring the progress of science. Thomas Kuhn describes science in sociological terms: a community with a commitment to a collection of shared beliefs, techniques, and goals. Norwood R. Hanson emphasizes the explanatory function of scientific theories: science is the pursuit of patterns. Paul Feyerabend accentuates the human element in science, with concomitant characteristics such as fallibility, and inconclusiveness.

Following a brief discussion of the complexities of observation in science, the author explores some possible strategies for resolving conflict between science and religion, each based upon a viewpoint of the nature of science discussed earlier. None of the strategies is found to be free from difficulty. Since each philosophy of science emphasizes characteristics with overlapping domains of applicability and validity, the author advocates an informed strategy embracing an eclectic approach.

INTRODUCTION

Christians hold certain religious beliefs to be true and cherish them for the meaning they give to their lives. Yet they live in a world shaped significantly by advances of knowledge attributed largely to science and its methodological approach.

When scientific pronouncements and religious beliefs conflict, what options are open to the Christian? The answer depends upon a host of things, but surely upon how science *and* religion are perceived. The present essay is confined largely to a consideration of the potential role played by various views of science, though many of the points made might be adapted readily to views of religion as well.

The caricatures of selected philosophies of science and the subsequent criticisms are intended to emphasize the complexities of the snare-infested quagmire awaiting the naive reconciler of science and religion.

INFALLIBLE INDUCTION [BACONIANISM]

In the nineteenth century, "Baconianism" was a prevalent Protestant, Anglo-American perception of the nature of science.[1] Numerous discussions with students and scientists suggest to the present author that Baconianism, with its appeal to common sense and realism, commands quite a following even at present. Therefore, it is appropriate to begin by enumerating several characteristic beliefs of nineteenth-century Baconianism, *viz*., beliefs in the certainty of facts and their distinction from reasoning, the power of the inductive method, and the inevitable harmony of science and Scripture.

For the Christian, the "autonomy" of fact followed from its firm basis in human senses, senses that were eminently trustworthy since they were a manifest part of the benevolent design of the Creator Himself.[2] The distinction between fact and inference could be easily and unambiguously discerned.[3] Even the "unbeliever" shared this attitude toward the autonomy of fact, as a letter written by Thomas H. Huxley in 1860 illustrates.

> *Science seems to me to teach in the highest and strongest manner the great truth which is embodied in the Christian conception of entire surrender to the will of God. Sit down before fact as a little child, be prepared to give up every preconceived notion, follow humbly wherever and to whatever abysses nature leads, or you shall learn nothing.*[4]

The scientific method was represented as consisting of simple, straightforward steps: begin with an unprejudiced mind, observe a sufficient number of facts, compare them, and the relevant scientific law would emerge, almost as a matter of course.[5] The inevitability of selectivity in the collection of facts was either largely unrecognized or conveniently ignored. Witness the testimony of Charles Darwin, reminiscing on the path leading to his *Origin of Species*:

> *My first note-book was opened in July 1837. I worked on true Baconian principles, and without any theory collected facts on a wholesale scale....*[6]

Contemporary scientists and theologians alike viewed laws and theories of science as simple generalizations of facts.[7] The collection, description and classification of facts of nature would assuredly lead to a deep understanding of nature as its laws progressively unfolded.[8]

Induction was not only a sufficient method in science, but it was a necessary one, and its necessity rested upon the finiteness of man as a part of God's creation. After all, Divine ingenuity must be expected to have produced incredible diversity, complexity and subtlety in nature. Shrewd hypotheses and fallible, human reasoning would be woefully inadequate to encompass the works of the Infinite One. The only reliable method of discovery was a patient, meticulous collection of facts.[9]

As for the efficacy of induction, that was no surprise when one recognized its origin. It was not until men

> *... had fallen back on God's facts in the Bible for the knowledge of ... things divine that...the facts of nature began to be sought for, as the only revelation of the ideas and principles of nature,... Who does not see the*

connection between the restoration of true Christianity and the new era of science...?[10]

If science and theology had a common methodology, what but harmony could result?[11] The Baconian method, in the hands of devout scientists, uncovered "wise designs" everywhere in nature. Theories at variance with Scripture could be counted upon to disagree with the "ablest observations" of nature as well. The inductive method unified all fields of knowledge. It was a method that could be trusted because it was given to man by a benevolent, wise Creator. In turn, its use led to discoveries that confirmed the existence of God. In short, all legitimate spheres of human enquiry proclaimed with one voice the Creator of Scripture.[12] The attractiveness of such an all-encompassing view of the world may well have dulled the sensibilities of its proponents to their own presuppositions and the circularities inherent in their argument.[13]

ERADICATION OF NONSENSE [LOGICAL POSITIVISM]

Developing in the early part of the twentieth century, and flourishing especially in the thirties, logical positivism saw itself as the natural development of a philosophy of science espoused in the 1880's by the Austrian scientist/philosopher Ernst Mach. To the logical positivist, the touchstone which legitimatizes science and unifies knowledge is experience. Science is fundamentally a description of experience; metaphysics is excluded, including such disciplines as theology and ethics.[14] The rejection of metaphysics was not unprecedented; the strategy employed was. Since no experiential observation can verify the truth or falsity of a statement that asserts the existence of a reality transcending the realm of experience (i.e., a metaphysical reality), the statement itself is nonsensical — meaningless![15]

The most distinctive doctrine of logical positivism is the principle of verifiability, which may be stated several ways: the meaning of a proposition is identical with the method of verification; anyone uttering a sentence must know in which conditions he calls it true or false — otherwise he doesn't know what he has said.[16] To illustrate the principle, let us apply it to the following statement: The paper on which the words you are now reading are printed is "ordelatious." Suppose that ordelatious is defined as: smoothness, coupled with a whitish color, a temperature below 50 degrees Celsius, and a slightly salty taste. The statement is meaningful, since by touching, viewing, probing with a suitable thermometer, and tasting, one could readily establish its truth or falsity in this case. If, however, ordelatious is defined as above, with an additional characteristic that transcends possible experience, then that transcendent quality is meaningless since its presence or absence makes no detectable difference. The application of this principle to statements about the transcendence of God or His participation in the world has been made by logical positivists in a straightforward manner.[17]

The initial appeal of logical positivism was undoubtedly due in part to the prospect of escaping the subjectivity that seems to plague philosophies that

embrace the metaphysical.[18] Nonetheless, the sharp categories and dichotomies originally set up by logical positivism have all come under sharp attack.[19] Predictably, some of the sharpest attacks have been directed against the verifiability principle itself.

In the first place, the principle is a metaphysical one; that is, the verifiability principle itself is not meaningful, given the criterion for meaning that derives from the principle. In other words, one cannot verify by sense experience the statement that all meaningful statements are verifiable by sense experience.[20] To respond to this criticism by relegating the principle to a "useful convention" is to engage in question-begging on the one hand, and to open the door to metaphysical philosophies on the other hand. A further difficulty for logical positivism resides in the very concept of verification. In the case of scientific statements about the world, the validity of inductive inference is generally assumed, a problematic issue since David Hume allegedly showed that all attempts to validate inductive inference utilize inductive reasoning, and hence entail circularity.[21] The response of logical positivists to this criticism has been to relegate the problem to the realm of metaphysics, where (for them) it becomes a fictitious problem.[22]

REJECTION OF ERROR [POPPERIANISM]

A radically different approach was taken by Karl Popper.[23] Though never a member of the "Vienna Circle," from whence logical positivism arose, Popper felt a strong affinity for the "rational attitude" the philosophy promoted.[24] But he refused to accept the "solution" offered by logical positivists to Hume's problem of induction. Rather than accept induction, without rational justification, he insisted that induction is not necessary, nor is it used to gain knowledge of the unknown — in short, it is *not* a fact.[25]

If induction is not the method of science, one of the questions that arises is whether there are *any* characteristics to distinguish science from myth. Youthful encounters with Marxism, Freudian psychoanalysis and Einstein's general theory of relativity led Popper to note a remarkable contrast in attitude in these fields: the propensity of Marxists and psychoanalysts to interpret any conceivable event as a verification of their respective theories, and the expressed willingness of Einstein to abandon his theory should it fail certain crucial tests.[26]

Thus, Popper came to emphasize falsifiability as a crucial line of demarcation between science and pseudoscience. Consider the simple "theory": All swans are white. To conclusively verify this theory entails the exhaustive inspection of *all* swans; to falsify the theory requires only a single counterinstance, *viz.*, one non-white swan. While the scientist cannot hope to verify what *is* the case, he *can* hope to discover what is *not* the case. Hence, he should construct theories that entail specific predictions. Given the incompleteness of knowledge, at least some of these predictions will *not* be borne out by experience; hence, the particular theory will be refuted. But rather than looking upon a refutation

as a failure of the theory, it should be perceived as a triumph of scientific methodology. Indeed, the goal of the scientist becomes the refutation of theories instead of their defense, since rapid refutation of successive theories leads to progress in an inverted sort of way, *viz.*, the discovery of error, or a backing away from error. This methodology utilizes shrewd guessing and a relentless search for discrepancies between these guesses and experience — in short, knowledge grows by trial and error.[27]

A scientific theory that is specific and falsifiable, yet has survived many attempted refutations, is said to be "highly corroborated." This is simply an appraisal of its success up to a specified time and under specified circumstances and is not (Popper insists) logically equivalent to asserting that it is true. Although

> *...the striving for knowledge and the search for truth are still the strongest motives of scientific discovery....Science is not a system of certain, or well-established statements;...it can never claim to have attained truth, or even a substitute for it, such as probability....*[28]

Popper's philosophy of science is a direct response to what he terms "insurmountable difficulties" associated with inductive logic.[29] Yet his critics claim that by introducing the concept of corroboration he has sneaked back into science inductive inference, the logical process he sought to banish. What is the essential difference between justifying a theory by confirming instances or by absence of falsifying ones? they ask.[30]

Popper's central concept of falsifiability of refutability has also come under fire. In the first place, it goes against the grain of a common-sense narrative of the historical development of science. Does it not seem artificial and forced, to recount the story of the discovery of capillaries as the falsification of some contradicted conjecture(s) rather than the confirmation of a hypothesis entertained by William Harvey?[31] Secondly, existential statements such as "There are molecules" are not refutable in that one can always change the properties of the postulated entities to agree with experiment, yet these sorts of statements have proved fruitful in the development of scientific thought.[32] Finally, may not "falsifiability" be a superfluous concept? Though "all swans are white" is falsifiable, this formulation of the scientific theory would probably have little impact upon the research activities of scientists encountering the "first" non-white swan.[33]

SOCIOLOGICAL COMMUNITY [KUHNIANISM]

An influential viewpoint of the nature of science has been developed by Thomas S. Kuhn.[34] As a graduate student in physics assigned to assist in the preparation of a series of lectures on the development of modern mechanics, Kuhn was surprised to learn that the transition from ancient to modern ideas was not as straightforward, logical and inevitable as he had assumed.[35]

Kuhn's account of the growth of knowledge emphasizes the sociological aspects of science. "Normal" science involves a community of participants sharing a constellation of values, beliefs, and techniques. An accepted paradigm

(example par excellence) serves to focus community interest. Commitment to the paradigm frees the scientific community from a continual (unproductive) preoccupation with fundamentals and channels research in a way that at once narrows the scope and increases the depth. For example, Newton's *Principia* posed a set of puzzles in a mathematical setting that included theoretical problems, the measurement of specified parameters and constants, the refinement of techniques of measurement, and a variety of predictive implications — in short, a set of scientific activities with reasonable assurance of success.

Increased specialization of research and sophistication of theory are accompanied by a precision of expectations which sometimes results in anomalies — discrepancies between prediction and observation. Should an anomaly persist, despite all efforts to solve the puzzle it creates, a crisis is likely. Symptoms include a proliferation of versions of the theory in question, debates over fundamentals, a preoccupation with philosophy, and an open questioning of accepted rules. As "abnormal" scientific activity increases, a new point of view may come to predominate, often promoted by charismatic scientists who are either young, relatively new in the field, or exceptionally creative. The new paradigm gains ascendancy by processes analogous to political persuasion and religious conversion, with incommensurable viewpoints frequently leading to encounters in which advocates of opposing sides "talk through" each other. After the "revolution" scientists share a new paradigm, which not only influences the way they view a given set of phenomena, but also (often) gives to them a different set of significant problems. Even the textbooks are rewritten in such a way that precursors of the new paradigm are carefully incorporated into the sketchy "history" of the discipline.

The normal-abnormal dichotomy that Kuhn emphasizes for science has been criticized for being artificial, misleading and unilluminating,[36] while his emphasis upon the role of non-rational processes during times of scientific crisis has been attacked for the relativism it seems to encourage.[37]

EXPLANATORY APPEAL [HANSONIANISM]

The late Norwood Russell Hanson has characterized scientific theories as "conceptual gestalts." They provide "patterns within which data appears intelligible."[38] Indeed, an important function of science is to provide explanatory models for the phenomena found in the world. Following the philosopher Charles Pierce, Hanson claims that the actual process used in the growth of knowledge is a quasi-logical one termed retroduction. Retroduction combines substantial knowledge with brilliant insight in an imaginative leap towards what *may be* the case.[39] An example is the discovery of the law of gravitation.[40] The law does *not* follow deductively nor can it be obtained inductively from Kepler's three laws of planetary motion. But *if* Newton's law of gravitation is correct, Kepler's three laws, several motions of the moon, the ocean tides, and the motion of falling objects are all explained as a matter of course. Although Newton's gravitational law (or theory) is empirical, it is more than simply that.

It is more than a refutable statement like: All swans are white. It does more than summarize a cluster of prior observations. It is a theory from which those observations are explicable as a matter of course.

A more current example of the explanatory appeal of a theory is that of plate tectonics. Given the theory, one can place a wealth of data into a plausible scenario that makes sense, for example, of the global distribution of earthquakes, volcanoes, heat flow, crustal thickness, ocean floor topography, and sea floor magnetism. To the question, Why should one accept the theory of plate tectonics? a persuasive answer for many is simply, Because it makes sense of a whole string of otherwise disparate observations about the earth.

The objection might be made that a plausible explanation has been mistaken for the truth of the matter. A likely rebuttal is that science is no longer preoccupied with truth but with models, and the concept of truth in science no longer refers to certainty but to probability.[41]

EPISTEMOLOGICAL ANARCHY [FEYERABENDIANISM]

Underlying all of the philosophies of science discussed thus far is the belief that the progress of science depends crucially on some distinctive methodological rule or procedure. For the Baconian, a careful induction from patiently-collected facts will inevitably lead to truth. For the logical positivist, metaphysical elements must be weeded out, so that scientific theories are confined to an ever-growing cluster of verifiable statements about the world. For Popper, theories are created by bold conjectures; they must be refutable by design and will be ruthlessly eliminated (and/or modified) as their predictions deviate from observations. For Kuhn, specialization in research will lead to an increased precision of prediction, the subsequent discovery of anomalies, an eventual paradigm-switch and a new theory with more finely-honed problem-solving capabilities. For the follower of Hanson, intelligibility provides a goal that will (presumably) become increasingly difficult to achieve unless the explanatory theory corresponds rather well with the reality of the world.

While each of these philosophies offers useful insights into the nature of science, Paul Feyerabend has offered some provocative criticism of the assumption of some unique, identifying principle or rule as defining science.[42] Insisting that science is a creative, human activity, he refuses to allow it to be hampered by "stultifying, unimaginative rules." Given any rule, sometimes its opposite should be adopted, he urges, suggesting the appropriateness at times of hypotheses which, in turn, are ad hoc, contradict accepted experimental results, embrace a smaller collection of facts than their rivals, and are even self-contradictory. He characterizes his pluralism in methodology with the motto "Anything Goes"!

Against Popper, Feyerabend advocates the *retention* of theories that *have already been refuted*, for the following reasons.[43] First, because criticism based upon abandoned theories has often proved fruitful in the past (Copernicus' study of the "ancients" contributed to his innovation in astronomy). Second, because "no idea is ever examined in all its ramifications and no view is ever

given all the chances it deserves." Third, because the critical examination of a prevailing viewpoint is best done from outside the system. Fourth, because the evidence adduced to refute a theory may itself be theory-contaminated and potentially refuting evidence may be excluded from consideration by the prevailing theory. Fifth, because "there is not a single interesting theory that agrees with all the known facts in its domain" so that to reject refuted theories is to reject all theories.

As for the progress of science, as manifested by Newtonian concepts and the achievements of the space program or by molecular biology and the advances of modern medicine, Feyerabend claims that we've been duped. The progress of science, in whatever sense one wishes to define it, is not a valid argument for some infallible method of science; that progress has occurred precisely because the "rules" of scientific methodology have been violated.[44]

Feyerabend's philosophy is appealing because of its explicit recognition of the humanness in science — it permits scientific decisions to be based upon personal judgment rather than upon a rigid set of rules. It allows Buffon to react to a discrepancy by a factor of two between observation of the movement of the line of the moon's apsides and Newton's theory thusly: So many facts support Newton's theory that this single discrepancy must be explained away.[45] It allows Einstein to react to the report that measured values for the bending of light near the sun and for the red shift disagreed with his predictions with this remark:

> *My gravitational equations are convincing because they avoid the inertial system (the phantom which affects everything but is not itself affected). It is really strange that human beings are normally deaf to the strongest arguments while they always are inclined to overestimate measuring accuracies.*[46]

An unattractive feature of epistemological anarchy for some is its undiscriminating attitude toward an almost infinite number of possible methodologies for practicing science. Limits of acceptability seem so broad that there remains no discernable distinction between delusion and knowledge, whim and reason, fantasy and truth. Feelings of uneasiness are reinforced by assertions such as the following.

> *The task of the scientist, however, is no longer 'to search for the truth,' or 'to praise God,' or 'to systematize observations,' or 'to improve predictions.' These are but side effects of an activity to which his attention is now mainly directed and which is 'to make the weaker case the stronger' as the sophists said, and thereby to sustain the motion of the whole.*[47]

THEORY-LADEN OBSERVATIONS

A common-sense philosophy might suppose that science begins with the simple collection of sense data — observation being one of the most elementary and unproblematic aspects of science. The following examples have been chosen to display the inadequacy of this common-sense view of science.

Consider the discovery of the planet Uranus.[48] In March 1781, William Herschel recorded in his journal the sighting of a "curious either nebulous star

or perhaps a comet." Subsequent sightings over the next few days indicated that the "comet" moved with respect to the fixed stars. After several months of unsuccessful attempts to calculate the orbit of this "comet," the astronomer Lexell suggested that it might be a planet. Further computations confirmed his suggestion. A subsequent search of available astronomical records uncovered at least seventeen sightings of this planet in the ninety years prior to Herschel's observation. In all of these previous sightings, the object was referred to as a star. It seems clear that scientific advancement requires more than simply seeing!

For illustration, consider a command to record what you are *now* experiencing. If you take this command seriously, you may still be puzzled. Should you include your rhythmic breathing, the pressure of the chair on your posterior, the background noises, the light in the room...? Supposing you somehow succeeded in recording the totality of your present experiences, you would still not be doing science. Science necessitates a point of view, a theoretical mind-set, if you will, to ensure selectivity in data collection, not to mention an imaginative creativity.[49]

The difficulties associated with early telescopic observations are not generally appreciated.[50] There is the general problem of the unfamiliar. Who has not experienced the bewilderment of that "first look" through a microscope, with all the blurry, wiggly globs that became clear only after consulting the textbook drawings which accentuate what it was that one was supposed to see? The early telescopes undoubtedly were of poor quality, and the images produced possessed a liberal amount of distortion. If one views a familiar building through such an instrument, compensation can be readily made, but how can one apply analogous corrections to the images of celestial objects only seen previously from far away by the naked eye? A further problem facing early observers was that of reliability and consistency. The magnifying power of the instrument seemed dependent upon the object (its nature? its distance? its size?), being greatest for the moon and much less for the stars. Viewed through the telescope, the moon's terminator (the boundary between light and dark portions) displayed an unevenness suggesting topographic relief, yet the outer boundary appeared perfectly round and smooth. Is it any wonder that one of Kepler's students reported a session with the telescope in these words:

> *...I tested the instrument...in a thousand ways, both on things here below and on those above. Below it works wonderfully; in the heavens it deceives one....*[51]

In light of the foregoing points, Galileo's assertion that the telescope works in the same way everywhere seems less than convincing. On the other hand, it is highly significant that Galileo had a cause to promote, *viz.*, the Copernican system, and he saw early telescopic observations as providing arguments in favor of Copernicanism. Seen from the twentieth century, it seems that Galileo's predisposition towards Copernicanism affected his judgment as to the significance (or insignificance) of otherwise puzzling instrumental distortions.

Further evidence of the interplay between theory and observation comes from Galileo's account of what he found on the surface of the moon.[52] When he pointed his telescope toward the moon, he *saw* discontinuities which he *reported* as craters. This suggests a commitment to a specific model for their origin. Craters might be produced by artillery explosions, falling meteors or volcanoes, but surely not by erosion, subsidence, or digging!

As a final instance of the complexity of observation, one might cite experiments in which subjects were fitted with inverting spectacles, causing the world to be seen upside-down. After a time, compensation was made spontaneously by the subjects, and the world was seen right-side up. When the spectacles were subsequently removed, the subjects again saw the world upside-down, for a time.[53]

The nineteenth-century Baconian would say that "seeing is believing." The preceding examples suggest that things are not quite that simple. In some cases, a more appropriate statement might be: "believing is seeing."[54]

TENSION RESOLVED?

With this background, let us explore several strategies open to the Christian when he perceives a conflict between a scientific pronouncement and a scriptural doctrine. The first two place science "above" theology; the final three place theology "above" science.

SCIENCE: INDEPENDENT DISCIPLINE [LOGICAL POSITIVIST]

Science deals with sense data that are observable and experiential; religion deals with the *a priori* and the metaphysical. Therefore, do your science; keep it separate from your theology; don't expect to get clues from Scripture about nature.Advocates of an approach to this sort of independence of science from religious doctrine include Galileo,[55] who wrote

> *...in discussions of physical problems we ought to begin not from the authority of scriptural passages, but from sense-experiences and necessary demonstrations.*[56]

One objection to this approach is that it misses the point of the distinction between science and religion as seen by logical positivism.

> *...there is no logical ground for antagonism between religion and natural science. As far as the question of truth or falsehood is concerned, there is no opposition between the natural scientist and theist who believes in a transcendent god. For since the religious utterances of the theist are not genuine propositions at all, they cannot stand in any logical relation to the propositions of science.... His assertions cannot possibly be valid, but they cannot be invalid either...*[since he] *says nothing at all about the world....*[57]

Another objection relates to a point raised when logical positivism was discussed above, *viz*., science is *not* devoid of the metaphysical. Themes such as conservation, quantification, atomistic discreteness, hierarchical structure, and the principle of uniformity in nature are not empirically verifiable (or falsifiable), but they have been immensely fruitful.[58] Thus, the line separating

science from religion is not as well-defined as this position asserts. If the metaphysical were to be strictly excluded, science would be severely restricted.

A further objection to the strategy arises from a recognition that Scripture speaks of nature. Though surely not a central theme of Scripture, statements about nature do occur as they impinge upon the themes of Scripture. To insist that any subject must be treated centrally or exhaustively in order to be treated truly is surely wrong.[59] To treat the cosmic and historical statements of Scripture as so much irrelevant baggage — to look exclusively for the "religious" truths in Scripture is analogous to ignoring Lewis Carroll's cat and insisting that the grin can stand alone. It is worse than reducing Scripture to a skeleton that won't support its own weight. It is taking away the skeleton, the historical and physical framework which Scripture presupposes.[60]

Finally, treating science as an independent discipline is a defeatist approach. It is to surrender the concept of the unity of truth, without which the whole world view of the Christian loses much of its appeal.[61]

SCIENCE: EXEGETICAL TOOL [BACON]

An alternative strategy is epitomized by the exclamation: "So that's what the Bible means!" A passage written by Galileo may be cited in support of this approach:

> *...it is the function of wise expositors to seek out the true senses of scriptural texts. These will unquestionably accord with the physical conclusions which manifest sense and necessary demonstrations have previously made certain to us.*[62]

In this mode, interpretations of Scripture must conform to current scientific knowledge. This often results in naturalistic explanations for miraculous events with concomitant restrictions on the literalness of the passage in question. This strategy has been applied to the Scriptural stories of the Creation, the Flood, the Egyptian plagues, and the conquest of Jericho, to mention just a few.[63]

Understandably, this approach has a special appeal to the Christian who chooses science as a profession. Ironically, arguments used to support this strategy also raise issues that lead to objections. Proponents may point out the tendency of the naive "believer" to equate his *interpretation* of Scripture with Scripture itself. The folly of this tendency will be easily recognized if science is used explicitly as an exegetical tool. Furthermore, the procedure is completely justified by the fact that God is the Author of both nature and Scripture. One of the problems with this argument is that it easily blurs an equally crucial distinction between nature and *its* interpretation, science. To insist that science holds the key to Scripture is merely to exchange one interpretation for another, to trade naivety about Scripture for naivety about nature, to replace one form of arrogance with another.

Proponents may also insist that for Scripture to remain relevant, it must be interpreted in the light of accepted scientific knowledge — that the progressive nature of the growth of scientific knowledge toward the correct understanding

of the universe demands a revision of outmoded Scriptural interpretations. Based upon conservative ideas of inspiration, revelation, and truth, opponents might object that, given the changing character of scientific knowledge, the endless adjustments of Scriptural interpretation that the proposed strategy would require are out of harmony with the Judeo-Christian concept of an unchanging God, who has spoken the truth in Scripture.[64]

Finally, what proponents view as the advance of truth, opponents see as one more evidence of a deplorable trend toward the secularization of knowledge. What the proponents call rational explanation, the opponents fear as rationalization and an explaining away. Even in cases where these objections may lack logical foundation, their psychological impact is significant.

SCIENCE: INCOMPLETE INVESTIGATION [BACON]

The first of three strategies in which theology is placed "above" science handles conflicting claims of science and religion by asserting that the scientific data is incomplete. Of course, the assertion is trivially true given the open-endness of science. Therefore, the assertion is normally intended to encompass the stronger claim that the present data is so incomplete that the offending theory is fundamentally wrong. The belief is often expressed that further investigation will vindicate this attitude and also the veracity of Scripture.

The argument from the incompleteness of science is an argument from missing data — an argument from ignorance, in a way. Historically, this ploy has been notably unsuccessful. For example, a long-standing strategy of natural theology was to allege that support for the argument of God's continued action and presence in the world resided precisely in those regions of inquiry that scientific investigation had not penetrated. Subsequent advances of science drove that sort of "God of the Gaps" from His universe.[65] Furthermore, the belief that continued collection of data relevant to an offensive theory will result in substantial modification of that theory assumes (incorrectly) that a theory is merely a summary of data and that data is not theory-dependent. Finally, the above strategy exhibits an unwarranted faith in scientific methodology. To believe that "sufficient" scientific research will inevitably lead to conclusions supporting the reality of the supernatural is to ignore the secular, naturalistic presuppositions of science.

SCIENCE: SUPERFICIAL INVESTIGATION [KUHN]

A variation on the incompleteness argument is this: the apparent disagreement between science and theology arises due to a failure to attend carefully to the presuppositions and/or anomalies associated with the offensive theory. The obvious way to rectify the situation is to concentrate research in the problem area; to refine the measurements, to accentuate the anomalies, and to scrutinize meticulously the presuppositions. After all, the argument goes, it is the focusing of manpower and effort on a problem that leads to a solution. Briefly characterized, this strategy is the search for inconsistencies, and it is fraught with dangers.

In the first place, a sort of uniqueness theorem is invoked, *viz*., only the truth can be consistent. Yet it is a well-recognized logical possibility that, for any finite collection of data, several — perhaps many — theories may be devised. The elimination of an offensive theory may not prove to be easy, or even possible, even if it is *false*!

In the second place, even if an anomaly is discovered and documented and generally acknowledged, rejection or modification of the offensive theory is not assured. A contemporary illustration of this point comes from the field of paleomagnetism.[66] In the early decades of this century, it was established that rocks with a magnetic polarity opposite that induced by the earth's present magnetic field occur worldwide. By the fifties, experts generally interpreted the data to mean that the earth's magnetic field had experienced reversals of polarity in the past. However, in the early fifties, both theory and experiment suggested the possibility of a self-reversal mechanism to account for the direction of magnetization of rocks. About the same time an unexpected correlation between the oxidation state of the minerals and their magnetic polarity was discovered. By the mid-sixties, several investigations had confirmed the existence of polarity-oxidation correlations (suggesting self-reversal), while at the same time evidence was mounting for the reality of field reversal. There were expressions of concern that paleomagnetism might contain internal contradictions, one scientific expert casting the difficulty as "one of the major unsolved problems of Earth science."[67] After about 1972, the problem faded away, *not* because it was solved, but presumably because it defied solution and "all" other data filled the paleomagnetic model of field reversal.

This brings up a third difficulty with the search for inconsistencies. The goal of the endeavor is largely destructive rather than constructive. The search for anomalies and loopholes in a theory cannot compare with the challenge and sense of satisfaction that comes from the construction and refinement of successful scientific models. Thus, it has happened that some who became experts in a particular field for the express purpose of "slaying the fiery dragon" have ended up embracing the paradigm they initially sought to demolish — not in the spirit of a "turncoat" but as they have seen the fruitfulness of the paradigm — not because the prevailing paradigm was flawless, but simply because there seemed no viable, positive alternatives.

In a laudable effort to take a more positive approach, some creationists have insisted that creationism offers the potential for *more* puzzle-solving activity than does the prevailing paradigm. But creationists have often neglected addressing an equally crucial point, *viz*., the puzzle-generating framework must also offer some prospect of success. The concept of "special creation" is, by its very nature, not subject to scientific testing at all at the level of mechanism (at least not as ordinarily represented — i.e., an ex nihilo, fiat series of events).

SCIENCE: UNSCIENTIFIC [POPPER]

A popular strategy among anti-evolutionists is to assert that the offensive theory is irrefutable. The assertion may be based upon two independent

considerations which will be taken up in turn: the nature of the subject and the nature of the theory.

Theories of origins construct certain sequential events of the remote past alleged to have actually occurred. The evidence from science for such historical events is circumstantial; experiments conducted in the present can show, at best, what is *possible*. Actual occurrences are irretrievably imbedded in the past. Personal testimony — useful in ordinary historical cases — is unavailable (excluding revelation). To leap from the plausible to the possible to the probable to the actual is to abandon accepted rules of logic. It is to confuse speculation with science.

Although this line of argument may be psychologically persuasive, as it stands it simply won't do. Science and scientific theories are not systems confined to the strictures of logical demonstration. As was emphasized earlier in this essay, scientists use not only deduction and induction but also retroduction, which involves a creative, intellectual leap that *suggests* that something *may* be. The resultant theory is accepted because it makes sense out of a wealth of data, not because it "follows" from that data. Scientists are in search of "explanations," not proofs.

Turning to the nature of the theory of evolution, it has been criticized for its logical circularity.[68] Thus, it was the doctrine of natural selection that convinced Victorians that evolution had occurred. Natural selection was then equated with evolution. The chief direct evidence bearing on evolution was the fossil record, which was at the same time, by means of the notorious gaps, a most telling argument *against* natural selection. But, conceiving of evolution as the result of natural selection easily (albeit incorrectly) led to the identification of any evidence for one as evidence for the other.

The objection to this criticism is simply to note that "all comprehensive theories, all fundamental theories ... [including] the corpuscular theory of the Newtonians, [and] the relativity theory of the twentieth-century physicists are similarly circular."[69]

Another possible criticism of the evolutionary dogma is that it is taken for granted. For example, in the sixties the International Union of Biological Sciences organized conferences to address the problems of theoretical biology. A perusal of the first published reports shows that though substantial time was devoted to criticisms of proposed mechanisms of evolution, it was almost invariably assumed that evolution, by whatever means, did occur.[70] But the criticism loses much of its force with the realization that principles have come to be taken for granted in other areas of science as well. For example, the principle of the conservation of energy has proved to be an extremely fruitful one, even though on occasion new forms of energy had to be "invented" in order to retain the principle.[71]

SCIENCE: AN ECLECTIC VIEW

What is science? A summary of facts? A set of verifiable/falsifiable statements about the world? A group of shared beliefs providing fruitful puzzles

to solve? A predictive tool? An explanatory system for a series of otherwise disparate phenomena? A fallible, human activity? Each of these suggestions requires qualification, but each provides a helpful insight into the nature of science. A careless disregard for any of these insights will likely lead to misunderstanding and frustration as the devout scientist in our time struggles to resolve the tensions he finds between science and religion and seeks to communicate his position effectively to his fellow Christians and to his naturalistic, scientific peers.

ACKNOWLEDGMENTS

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ENDNOTES

1. (a) Bozeman TD. 1977. Protestants in an age of science: the Baconian ideal and antebellum American religious thought. Chapel Hill, NC: University of North Carolina Press, p xii; (b) Daniels GH. 1968. American science in the age of Jackson. NY: Columbia University Press, p 63.
2. Bozeman, p 11, 54, 55; Daniels, p 66-67.
3. Bozeman, p 105.
4. Quoted in: Hooykaas R. 1963. Natural law and divine miracle: the principle of uniformity in geology, biology and theology. Leiden: E. J. Brill, p 210. Compare Francis Bacon, Novum Organum, Book I, Aphorism 68.
5. Daniels, p 66.
6. Darwin C. 1969. The autobiography of Charles Darwin, 1809-1882: with original omissions restored; edited with appendix and notes by his granddaughter, Nora Barlow. NY: W. W. Norton and Company, p 119. Darwin wrote this work between 1876 and 1882. For a comment on his "Baconian method," see: Grene M. 1974. The knower and the known. Berkeley, CA: University of California Press, p 191ff.
7. Bozeman, p 64; Daniels, p 121.
8. Daniels, p 192, 66.
9. Bozeman, p 18. Compare Daniels, p 73-77.
10. Bacon L. 1846. Sermon at the ordination. In: Discourses and Addresses at the Ordination of the Rev. Theodore Dwight Woolsey, LL.D. to the ministry of the Gospel, and his inauguration as President of Yale College, October 21, 1846. New Haven: B. L. Hamlen, p 25. Compare Bozeman, p 124.
11. Bozeman, p 110-111, 155; Daniels, p 82.
12. Bozeman, p 50, 108.
13. Daniels, p 200.
14. Passmore J. 1972. Logical positivism. In: Edwards P, editor. The Encyclopedia of Philosophy, vol 5. NY: Macmillan Publishing Co., p 52. Hereinafter referred to as EP.
15. (a) Ayer AJ. 1965. Demonstrations of the impossibility of Metaphysics. In: Edwards P, Pap A, editors. A Modern Introduction to Philosophy: Readings from Classical and Contemporary Sources. Rev ed. NY: Free Press, p 687-688. Hereinafter referred to as MIP; (b) Ayer AJ, Copleston FC. 1965. Logical positivism — a debate. In: MIP:748. Compare Ayer AJ. 1946. Language, truth, and logic. NY: Dover Publications, p 33-45.

16. (a) Passmore, p 52; (b) Ayer, Impossibility of metaphysics, p 687; (c) Ayer & Copleston, p 742ff; (d) Ashby RW. 1972. Verifiability principle. In: EP 8:241.
17. (a) Stace WT. 1965. Metaphysics and meaning. In: MIP, p 697ff; (b) Ayer, Language, truth, and logic, p 115-119.
18. See, for example, Ayer & Copleston, p 726-756.
19. Passmore, p 56.
20. (a) Ewing AC. 1972. Meaninglessness. In: EP:705ff; (b) Ewing AC. 1962. The fundamental questions of philosophy. NY: Collier Books, p 44-47. A counter argument asserting that all factual propositions are necessarily subject to the principle of verifiability can be found in Ayer, Language, truth, and logic, p 41, 93-99.
21. For a brief introduction to the "problem of induction" and a sketch of several proposed solutions, see: Salmon WC. 1967. The foundation of scientific inference. Pittsburgh: University of Pittsburgh Press, p 5-56.
22. Ayer, Language, truth, and logic, p 49-50, 98. For a more complete argument, see: Hanson NR. 1969. Perception and discovery: an introduction to scientific inquiry. San Francisco: Freeman, Cooper and Co., p 407-419.
23. Popper KR. 1968. The logic of scientific discovery. 2nd ed. NY: Harper & Row. First published in Vienna in 1934 as Logik der Forschung. Compare: Quinton A. 1972. Karl Raimund Popper. In: EP 6:398-401.
24. Popper K. 1974. Autobiography of Karl Popper. In: Schilpp PA, editor. The Philosophy of Karl Popper. LaSalle, IL: Open Court, p 70.
25. Popper, Replies to my critics. In: Schilpp, p 992, 1013-1015.
26. Popper, Autobiography. In: p 24-29.
27. Popper, Logic of discovery, p 39, 315-317, 420-441.
28. Ibid., p 278, 279.
29. Ibid., p 29.
30. Quinton, p 399; Salmon, p 26-27.
31. Harré R. 1972. The philosophies of science: an introductory survey. NY: Oxford University Press, p 50.
32. Ibid., p 51. Compare Popper, Logic of discovery, p 69-70.
33. Kuhn TS. 1977. The essential tension: selected studies in scientific tradition and change. Chicago: University of Chicago Press, p 280ff. For Popper's indirect response, see: Popper, Replies to my critics. In: Schilpp, p 982-983.
34. Kuhn TS. 1970. The structure of scientific revolutions. 2nd ed. Chicago: University of Chicago Press. In Gary Gutting's book (1980. Paradigms and revolutions: appraisals and applications of Thomas Kuhn's philosophy of science. Notre Dame, IN: University of Notre Dame Press) the claim is made that Kuhn's book has had a wider academic influence than any other of the past two decades.
35. Kuhn, Scientific revolutions, p v; Kuhn, Essential tension, p xi-xii.
36. For example, see: Toulmin S. 1972. Human understanding: volume I: the collective use and evolution of concepts. Princeton: Princeton University Press, p 98-119.
37. For an example of the emphatic rejection of relativism, despite logical difficulties, see Salmon, p 45-46. For specific criticisms of Kuhn, see (a) Toulmin, p 76, 102-105; (b) Popper K. 1970. Normal science and its dangers. In: Lakatos I, Musgrave A, editors. Criticism and the Growth of Knowledge. Cambridge: Cambridge University Press, p 56-58. For Kuhn's response, see Kuhn, Scientific revolutions, p 105-107; Kuhn, Essential tension, p 320-339.
38. Hanson NR. 1972. Patterns of discovery: an inquiry into the conceptual foundations of science. Cambridge: Cambridge University Press, p 72, 87, 90.

39. Ibid., p 72-86. Compare the nineteenth-century idea of William Whewell. See: (a) Blanché R.1972. William Whewell. In: EP 8:288-289; (b) Ruse M. 1982. Darwinism defended: a guide to the evolution controversies. Reading, MA: Addison-Wesley, p 45-46.
40. Hanson, Patterns, p 107-108.
41. Gingerich O. 1982. The Galileo affair. Scientific American 247(2):137, 143.
42. Feyerabend P. 1978. Against method: outline of an anarchistic theory of knowledge. London: Verso Edition. See specifically p 20, 23-24, 28, 29, 49, 65, 68.
43. Ibid., p 31, 49.
44. Ibid., p 304.
45. Hanson, Patterns, p 110.
46, Feyerabend, Against method, p 58.
47. Ibid., p 30.
48. Kuhn, Essential tension, p 171ff.
49. Popper, Logic of discovery, p 106.
50. Feyerabend, Against method, p 119, 123, 127-129.
51. Quoted in Feyerabend, Against method, p 123.
52. Hanson, Patterns, p 56.
53. Cited in: Bohm D. 1965. The special theory of relativity. NY: W. A. Benjamin, Inc., p 201.
54. For a brilliant discussion of the complexities associated with observation, see: Hanson NR. 1969. Perception and discovery: an introduction to scientific inquiry. San Francisco: Freeman, Cooper, and Co., p 59-198.
55. Admittedly, it would be anachronistic to place Galileo among logical positivists. The strategy under discussion, as well as subsequent ones, is intended merely to illustrate a certain type of approach. It must not be thought of as inexorably tied to a particular philosophy of science.
56. Galileo. 1957. Letter to Madame Christina of Lorraine, Grand Duchess of Tuscany: concerning the use of biblical quotations in matters of science. In: Drake S, translator. Discoveries and Opinions of Galileo. Garden City, NY: Doubleday Anchor Books, p 182. The "Letter to Christina" is witty and incisive. It is worthwhile reading for anyone seriously interested in a harmony between religion and science.
57. Ayer, Language, truth, and logic, p 117, 116.
58. Holton G. 1973. Thematic origins of scientific thought: Kepler to Einstein. Cambridge: Harvard University Press, p 29, 63.
59. Schaeffer F. 1972. He is there and He is not silent. Wheaton, IL: Tyndale House, p 74.
60. Schaeffer F. 1975. No final conflict: the Bible without error in all that it affirms. Downers Grove, IL: InterVarsity Press, p 14. See also: Schaeffer F. 1972. Genesis in space and time. Downers Grove, IL: InterVarsity Press.
61. For a helpful treatment of truth that emphasizes its unity, see: Holmes AF. 1977. All truth is God's truth. Grand Rapids, MI: Wm. B. Eerdmans Publishing Co.
62. Galileo, Letter to Christina, p 186. For his treatment of the long day of Joshua, see p 211-215.
63. For applications of this strategy from the fields of anthropology, astronomy, biology, and geology, see: Ramm B. 1954. The Christian view of science and Scripture. Grand Rapids, MI: Wm. B. Eerdmans Publishing Co., p 97-242.
64. Views of inspiration, revelation, and truth play a pivotal role in the entire discussion of the relationship between science and religion, but a treatment of these matters is not within the selected scope of the present essay.

65. Gillispie CC. 1959. Genesis and geology: the impact of scientific discoveries upon religious beliefs in the decades before Darwin. NY: Harper & Row, p 220.
66. This example is documented in an unpublished research paper written in 1975. For a general introduction to paleomagnetism, see: Tarling DH. 1971. Principles and applications of paleomagnetism. London: Chapman and Hall. For a discussion of the polarity-oxidation correlation, see: Gass IG et al., editors. 1971, 1972. 2nd ed. Understanding the earth: reader in the earth sciences. Cambridge, MA: M. I. T. Press, p 250-255.
67. Bullard E. 1969. Reversals of the earth's magnetic field. Philosophical Transactions of the Royal Society A263:481-524.
68. Grene M. 1974. The knower and the known. Berkeley: University of California Press, p 193-195.
69. Ibid., p 194. Grene qualifies her criticism of the theory of evolution thusly: its circularity is too narrow.
70. Waddington CH, editor. 1968, 1969. Towards a theoretical biology, vols. I and II. Chicago: Aldine Publishing Co.
71. A startling example of this was Pauli's neutrino hypothesis. See: Fierz M. 1974. Wolfgang Pauli. In: Gillispie CC, editor. Dictionary of Scientific Biography 10:424. NY: Charles Scribner's Sons.

ARTICLES

HISTORICAL DEVELOPMENT OF THE CURRENT UNDERSTANDING OF THE GEOLOGIC COLUMN: PART II

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WHAT THIS ARTICLE IS ABOUT

*In Part I (*Origins *8:59-76) of this series on historical interpretations of the geologic column, the author discussed the early developmental stages in the science of geology. After the basic concepts of geological principles were formed, a period of reinterpretation of the earth's crust followed. Part II discusses these times.*

Notable geologists, including William Buckland, Adam Sedgwick, Roderick Impey Murchison, and Charles Lyell, began to view the earth's formation in terms of very long ages. Though none would accept an atheistic origin for the earth, all felt compelled to believe that Scripture was an inadequate guide to aid their interpretation of the features in the geologic column. God was still considered to be the founder and originator of life. The uniformitarian principle postulated by Hutton years earlier became nearly universally accepted, and the Noachian flood was not considered to be a suitable explanation for the geologic column.

In order to answer the problem of increasing complexity within the geologic column, a multiple-creation hypothesis was developed by a number of geologists. God was still actively involved, but the six-day creation week was substituted with a form of progressive creation. The concept of Darwinian evolution which involved gradual change from one species to another was not widespread, and the diversity seen in the geologic column was attributed to multiple-creation events.

Realizing that these concepts damaged a literal interpretation of Scripture, conservative Christian scientists reacted understandably in vigorous defense of more traditional views. A time of heated debates and discussions ensued. These exchanges resulted in a polarization of views concerning earth history, a legacy that our current generation continues to inherit.

FORMULATION OF THE GEOLOGIC COLUMN

Few, if any, brief periods in the history of science have witnessed a series of breakthroughs and advances comparable to those encountered in the science of geology between 1785 and 1820. The very basic tools essential for study of the crust of the earth had been created and were now in place (see Part I in *Origins* 8:59-76). The nature of igneous and sedimentary rocks, and the processes by which they may be formed (volcanism, weathering, erosion, sedimentation, etc) were clarified. The value of guide fossil assemblages in mapping, correlating, and arranging strata in chronological order had been discovered and successfully applied on a regional scale. Comparative anatomical studies of living vertebrates had provided for the first time a powerful

tool, a key for both meaningful classification and accurate identification of living and fossil forms, hence also terrestrial rock formations. Comparable studies of marine and fresh water invertebrates and plants were in progress. There was a new devotion to exact methods and descriptions. The application of such rigorous methods to fossils elevated the study of geology and of fossils to a respected position.

In the next generation, 1820-1850, we encounter the team of professional geologists who were active when the geologic column was formulated as a system for stratigraphic classification. Our consideration is limited to selected leaders, chiefly from Great Britain, where the greatest advances were made during these decades and where there was the deepest and most general concern for the harmony of science with Scripture.

Most of the geologists included in this section described and named series of fossil-bearing strata which were accepted as the basis for divisions of the geologic column as understood today — periods, epochs, etc. (see Table 1). Most were catastrophists. All accepted multiple creations, a concept Murchison as well as Buckland had been active in developing, and which was quite generally adopted by catastrophists of the 1820s to 1850s. All opposed transmutation of species (evolution).[1] Several were initially trained in theology, moving from thence into the developing science of geology. Werner's Neptunism tended to stultify progress on the continent, where his influence persisted for some years, hence the greatest advances were in Great Britain.

William Buckland (1784-1856)

The Reverend William Buckland, who occupied the chair in geology at Oxford, was the foremost English geologist in the decade of the twenties and continued to be held in high esteem throughout his long career. He had studied theology at Oxford, and during the twenties was one of the leading proponents of diluvial geology and a "chief architect of the catastrophist synthesis."

From newly discovered caverns Buckland described with considerable precision a diverse assemblage of hitherto unknown vertebrates from England including hyenas, lions, tigers, elephants, rhinoceroses, hippopotamuses and nearly two dozen kinds of birds. These remains and others from caves, fissures and alluvial deposits seemed to Buckland (e.g., 1823:726-727) to provide compelling evidence for the universal deluge. Consequently Buckland (1823) described as a discrete geologic unit the diverse gravels, sands, and other alluvial deposits above the Tertiary and below the obviously subrecent deposits, attributing them to the universal deluge. The name given, Diluvial or Diluvium, had been used for similar deposits by Conybeare, Phillips and others, but had not heretofore been accompanied by a regional diagnostic description. Lyell renamed this epoch Pleistocene in 1839 (Zittel 1901:538).

Although Buckland's flood geology (1819:24) was immensely attractive, with wide appeal to many of his contemporaries, it was not particularly conservative by some theological standards. There was adequate confirmation of the Mosaic record provided by the abundant evidence of a universal

TABLE 1

SELECTED CLASSIFICATIONS OF ROCK STRATA

ARDUINO 1759	WERNER 1790s	WILLIAM SMITH 1789, 1812, 1815	CONYBEARE & PHILLIPS 1821-1822	DE LA BECHE 1833
TERTIARY — Volcanic	ALLUVIAL Volcanic		SUPERIOR ORDER or TERTIARY: Alluvial; Diluvial; Upper Marine; (Freshwater: London Clay Plastic Clay)	Modern Group; Erratic Block Gr.; Supracretaceous Group
		London Clay		
SECONDARY	STRATIFIED (FLÖTZ)	Chalk	SUPERMEDIAL ORDER: Chalk; Chalk Marle; Green Sand; Weald; Iron Sand; Oolitic Series	Cretaceous Group; Oolitic Group
		Greensand; Brick-Earth		
		Purbeck, Portland; Coral Rag. Cornbr.; Upper Oolite; Under Oolite; Red-ground	Purbeck, Portland; Coral Rag. Oxford; Onferior Oolite - Lias; New Red Sandstone	Red Sandstone Gr.; Red Marl; Muschelkalk; Red Sandstone; Zechstein
		Magnesian Limestone; Coal Measures	MEDIAL ORDER (Carboniferous): Magnesian Limestone; Coal Measures; Millstone-Grit; Carboniferous or Mountain Limest.; Old Red Sandstone	STRATIFIED: Carboniferous Gr.; Coal Measures; Carboniferous Limestone; Old Red Sandstone
		Mountain Limest.; Red and Dunstone		
	TRANSITION	Killas and Slate	SUBMEDIAL ORDER: Transition Limest.; Serpentine; Sienite; Greywacke; Clay Slate	Grauwacke Group; (Inferior strati. Nonfossilif.)
PRIMARY	PRIMITIVE	Granite, Sien Gneiss	INFERIOR ORDER: Granite	UNSTRATIFIED: Serpentine. Trap Granite, Volcan.

TABLE 1 (Continued)

	LYELL 1841	J.P. SMITH 1854	HITCHCOCK 1860 US	1981
POST-PLIOCENE	Recent	(River and Lake Deposits)	Alluvium	Quaternary
	Post-Pliocene	TERTIARY Pleistocene	CENOZOIC Recent Pleistocene	CENOZOIC Recent Pleistocene
TERTIARY	Newer Pliocene Older Pliocene	Pliocene	Tertiary Pliocene	Tertiary Pliocene Miocene
	Miocene Eocene	Miocene Eocene	Miocene Eocene	Oligocene Eocene Paleocene
SECONDARY	Cretaceous	Cretaceous	Cretaceous Chalk Gault Greensand	Cretaceous
	Wealdon Oolite or Jura Lias	Oolitic	MESOZOIC Jurassic Wealdon Oolitic Lias	MESOZOIC Jurassic
	Trias or New R Sandstone	SECONDARY Triassic	Triassic	Triassic
	Magnesian Limestone	Permian	Permian	Permian
	Carboniferous Coal Measures Millstone Gr Mountain Limestone	Carboniferous Coal measures Millstone Gr Mountain Limestone	Carboniferous Coal Measures Millstone Gr Mountain Limestone	Carboniferous Pennsylvanian Mississippian
	Old Red Sandst or Devonian	Old Red Standst (Devonian)	PALEOZOIC Devonian Upper Middle Lower	PALEOZOIC Devonian
PRIMARY FOSSILIFEROUS	Silurian	PRIMARY FOSSILIFEROUS Upper Silurian	Upper Silurian (9 units)	Silurian
		Lower Silurian (Cambrian)	Lower Silurian (4 units)	Ordovician
	Cambrian	Lowest Silurian (Cumbrian)	Cambrian	Cambrian
		META-MORPHIC	AZOIC	PRE-CAMBRIAN

catastrophic deluge and the recency of man, two *essential* matters. Moreover, in the crust of the earth on every hand Buckland discerned evidence of design by an all-wise Creator. On this topic he wrote extensively (especially 1819, 1836). Attempting to answer his critics who still felt Scripture was violated, he suggested that early epochs were passed over by the sacred historians "who for moral purposes, had only to let us know there had been a beginning." The word "beginning" as used by Moses, Buckland suggested, may have been used "to express an undefined period of time which was antecedant ... to the creation of the present animal and vegetable inhabitants," confining the "detail of his history to the preparation of this globe for the reception of the human race" (Buckland 1819:22-23, cf. Gillispie 1951:102-110).

As further support of his attempted harmonization of geology and Genesis, Buckland appealed to John Bird Sumner, "a divine whose rational and sober piety no person will venture to dispute" (later appointed Archbishop of Canterbury):

> *No rational naturalist would attempt to describe, either from the brief narration in Genesis or otherwise, the process by which our system was brought from confusion into a regular and habitable state. No rational theologian will direct hostility against any theory, which, acknowledging the agency of the Creator, only attempts to point out the secondary instruments he has employed.... But we are not called upon to deny the possible existence of previous worlds, from the wreck of which our globe was organized ...* (Buckland 1819:26).

An additional insight into ways geologists attempted to harmonize science and Scripture is well illustrated in a paragraph from the introduction to the book in which the Carboniferous Period is named (cf. Figure 3) and established by Rev. W. D. Conybeare (Conybeare & Phillips 1822:L), a friend and associate of Buckland:

> *Before we examine the bearings of physical science on Revelation, our ideas should first be settled as to what may be reasonably expected from Revelation in this respect. Both its opponents, and some of its defendants, often argue as if it should have included the discovery of a system of physical truth; which it would not be difficult to show, gives an entirely erroneous view of its professed object; to treat, namely, of the history of man only, and that even but as far as affects his relations to his Creator, and the dealings of Divine Providence in regard to him.*

These various arguments of Buckland, Sumner, Conybeare and many others in the geological mainstream and the clergy suggest the kinds of thinking which prevailed while the geologic column was being hammered out. But many were not convinced that such arguments were safe or sound, as we shall note later.[2]

As the impact of later geological studies was felt, particularly those of Lyell and of Agassiz on glaciation (Figures 1-2), Buckland had much less to say on the effects of the flood, actually devoting some of his energies in later years to moderating and "explaining away some of the diluvial extravaganzas of his youth" (Millhauser 1959:46).

FIGURE 1. View of terminal moraine from a glacier which descended from the hills to the right of the area pictured. One of several moraines described by Buckland (1841) after he, together with Agassiz, first recognized evidence of glaciation in the British Isles (Fall of 1840). Near Thornhill, north of Dumphries, Scotland.

FIGURE 2. Cut through the moraine showing unsorted rock matrix.

FIGURE 3. Two scale tree stumps from a cluster of 11 stumps and 8 prostrate trunks exposed on a surface approximately 35 by 75 feet. These are among a variety of fossils typical of the Carboniferous system which was described by Conybeare & Phillips in 1822. Victoria Park, Glasgow, Scotland.

Adam Sedgwick (1785-1873)

Reverend Adam Sedgwick, for more than fifty years Professor of Geology at Cambridge University, and Sir Roderick Impey Murchison (1792-1871), Director-General of the British Geological Survey (1855-1871), were geological heavyweights whose numerous major scientific contributions and whose cooperation and conflicts in disentangling the complexities of the lower Paleozoic contribute unforgettable pages to the annals of the history of geology. From this rich and fascinating history only a few additional points are selected that especially bear on the development of the geologic column and the ongoing conflict between interpreters of geology and interpreters of Genesis, often the same persons interpreting both.

In the mountainous country of Wales, and in the Lake District of Cumberland and Westmoreland, there occurs a vast series of variously deformed, folded and faulted rocks with the most complicated structure and relations of any in Britain (Figures 4-5). While it was recognized that they were older and must belong to the "Transition Series," "the chaos of the greywacke" remained obscure long after the basic sequence of Britain had been worked out and mapped. This was exactly the kind of challenge that appealed to Sedgwick, unquestionably one of the keenest field observers of his time. In 1831 he spent two field seasons in North Wales, identifying units, tracing out flexures, displacements and structural relations until he succeeded in resolving the "chaos," in working out the sequence and the major subdivisions which later were to become part of his basis for the Cambrian system.

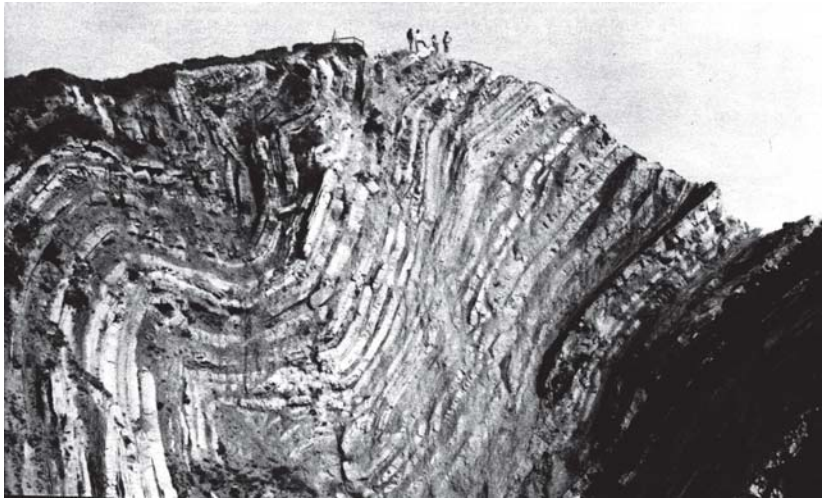
Of importance to those who may have the impression that geologists erected the geologic column to accord with their ideas of how a succession of fossils should occur, Sedgwick here, as in the comparable sequence in the Lake District to the north, which he had studied ten years earlier, disentangled the sequence entirely without the use of fossils. Only later when the fossils represented were studied was this additional information included in the description.

In 1855, long after he had done the work upon which his Cambrian system was established, and after his publication together with Murchison describing the Devonian System (based on the complex folded greywackes of Devon and Cornwall), Sedgwick wrote that "to begin with the fossils, before the physical groups are determined, and through them to establish the nomenclature of a system, would be to invert the whole logic of geology" (quoted in Clark & Hughes, Vol. 2, 1890:307-308).

Sedgwick's willingness to change his opinions when more information led him to question his earlier conclusions is illustrative of his candor. In a presidential address to the Geological Society (1831:313-314), he came out publicly and forcefully against his former belief that the "vast masses of diluvial gravel, scattered almost over the surface of the earth" should be attributed to the Genesis flood:

FIGURE 4. Folded Carboniferous strata exposed in sea cliffs at Little Haven, St. Bridges Bay on the southwest Welsh coast. The tectonic activities affecting these strata also profoundly distorted the underlying lower Paleozoic "Transition" series in Wales that were deciphered by Sedgwick and Murchison in the 1830s.

FIGURE 5. Exposures of folded and overturned Jurassic strata at Lulworth Cove. Part of an east-west monoclinal complex which records evidence of tectonic disturbances affecting Jurassic and Cretaceous strain in southern England.



> *They do not belong to one violent and transitory period.... Our errors were, however, natural, and of the same kind which led many excellent observers of a former century to refer all the secondary formations of geology to the Noachian deluge. Having been myself a believer, and to the best of my power, a propagator of what I now regard as a philosophic heresy, and having more than once been quoted for opinions I do not now maintain, I think it right, as one of my last acts before I quit this Chair, thus publicly to read my recantation.*

In no sense, however, did this mean he denied the Flood. The mistake was in wrongly attributing the so-called "Diluvial" deposits to its actions. He continued:

> *Are then the facts of our science opposed to the sacred records? and do we deny the reality of a historic deluge? I utterly reject such an inference.... And in the narrations of a great fatal catastrophe, handed down to us, not in our sacred books only, but in the traditions of all nations, there is not a word to justify us in looking to any mere physical monuments as the intelligible records of that event: such monuments, at least, have not yet been found, and it is not perhaps intended that they ever should be found.*

In 1844, in a long letter to a friend troubled by severe criticisms of geologists made by the influential William Cockburn, Dean of York, and other conservative churchmen, Sedgwick explained how he interpreted the Scriptures to avoid conflict with his interpretation of the geologic strata:

> *The two first verses [of the first chapter of Genesis], are an exordium, declaring God the Creator of all material things; and I believe it means, out of nothing, at a period so immeasurably removed from man as to be utterly out of the reach of his conception. After the first verse there is a pause of vast and unknown length, and here I would place the periods of our old geological formations, not revealed because out of the scope of revelation.... The work of actual present creation now begins. The spirit of God broods over the dead matter of the world, and in six figurative days brings it into its perfect fashion, and fills it with living beings* (quoted in Clark & Hughes, Vol. 2, 1890:79).

Because of his prominence and the theological views he adopted in attempting to preserve the integrity of both Scripture and science, Sedgwick was a frequent target of conservative churchmen. In turn, Sedgwick the critic thought some scientific ideas genuinely dangerous to religion, faith and morality, the most insidious of which, in his view, was the idea of transmutation of species (organic evolution), an idea which persisted in coming up from time to time, although never from the mainstream geologists in England. In describing the changing vistas of life that seemed to be exhibited by the fossil record, even as early as 1831 he was constrained not only to interpret these changes as resulting from "creative additions," but at the same time to disclaim "the doctrines of spontaneous generation and transmutation of species, with all their train of monstrous consequences," a theory "no better than a phrensied dream" (1831:305).

In 1844 when the anonymous book by Robert Chambers, *Vestiges of the Natural History of Creation*, introduced a theory of theistic organic evolution ostensibly supported by facts of geology, the whole community of geologists,

so often criticized, became the sharpest critics. The book was well written with an "agreeable style and reverential tone." Though speculative and containing numerous technical mistakes, it was immediately popular, arousing widespread discussion. There were four editions in the first eighteen months, and eleven editions by 1860.

Such a book called for an answer. Sir Richard Owen, Hugh Miller and Adam Sedgwick prepared the most comprehensive refutations, and other leading geologists wrote shorter critical reviews. Lyell (1851:xxiii) attested to his long-time opposition to such views, endorsing the refutations prepared by these men. Those who had been criticized for "liberal" interpretations of Scripture were now the critics of still more liberal interpretations. They resisted strongly the idea of organic evolution, especially any theory that might degrade man to the level of animals.

In 1845 Sedgwick prepared an 85-page response which he added to his widely read "Discourse on Studies of the University," and four years later, seeming to sense an ominous threat, he published a comprehensive, 442-page, technical, point-by-point refutation of the transmutation theory as presented by Chambers. Sedgwick searched for the most forceful words at his command to portray the evils that could result. Selections from personal letters to Charles Lyell and Macvey Napier in 1845 are less restrained, conveying his inmost feelings:

> *The sober facts of geology shuffled, so as to play a rogue's game; ... the author perpetually shoots ahead of his facts, and leaps to a conclusion, as if the toilsome way up the hill of Truth were to be passed over with a light skip of an opera-dancer.... If the book be true, the labours of sober induction are in vain; religion is a lie; human law is a mass of folly, and a base injustice; morality is moonshine; ... and man and woman are only better beasts! ... arsenic, covered with gold leaf* (quoted in Clark & Hughes, Vol. 2, 1890:83-85, 87).

A few years later, in December 1859, responding in a personal letter to his former student and long-time friend, Charles Darwin, Sedgwick (in Clark & Hughes, Vol. 2, 1890:356) wrote concerning the *Origin of Species*, which presented organic evolution to the world in a far more scientific way, "If I did not think you a good-tempered, and truth-loving man, I should not tell you that ... I have read your book with more pain than pleasure. Parts of it I admired greatly, parts I laughed at till my sides were almost sore; other parts I read with absolute sorrow, because I think them utterly false and grievously mischievous."

This was one of the founders of the geologic column, the Sedgwick who described and named the Cambrian and, together with Murchison, the Devonian Systems.

Sir Roderick Impey Murchison (1792-1881)

The other major participant in unraveling the Lower Paleozoic Systems, the "chaos of the greywacke," was Murchison who went to South Wales and worked from the top of the section down, while Sedgwick in the north was working from the bottom up. Murchison was by 1835 able to present to the Geological Society a carefully worked sequence of the units in the upper

Transition rock together with accurate descriptions of lithology, fossil and physical relations, although the details of its lower member, including boundary relations with still older rocks to the north, remained in doubt. His classic monograph, *The Silurian System*, appeared in 1839. The deformed and faulted strata resulting from the complex tectonic history, combined with a sparsity of fossils, made system and member divisions and boundaries difficult to recognize clearly at some levels (Figures 4-5).

Thus, when Murchison heard that comparable rocks in a nearly horizontal position were widespread in Russia, he was pleased to accept an invitation from the Czar to study the strata. There he was able to demonstrate the wide geographic extent of the Silurian and Devonian Systems. He also encountered and studied a series of strata in the province of Perm which appeared to be equivalent in position and age to the "Red Underlyer" and "Zechstein" formations of Germany and part of the "New Red Sandstone" of Britain. Since they were far more diverse lithologically and more widely exposed, he proposed in 1841 their designation as the type area for a new system — the Permian — and that they be included as the youngest system of the recently named Paleozoic succession (Zittel 1901:454). Thus Murchison was responsible for establishing three of the twelve basic systems — Silurian, Permian and, together with Sedgwick, the Devonian — a larger number than any other worker.

John Phillips (1800-1874)

John Phillips, William Smith's nephew who was later to succeed Buckland at Oxford, developed museums in York, London, Dublin and Oxford. Consequently he had to arrange fossils from many of the systems, giving him an overview. In the field he revised and reworked with great care and detail the fossil sequence in the Devonian of Cornwall and Devon that had long presented problems (1841).

In 1841 Phillips proposed that the name Paleozoic (sometimes applied by Murchison and Sedgwick to the Silurian) should be used in a more inclusive sense for all of the systems of the Transition of Werner (Cambrian to Devonian) as well as the overlying Carboniferous and Zechstein (Permian in 1845); that Mesozoic be used for the remainder of the Secondary (Triassic, Jurassic and Cretaceous); and Cainozoic be used for the Tertiary. The suggestion met with favor, and soon became generally accepted. The geologic column was taking shape.

In the development of the geologic column some systems, such as the Jurassic and Cretaceous, were partially or essentially completely worked out before receiving their present names. "In the very beginning of the nineteenth century the fundamental features of the Jurassic succession had been so securely established" by the founder of the index fossil concept, William Smith, "that subsequent observers had little to amend" (Zittel 1901:497). Placed together under the Oolitic series, it appeared with some refinements in W. D. Conybeare and W. Phillips, *Geology of England and Wales* in 1822. Eventually the

designation "Jurassic System," based on studies of favorable deposits exposed in the Jura Mountains of France and Switzerland, was generally adopted.

Sir Charles Lyell (1797-1875)

The most esteemed position in geology in the 19th century is often accorded to Charles Lyell, not because of any geological discovery or breakthrough, although he did a fair share of original work, but rather because of the profound influence he exerted on his contemporaries and on the development of geology since that time. It has been said that "even though he had numerous forerunners," modern geology began with him (Simpson 1975:262).

Lyell's most famous work, *Principles of Geology*, appeared in 1830.[3] In it he organized the geological information of his time, deducing therefrom the far-reaching underlying principles and processes as he understood them (Figures 6-7). It was an assault both on Wernerian Neptunism and the catastrophism of Cuvier, theories which had attracted a significant following among geologists. Within a few years of its appearance it had convinced most geologists, even catastrophists, that the great majority of changes in the physical world are the result of ordinary geological processes, mostly of a gradual nature, such as may be observed in operation today.

Lyell's support of the uniformitarianism of Hutton goes farther than many geologists are willing to go today. That the present is the key to the past, the forces and processes active in nature today — erosion, deposition, cooling, crystalization, etc. — provide clues to understanding similar processes in former times, is universally accepted. That the rates and magnitudes of geologic activity have dominantly remained at the same level has, as indicated above, faced serious challenges (e.g., see Gillispie 1951:134-135).[4]

Lyell's principal contribution to the geologic column was the formalizing and naming of three subdivisions for the Tertiary — Eocene, Miocene, and Pliocene — which appeared in an early edition of *Principles*. One of his bases for considering these as valid natural divisions was the consistent decrease in the proportion of living species of marine shells in the progressively older epochs. Later in the decade, he proposed that the name Pleistocene be used for Buckland's Diluvium, a term which by this time was recognized to be misleading and confusing (Wilson 1972:305-308, 483-485).

Although Lyell was the chief apostle of uniformitarianism, he believed in a Creator, and during the years the geologic column was being established he opposed both evolution and those popular views of progressive creations that involved an advance or trend toward higher types. Lyell (1832:271-272) deemphasized the Genesis flood as a universal geological agency, confining it to the parts of the world inhabited in the days of Noah. "On the contrary, the olive-branch brought back by the dove, seems as clear an indication to us that the vegetation was not destroyed, as it was then to Noah that the dry land was about to appear." Some years after *Origin* appeared he accepted the theory of the origin of species by evolutionary processes.

FIGURE 6. Manor house on the Kinnordy estate near Kirriemuir, Scotland, where Charles Lyell was born in 1797. The estate is still held by the Lyell family. As with Darwin, family wealth supplemented by income from his books allowed Lyell to devote his full energies to the study of his chosen area of science.

FIGURE 7. Glen Tilt in the Grampian Highlands of Scotland where Hutton in 1785 discovered granite veins that had intruded sedimentary rock and altered the rock bordering the veins. These observations were basic both in demonstrating the igneous origins of granite and in providing evidence for "metamorphism," the latter term introduced by Charles Lyell who adopted and expanded many of Hutton's views. Lyell visited the classic locality with Buckland in 1824.

Louis Agassiz (1807-1873)

During the early years of his career Agassiz lived in his native Switzerland, in Germany and in France, where he came under the spell of and developed a close friendship with Cuvier. The scientific studies which led to his reputation as the most respected geologist on the continent were published in his five-volume monograph of brilliant original research on fossil fishes (1833-1843), his extensive studies of glaciation, which resulted in the general acceptance of the concept of widespread continental as well as alpine glaciation (1836-1846), and his valuable studies on fossil echinoderms and molluscs. The last 27 years were spent in America, mostly at Harvard, where he founded the Museum of Comparative Zoology, and became famous for his unparalleled skill as a teacher, for his vigorous opposition to Darwinian evolution, and for his adherence to strict fixity of species.

While visiting Agassiz in 1838 in Switzerland, William Buckland was shown clear evidence of formerly much more extensive alpine glaciation. After the British Association meetings in Glasgow in 1840, Agassiz and Buckland set out to search for similar deposits which Buckland recalled having seen years before in Scotland (Figures 1-2). They soon encountered the typical moraines, glacial till, and polished, furrowed and striated surfaces so characteristic of glaciated regions. Buckland now recognized that much of what he had been calling Diluvial was, in fact, of glacial origin. Buckland immediately went to see Lyell at his home at Kinnordy, and the two men set out in search of glacial deposits. They were present on every hand. The pieces of the long-standing enigma — terminal moraines and till lacking the sorting (Figure 2) and the form to be expected in deposits of running water from floods or streams, polished and striated surfaces, erratic boulders, kettle lakes, and bogs — finally fell into place perfectly, solving a host of difficulties. Lyell was convinced.

Both men prepared papers on glaciation in Scotland which were given after a paper by Agassiz at the Geological Society meetings the following December. "The declaration of Buckland and Lyell in favor of Agassiz's glacial theory created a sensation" (Wilson 1972:500-501). Though there was strong resistance, as is always the case with new insights and interpretations, it soon faded as others compared the evidence with that in the vicinity of existing glaciers. As a result, the events responsible for the Pleistocene series as presently understood became generally recognized.

The role of Agassiz in the development of the progression theory will be taken up in the section on the multiple creation hypotheses which follows.

MULTIPLE CREATION HYPOTHESES

It has been shown that during the decades when the geologic column was being formulated, the founders had nearly all come to have certain beliefs and working hypotheses, including among others the following:

1. The history of life on the earth involved extended periods of time vastly longer than six thousand years.

2. Some organisms had a much longer history on the earth (fossil record) than others.

3. "Transmutation of species" (organic evolution) could not account for the later appearance of forms restricted to the more recent strata (belief based on both their understanding of evidence as well as their philosophical and religious views).

Although the geologists of this period were indebted to Cuvier for the theory of catastrophes, he seemed to prefer to explain the increasing proportion of extinct and unfamiliar forms he encountered in progressively older formations as a consequence of migration from distant areas, such as Australia, where a very different fauna exists, rather than from new creations. "I do not pretend that a new creation was required for calling our present races of animals into existence, I only urge that they did not anciently occupy the same places" (1812, trans. 1817:125-126). But elsewhere in the same essay he made statements that would lend support to the idea that he may have entertained the possibility of later creations of some fauna such as mammals and man. "... we are also led to conclude that the oviparous quadrupeds [reptiles] began to exist along with the fishes, and at the commencement of the period which produced the secondary formations; while the land-quadrupeds [mammals] did not appear upon the earth till long afterwards ..." (1817:107-108, translation of 1812 essay; compare p 171, 181 on recent appearance of man).

A theory of creative additions of new and different forms of life *in response to needs of a changing physical environment* was a concept that was expressed by a number of its leading exponents. Generally a view of *directional but discontinuous change* resulting in a *gradual ascent towards a higher type of being* was also expressed, hence the common designation "progressive creation."

As early as 1808, three years before Cuvier's theory of catastrophes was proposed, Robert Jameson, the famous Wernerian supporter in Edinburgh, postulated a succession of creations in which both animals and plants increased "in number, variety and perfection" from changing physical conditions as universal seas of Werner retreated and new habitats were formed (Gillispie 1951:99; Bowler 1976:34, 35).

Buckland (1836:107, 115) also included both the concepts of response to physical conditions and of directional change:

> *... The creatures from which all these [fossils] are derived were constructed with a view to the varying conditions of the surface of the Earth, and to its gradually increasing capabilities of sustaining more complex forms of organic life, advancing through successive stages of perfection (emphasis supplied).*

But he qualified it by stating that while the "lower classes prevailed *chiefly* at the commencement of organic life, ... they did not prevail *exclusively*." He gave numerous examples of complex forms in some of the "earliest strata."

Sedgwick also envisions "a gradual evolution of creative power, manifested by a gradual ascent towards a higher type of being," but he goes on to point out explicitly that:

> *... The elevation of the fauna of successive periods was not made by transmutation, but by creative additions; and it is by watching these additions that we get some insight into Nature's true historical progress, and learn that there was a time when Cephalopoda were the highest types of animal life, the primates of this world; that Fishes next took the lead, then Reptiles; and that during the secondary period they were anatomically raised far above any forms of the reptile class now living in the world. Mammals were added next, until Nature became what she now is, by the addition of Man* (quoted by Lyell 1851:xxxiii, xxxiv; Bowler 1976:37).

Elsewhere he states that "successive forms of animal life adapted to successive conditions."

Louis Agassiz is credited with developing and articulating a second version of progressive creation that *does not relate creative advance to change in the physical world*, but rather to *a grand design in the mind of God, leading from lower vertebrates to man*, and with parallel lines from lower invertebrates to more complex types. The steps were discontinuous, resulting from a series of miraculous creations in successive epochs. "As for me, I am convinced that species have been created repeatedly and successively ... and that the changes which they have undergone during any one geologic epoch are no more than very secondary and related only to their greater or lesser fecundity and to the migrations resulting from the influences of the period" (from his monograph on fossil fish 1833-1843, quoted by Gillispie 1951:166).

Sometimes he is ridiculed for suggesting that blind fish were created blind and placed where they live in perpetually dark caves by the Creator. But viewed as part of a grand created mosaic, one can understand the basis for his belief. For Agassiz, the development of the embryo was a recapitulation of the steps existing in the fossil record. "It may therefore be considered as a general fact ... that the phases of development of all living animals correspond to the order of succession of their extinct representatives in past geologic times" (quoted by Gould 1977:67).

Several others, such as Sedgwick and Lyell, strongly opposed any scheme that linked man with lower animals, such as Agassiz's recapitulation theory might suggest, though Agassiz would never allow an organic link. Most of the other founders of geology and the geologic column might be added to this list of those supporting one or a combination of elements from both views of progressive creation: Roderick Murchison, W. D. Conybeare, John Phillips, Sir Richard Owen, Hugh Miller, and Adolph Brongniart.

Lyell's hypothesis embodied two basic differences: 1) *creation of new forms was not sporadic or episodic*, but a process which went on perpetually, and 2) it was *not directional with a pattern of progression* toward higher or more perfect forms. In Volume II of *Principles* (1832:124) he suggests that the

pairs from which each species is derived have "been created in succession at such time and in such places as to enable them to multiply and endure for an appointed period, and to occupy an appointed space on the globe." In a letter to the British astronomer John Herschel, he confides that when he first "came to the notion, which I never saw expressed elsewhere, ... of a succession of extinction of species, and creation of new ones, going on perpetually now, and through an indefinite period of the past ... the idea struck me as the grandest which I had ever conceived so far as regards the attributes of the Presiding Mind" (quoted by Wilson 1972:439).

Lyell's opposition to both transmutation of species and progressive creation is clearly articulated, but there were aspects regarding creative introductions of species on which he was not as clear. Nor was it yet resolved nineteen years later:

> *By the creation of a species, I simply mean the beginning of a new series of organic phenomena, such as we usually understand by the term 'species.' Whether such commencements be brought about by the direct intervention of the First Cause, or by some unknown Second Cause or Law appointed by the Author of Nature, is a point upon which I will not venture to offer a conjecture* (1851:lxxiii).

CONSERVATIVE OPPOSITION TO GEOLOGICAL THEORIES

Virtually all of the founders of geology, including the uniformitarians Hutton and Lyell, were men with a belief in God, in a divine plan, a Presiding Mind. Many of the most prominent contributors were, in fact, trained in theology as well as geology — Conybeare, Buckland, Sedgwick and others. But as has been noted, several of the prevailing interpretations of the unfolding data of geology required a departure from traditional understanding of Scripture. For advocates of such interpretations Genesis could no longer be taken as a literal or complete account. There must be room to allow for greatly extended time periods, multiple creation events, and secondary causes.

There were reputable theologians who supported such views. Sir Robert Peel was even able to appoint Buckland to a prominent church position as Dean of Westminster, successor of Wilberforce (Gillispie 1960:152). But there were many, very many, who felt that irreparable damage to faith would result. There were countless articles, debates, and denunciations from respected theologians such as William Cockburn, Dean of York, who once debated Sedgwick. Even the most devout, the "unimpeachably pious" William Buckland, who continually sought to harmonize geological findings with Scripture, who opposed transmutation of species, who sought out evidence for the deluge, and who wrote two large volumes (1836) "on the power, wisdom, and goodness of God as manifested in the creation" for the Bridgewater Treatise series, came under repeated and sharp attack. Irrespective of "good intentions," it was felt that these men were undermining the authority of Scripture, starting down a road that eventually would lead men to infidelity and atheism.

Not a few conservative scholars and churchmen made the study of the relation of geology and Genesis a part of their life work, reading the extensive

body of new literature in the rapidly expanding field, traveling in some instances to important rock exposures in Britain and Europe, and writing a large number of books. Lyell, in his 1851 (xxxii) president's report to the Geological Society, commented on this "voluminous class of books commonly called Scriptural Geologies," indicating that "several had been issued from the press even since the last anniversary" in a single year (1850-1851). They were of an apologetic nature, since, so far as I have been able to determine, none of these authors published field or laboratory studies that contributed to the formulation of the new science. These books, however, do provide important insights into the intellectual milieu of the time, and especially the kinds of objections being raised during those years when the geologic column was being worked out and geology was being established as a science.

Three of the more comprehensive studies written early in the period when the systems of the geologic column were being formulated have been selected for brief comment.[5] Common features include:

1. Lengthy exegeses of relevant Scriptures in an attempt to demonstrate that the traditional understanding of the time constraints of Scripture and the literal nature of the account must be followed.
2. Attempts to explain in hundreds of pages how much of the evidence alleged to represent extended periods may be best accounted for by the Genesis flood, and to show how it does not support "modern interpretations."
3. A deep concern for the potential impact on faith of this prevailing trend in the new science.

These books also share many features with the writings of flood geologists which appeared about a century later. In many respects their books are surprisingly similar to publications of Price, Rehwinkel, Whitcomb & Morris, and others.

Conservative Concern

The profound concern for the effect on faith is well expressed by Penn (Vol. I, 1825:xix-xxii):

> *If there is anything that tends more than another to perplex the thoughts of the believer in Revelation in this age of geological inquisition, it is unquestionably the objects with which he sees himself surrounded in the disordered scenery of the globe, when he is urged to contemplate them as they are adventurously expounded by persons who resist all connexion of them with the narrative of Scripture; and when, moreover, their expositions are dogmatically asserted, to be the proper dictates of philosophy. And, as the exposition of these objects has hitherto been almost exclusively adventured by persons who have systematically resisted that connexion, a reflecting mind is bewildered by the difficulty of reconciling the author of the objects which are seen, with the author of the statements which are read; and seems often driven near to the distracting doubt, whether they can be One and the Same, and*

consequently, whether the first and introductory record of the body of Scripture can be truly of divine original: for, we are sure, that Nature is of divine original.

In reference to those who would suggest that it is the "*professed object* of Revelation to treat the history of *man only*," he warns of the danger and insecurity in attempting to determine what one may "*deem reasonable for Revelation to have imparted*."

The pulse of many who were less involved yet genuinely concerned is echoed in verse in the writings of contemporary poets:

Some drill and bore
The solid earth, and from the strata there
Extract a register, by which we learn
That He who made it, and revealed its date
To Moses, was mistaken in its age.

— William Cowper, in "The Task"
Late 18th century.

I could get along very well if it were not for those geologists.
I hear the clink of their hammers at the end of every Bible verse.

— John Ruskin, 1851

Sharp Exchanges

This section deals with a chapter in history which one could wish might not need to be included, yet which is part of the intellectual milieu that affects observation, interpretation and often selection of data. The tendency toward polarization which invariably results from accusations, charges and counter-charges almost always leads people to try to support positions taken rather than to search for truth.

Typical of the more extreme charges made by certain conservative writers are comments and phrases selected from George Fairholme, 1833, *Geology of Scripture* (x-xii, 14, 15, 70, 147):

"It was then the fashion of science, and for a large part of the educated and inquisitive world, to rush into disbelief of all written Revelation." "The wild character of an hypothetical philosophy." "Hasty and erroneous conclusions from physical facts." "Geologists (if indeed they are deserving of the name), whose great delight in this subject arises from the play of fancy under a false view." "Wild and absurd." "Wild and repulsive to our reason," "unreasonable theories." "Plunges into dark and devious mazes of hypothesis, rejects the guidance of history."

On the other side, "Scriptural Geologists" were sometimes alleged to be guilty of grievously misrepresenting "principal facts in the natural history of the earth," of lacking "practical acquaintance" with the subjects on which they held positive opinions, and of arbitrary "interpretations of the 'sacred books'" (Smith 1839:220, 30-31; cf. Ramm 1954:125-126). They are not uncommonly recipients of the epithet "lunatic fringe" (Gillispie 1951:152; Simpson 1960:144).

The Conservative Approach

> *The HISTORY OF CREATION is strictly a narrative of plain fact. The "LITERAL and popular interpretation" of that history ... is the only correct and true interpretation.*
> *The SCRIPTURAL ACCOUNT of the DELUGE, will alone account for the phenomena of the fossil strata* (George Bugg, Vol. 2, 1827:347).

> *I propose, in the following pages ... to account for the geological structure of the upper surface of our earth; taking in Mosaical History for my guiding star, to be kept constantly in view throughout my course"* (Fairholme 1833:xi).

Conservative Positions on Data and Explanatory Models

It is impossible to capture or to fairly portray in the space available even the principal arguments set forth in these comprehensive studies. Perhaps a few sentences on Fairholme's views, and brief quotations from the concluding remarks in the volumes by Penn and by Bugg, may convey something, at least, of the essence of their thinking, and may reflect the confidence and depth of feeling with which they were set forth.

Fairholme (1833:57-102 and elsewhere in his volume) attributed strata in the crust of the earth to deposits at the creation, the 1600-year-antediluvian-period, and the deluge of Genesis. There are some rudiments of the ecological zonation theory (a theory that proposes preflood ecological patterns as a factor in the sequence of fossil distribution) in his account, and he recognized bias in preservation as a factor, and much more.

Major theories opposed are cited:

> *Exclusive and peculiar fossils are wholly without evidence, — numerous successions and revolutions are unsupported and impracticable, — while the new creations they would involve, are miraculous and destructive to the Theory, and even to the Scriptures...*(Bugg, Vol. 2, 1827:346).

The Genesis flood is central to suggested explanatory models.

> ***The DELUGE affords an EPOCH among ANIMALS, by which the inexplicable phenomena found by Geologists, are easily explained; as far at least, as they are in our present state of ignorance intelligible to us. The shells of 16 centuries, elevated by the breaking up of the bottom of the sea, partly, perhaps in a consolidated state, partly in a slimy mud, and partially in a loose state, account for all the shells in the rocky strata, and (in connexion with those deposited during the Deluge) for shells scattered through the globe...***(Bugg, Vol. 2, 1827:347).

Penn's model (Vol. 2, 1825:387) similarly utilizes the deposits, including the biomass, of antediluvian centuries for redistribution during the year of the flood.

> *But, when we can be certified by competent testimony, that the body of the ocean acted both mechanically and chemically upon the present surface of the earth for sixteen hundred years and upwards, during which long period a vast proportion of its soils, now fixed and indurated, were soft and moveable; that, during the twelve months of its gradual departure, during which it was "sweeping over the whole globe," it*

was continually propelling over every part of that surface its various moveable soils, together with the animal and other contents of its basin; that, its propulsions were not uniform but irregular, and alternating according to its successive advances and refluxes....

Conservative Conclusion

> But as to the modern "Theory" of Geology, in all its essential properties ... *[it]* is not more contradictory to the plain meaning of Scripture, than it is to every known operation of nature, and every dictate of rational understanding (Bugg, Vol. 1, 1826:xv-xvi).
>
> " — BIBLE THEREFORE STANDS PERFECTLY UNAFFECTED.
>
> " — AND GEOLOGY FALLS TO THE GROUND" (Bugg, Vol. 2, 1827:348).

CONCLUSION

It has been demonstrated that the basic framework of the geologic column was founded by men with respect for Scripture, who, although not holding to conservative interpretations, opposed organic evolution. Anyone who reads the original literature will soon recognize that there was no conscious conspiracy on the part of these scientists to undermine the moral and religious authority of Scripture as sometimes has been charged. Completely apart from any merits or weaknesses, the geologic column is the result of an attempt by conscientious scientists to construct to the best of their ability a classification of rock strata that would account for the phenomena encountered in the crust of the earth.

ENDNOTES

1. Although not yet introduced by Darwin and Wallace, transmutation of species was the topic of frequent discussion, especially in the years following 1844 when it was introduced to the public in the widely read book, *Vestiges of the Natural History of Creation*, by an anonymous author (Robert Chambers).
2. Those among the founders of geology who were flood geologists generally followed Cuvier and Buckland in assigning to the flood only the superficial Pleistocene deposits. The great thickness of older strata was assigned to earlier episodes in earth history. The "Scriptural geologists" and flood geologists of recent decades (e.g., Price 1923; Whitcomb & Morris 1961; Rehwinkel 1951; Coffin 1969; Clark 1946) generally assign almost all of the earlier deposits to the flood and the Pleistocene (Buckland's Diluvial) to either the flood or to postflood times.
3. One sometimes gets the impression that Lyell's work was the first manual or textbook of geology. This is not correct. Several texts and manuals appeared in Britain before or about that time, some going through a number of editions and being printed in the U.S. and on the continent of Europe as well (Greenough, 1819, *First Principles of Geology*, London, 336 p.; de la Beche, 1833, *Manual of Geology*, 3rd ed., London, 622 p.; Conybeare & Phillips, 1822, *Geology of England and Wales*, London, 470 p.; Bakewell, 1829, *Introduction to Geology*, 3rd ed., London, 429 p.). Lyell's volumes differed in being not only a review of what was known, but also a creative synthesis which challenged much current theory.
4. A number of recent books and articles illustrate the trend. The delightful book by Derek V. Ager, 1973, *The Nature of the Stratigraphical Record*, John Wiley & Sons, New York, is one of the most perceptive and refreshing approaches,

comparing earth history to the life of a soldier — "long periods of boredom and short periods of terror."

5. (a) Granville Penn, 1825. *A Comparative Estimate of the Mineral and Mosaical Geologies*, 2nd ed. in two vols. London. 866 pages. (b) George Bugg, 1826, 1827. *Scriptural Geology; or Geological Phenomena Consistent only with the Literal Interpretation of the Sacred Scriptures, upon the Subjects of the Creation and the Deluge; In Answer to an "Essay on the Theory of the Earth" by M. Cuvier, ... and Buckland's Theory ... as Delineated in his "Reliquiae Diluvianae"* (especially on the fossil vertebrates and deposits interpreted by Buckland to have resulted from the Deluge). In two volumes. London. 735 pages. (c) George Fairholme, 1833. *General View of the Geology of Scripture, in which the Unerring Faith of the Inspired Narrative of the Early Events of the World is Exhibited, and Distinctly Proved by the Comparative Testimony of Physical Facts, on every Part of the Earth's Surface*. Philadelphia. 293 pages.

REFERENCES CITED

Ager DV. 1973. The nature of the stratigraphical record. NY: John Wiley.

Bowler PJ. 1976. Fossils and progress. NY: Science History Publication.

Buckland W. 1820 (1819). Vindiciae Geologicae or the connexion of geology with religion explained. Oxford: University Press.

Buckland W. 1823. Reliquiae diluvianae. London: John Murray. Reprinted 1978 by Arno Press (NY).

Buckland W. 1836. Geology and mineralogy considered with reference to natural theology. Vols. I, II. (In Bridgewater Treatise Series). London: William Pickering.

Bugg G. 1826, 1827. Scriptural geology. Vols. I, II. London: Hatchard & Son.

Chambers R. 1844. Vestiges of the natural history of creation. London: J. Churchill.

Clark HW. 1946. The new diluvialism. Angwin, CA: Science Publications.

Clark JW, Hughes TM. 1890. The life and letters of the Reverend Adam Sedgwick. Vols. I, II. Cambridge: University Press.

Coffin HG. 1969. Creation — accident or design? Washington DC: Review & Herald Publishing Association.

Conybeare WD, Phillips W. 1822. Outlines of the geology of England and Wales. London: W. Phillips. Reprinted 1978 by Arno Press (NY).

Cuvier M. 1817. Essay on the theory of the earth. Edinburgh. Reprinted 1978 by Arno Press (NY); translated from 1812 book.

de la Beche H. 1833. Manual of geology. 3rd ed. London.

Fairholme G. 1833. General view of the geology of Scripture. Vols. I, II. Philadelphia.

Gillispie CC. 1951. Genesis and geology. Cambridge, MA: Harvard University Press.

Gillispie CC. 1960. The edge of objectivity. Princeton, NJ: Princeton University Press.

Gould SJ. 1977. Ontogeny and phylogeny. Cambridge, MA: Harvard University Press.

Hitchcock E. 1860. Elementary geology. NY.

Lyell C. 1830-1833. Principles of geology. Vols. I-III. London: John Murray.

Lyell C. 1841. Elements of geology. Vols. 1 and 2, 2nd ed. London: John Murray.

Lyell C. 1851. Anniversary address of the president. Quarterly Journal of the Geological Society 7(1):XXXII-LXXV.

Millhauser M. 1959. Just before Darwin. Middletown, CT: Wesleyan University Press.

Penn G. 1825. A comparative estimate of the mineral and Mosaical geologies. Vols. I, II. 2nd ed. London: James Duncan.

Price GM. 1923. The new geology. Mountain View, CA: Pacific Press Publishing Association.

Ramm B. 1954. The Christian view of science and Scripture. Grand Rapids, MI: Wm. B. Eerdmans.

Rehwinkel AM. 1951. The flood. St. Louis: Concordia Publishing House.

Sedgwick A. 1831. Presidential address to the Geological Society. Proceedings of the Geological Society of London 1(20):281-332.

Simpson GG. 1960. The history of life. In: Tax S, editor. The Evolution of Life. Chicago: University of Chicago Press, p 117-180.

Simpson GG. 1975. Uniformitarianism, an inquiry into principle, theory, and method in geohistory and biohistory. In: Albritton, Jr., CC, editor. Philosophy of Geohistory:1785-1970. Stroudsburg, PA: Dowden, Hutchinson & Ross.

Smith JP. 1839. On the relation between the Holy Scriptures and some parts of geological science. London: Jackson & Walford.

Smith JP. 1854. The relation between the Holy Scriptures and some parts of geological science. London: Henry G. Bohn.

Whitcomb JC, Morris HM. 1961. The Genesis flood. Philadelphia: Presbyterian and Reformed Publishing Company.

Wilson LG. 1972. Charles Lyell. The years to 1841: the revolution in geology. New Haven, CT: Yale University Press.

Zittel K von. 1901. History of geology and palaeontology. London: Walter Scott.

LITERATURE REVIEWS

Readers are invited to submit reviews of current literature relating to origins. Mailing address: ORIGINS, Geoscience Research Institute, 11060 Campus St., Loma Linda, California 92350 USA. The Institute does not distribute the publications reviewed; please contact the publisher directly.

SKEPTICISM AND TRUTH

THE SKEPTICAL INQUIRER. Quarterly Journal published by the Committee for the Scientific Investigation of Claims of the Paranormal. Box 229. Central Park Station. Buffalo, NY 14215.

Reviewed by Ariel A. Roth, Geoscience Research Institute

The Skeptical Inquirer may be most easily described as being the opposite of its much larger counterpart, the popular weekly tabloid called the *National Enquirer*. While the latter reports on all kinds of oddities as truth, *The Skeptical Inquirer* is literally a debunking journal that reports oddities and unacceptable views as error. It is a small, interesting journal written in simple English that covers a great variety of subjects from worthless to extremely important, from scientific to religious, and from unpleasant to esthetic. One seldom knows what to expect next in this maverick periodical. Its general stance is to criticize those views which are not generally accepted by the scientific community or over which there is considerable disagreement. It favors naturalism, a belief that explains everything as simple cause and effect and thus rejects teleological explanations of nature. On occasion opposing views are given ample space for discussion, sometimes with well-voiced protest. Usually unacceptable views are criticized and destroyed.

The main sections of a typical issue are: news and comment, psychic vibrations (a criticism of paranormal claims), articles, literature reviews, and discussion and letters sections.

A number of topics tend to dominate and reappear from time to time. They include: extra sensory perception, coincidences, creationism, astrology, horoscopes, water-witching, clairvoyance, spiritualism, geocentric universe, flat earth, unidentified flying objects, biorhythms, the Loch Ness monster, the Bermuda Triangle, pyramid power, witchcraft, psychics, haunted houses, levitation, etc., etc. The journal generally strongly opposes all these views which are considered paranormal. To *The Skeptical Inquirer* the paranormal appears to be that which is not acceptable within a naturalistic philosophy. The journal claims accuracy and honesty, and

occasionally that goal appears to be reached. However, debunking is too often executed with dogmatism and scorn.

In this day and age when all kinds of cults, irrational beliefs and practices claim the attention of the public and indeed guide the lives of many, it seems appropriate to have a journal devoted to trying to help sort out the melee. In this journal a number of objective tests report on the uselessness of commonly accepted practices such as horoscopes and water-witching. In those areas which are amenable to good objective testing, the journal does seem to perform a useful purpose. When appropriate tests can be applied to questions raised, useful information can come forth. Within these limitations the journal is highly commendable.

However, the journal seems to present a confused picture of skepticism in that it is skeptical about most philosophical approaches while it openly accepts the philosophy of naturalism — a philosophy that excludes the supernatural. It is probably to be expected that many should feel a degree of comfort within a naturalistic system of thought, since this provides relatively easy and more tangible explanations. While these factors give support to naturalism, ease of testing and simplicity are not necessarily good criteria for truth. Reality is usually more complex than our simple minds envision. The many unexplainables that face us indicate that this is the case. In reading *The Skeptical Inquirer* one is intrigued by the "paranormal" behavior of those who can be so skeptical of some phenomena while they so openly accept other ideas.

The journal has not been successful in convincing this reviewer that it is fair in its skepticism about various ideas. In this respect its impact may be more to bolster the faith of the believer in naturalism than to convince a skeptic that here we have an objective evaluation of reality. For instance, why place without criticism a statement by the American Anthropological Association affirming evolution? It seems significant that *The Skeptical Inquirer* is not all that skeptical about the propriety of the American Anthropological Association as a spokesman for all of evolution. Physical anthropology with its frequently changing concepts of the assumed pattern of human evolution is prime turf for skepticism. Few areas of science have been subject to such continued major change and controversy. Thus, the skepticism of *The Skeptical Inquirer* appears selective.

The Skeptical Inquirer seems to disavow the skepticism most have that naturalism is the only reality. Most individuals object to being reduced to mere machines without design, purpose or destiny as naturalism proposes. This may be in part why millions more people read the *National Enquirer* than *The Skeptical Inquirer* which has a circulation of only a

few thousand. I hasten to add that, limited as it may be, I have more confidence in *The Skeptical Inquirer* than in the *National Enquirer*.

Skepticism is a concept that can be used to destroy itself. It is vulnerable to its own tenets. Carried to the extreme, skepticism leads to doubt about everything, including itself. This is both useless and philosophically unsatisfying. The goal of intellectual inquiry is truth, not skepticism, and there is a definite conflict between these two. In this respect there is tension between the terms "skeptical" and "inquirer" (not an unusual pattern in titles). Skepticism, when pursued to the extreme, tends away from truth, while inquiry tends to lead toward truth. In the case of *The Skeptical Inquirer*, skepticism usually dominates. The conflict between skepticism and truth has been resolved by taking a reductionist approach and accepting naturalism as the only reality. There is room in our search for truth for skepticism, but there also needs to be room for truth. As one who believes that there is an absolute reality, an absolute truth to be found, I am particularly concerned that room be made for this rare commodity.

The Skeptical Inquirer has been very useful in eliminating some commonly held misinformation. That it has helped in solving the more basic question of how to arrive at truth is doubtful. Its stance, which tends to reduce reality to a naturalistic understanding, is an intellectual pose that can be misleading. Thus far it has failed to address itself seriously to skepticism about a naturalistic philosophy, thus fostering an unbalanced approach to the truth question. It is a useful journal, however, only if one is aware of its bias. Because of this, skepticism about *The Skeptical Inquirer* is warranted.

GENERAL SCIENCE NOTES

CLIMATIC CHANGES AND CHANGES IN POPULATION

By Richard D. Tkachuck, Geoscience Research Institute

Creationists, though definitely not uniformitarians, often fall unawares into a uniformitarian mode in attempting to explain their views. The impact of climatic changes over measurable periods of time on peoples and cultures is a concept often foreign to the creationist mind. It is almost assumed that climatic conditions familiar to us were the same as those which greeted Noah as he stepped out of the ark. Yet the evidences of significant changes surround us everywhere and must be reckoned with. It is thus interesting to note that a recent article by McIntosh & McIntosh[1] provides some further evidences that climatic conditions and subsequent demography were not always as they are now.

The article is largely an anthropological history of Western Africa above the equator. Written not as a rigorous treatise but as a review for a wider readership, it nonetheless provides an excellent statement that climates do change and that climatic changes are the major factor in widescale movements and settlements of peoples.

When one visualizes Western Africa in one's mind, pictures of barren wastes and scrub come to view with respect to the Sahara and the Sahile. However, recent archaeological finds have shown that these regions once received significantly more moisture and supported a much denser human and animal population. Scattered through this now-arid and desolate region are numerous burial sites, urban dwellings and evidences of domesticated animals. The people appear to have had a complex sophisticated culture. In addition, there are numerous evidences of animal life that once inhabited the area. This is nicely represented by a map showing where the remains of elephants and giraffes can be found, as well as drawings of them done by the past populations. The chart shows that nearly the entire region could once support life that is now restricted to areas farther south and nearer the rainfall from the coast.

The article assumes the conventional interpretation that cultural events require long periods of time for change to take place and that the introduction of new technologies will spread across the continent at a very slow pace. One wonders how valid such suppositions are.

An interesting case is found in a different article by Deetz & Dethlefsen.[2] It is a fascinating piece seemingly far removed from the

creation-evolution controversies, but which, in my opinion, provides some helpful insights into the interpretation of ancient cultures. The authors examine the headstones in cemeteries in Massachusetts from the seventeenth to the nineteenth centuries. At that time three main forms of carvings were used on the tombstones. In the early periods a winged skull or Death's head was often carved. Later, this was replaced by a cherub's head, also winged, and finally, the cherub's head was replaced with an urn and willow tree. Since the headstones contain the date of death of the individual and subsequent placement of the stone, this study provides an interesting view into how a society changes.

The most fascinating part of this work is the observation that change was most rapid in the educated centers. In those communities where the interchange with other communities was limited, the change in style of headstones was more gradual. However, these outlying communities did change rapidly whenever a new stone cutter moved into the community. Thus, stylistic changes could be influenced by only one man joining the community.

This is significant, because it questions the necessity for long periods of time in order to have cultural evolution. It also implies that different cultural levels in a geographic area are not necessarily sequential but perhaps could be contemporaneous. Finally, if climatic conditions have rapidly changed in the past, would not this speed up the amount of cultural interchange and increase the rate of cultural change?

ENDNOTES

1. McIntosh SK, McIntosh RJ. 1981. African prehistory. American Scientist 69:602-613.
2. Deetz J, Dethlefsen ES. 1967. Death's head, cherub, urn and willow. Natural History 76(3):28-37.

EDITORIAL

PUZZLES

Recently a member of our Institute received a jigsaw puzzle as a gift. This puzzle was somewhat different from the ordinary dime-store variety in that the cutting process produced tessellated pieces, i.e., pieces exactly the same shape and size. These identically shaped pieces are completely interchangeable with any other piece and, additionally, each can be rotated so that it will fit another piece in any one of three interlocking configurations. As a result it is a trivial task to put the puzzle together if the only goal intended is for the pieces to fit. However, the picture formed under such random conditions would not be intelligible. In order to arrive at a proper reconstruction, only the picture represented on the individual pieces can receive consideration, for the *shape* of the pieces cannot aid in its reassembling.

While musing over the construction of the puzzle, I was struck with a possible insight into the conflict between scientists who hold respective sides in the creation/evolution controversy. Using the puzzle as a metaphor, consider the following. Let individual data points represent a tessellated puzzle piece. Small collections of these pieces may be combined into a small picture which could describe a biochemical pathway, a physical process, or some ecological parameters. Continuing with the first example, large metabolic maps would represent collections of smaller groupings. But even these larger collections can be further combined with other large collections and become descriptions of organ systems or other complex physiological processes. Further collections at this level will produce descriptions of the organism and how it reacts with the surrounding environment. The process of science spends most of its time at this level of puzzle solving.

While for a time the above process is satisfying, eventually higher levels of synthesis are sought. As more and more complete descriptions of organisms are developed, unifying principles are sought to contain them. Somewhere at the higher levels of synthesis the concept of meaning begins to appear. It is at this level where the creationist and evolutionist diverge. These two groups seldom if ever disagree on data; it is the larger synthesis and meaning that brings the problems. But why do problems begin only at the highest level of the puzzle? It would seem that the larger the sections of the puzzle assembled, the easier it would be to complete the rest of the picture. Alas, such is not the case.

Perhaps the protagonists in the creation/evolution controversy have not understood how the puzzle of origins is constructed and as a result are not playing by the same rules for putting the picture together. Puzzles usually come in containers which depict the completed picture on the outside. But in the puzzle of origins neither creationists nor evolutionists have seen the picture on the box that the puzzle came in. No human eye-witnesses were there when it all began, although creationists claim valid historical documents that do

describe the event in sparse outline, and both groups are aware that a large number of the pieces are still missing or even lost.

How then shall the puzzle be constructed? To produce a picture at the meaning level can be done only by patterning it after one's world view — the composite of all one's acquired knowledge and experiences. It is a fiction of the darkest hue to believe that we can divorce ourselves from the persons we are and in an undetached manner observe our surroundings and come up with an accurate rendition of the world about us. The rational person continually searches for meaning in his surroundings. To give up this search is to become insane.

The fundamental difference between the creationist and evolutionist is that the former includes some pieces which reputedly have on them partial pictures of God. The latter group rejects these as not being important to their construction and therefore ignores them or may even deny their existence. If such God-pieces are accepted they are said to belong to a totally separate puzzle. Thus the source of the argument is seen. The creationists' world view says there is only one puzzle and that all the pieces found from whatever source fit somewhere in the picture. The evolutionist says there could be separate unrelated puzzles and that one cannot mix puzzles in order to get a completed picture.

Unfortunately, the end result is that it becomes futile to argue over the drastically conflicting pictures that are being produced. Large numbers of pieces fit together in both pictures and both groups of puzzle makers claim great beauty and symmetry. Each group recognizes incompleteness where certain areas of the puzzle are dissonant with the overall picture being produced.

This line of discussion might logically lead to the question, "What is the justification for creation-oriented research?" If minds cannot be changed, is it not futile to present data in the face of the opposition? One answer is that research can serve by offering alternative solutions to those who are still undecided on the question of origins. But there is a deeper philosophical purpose as well. One's world view is not static and continually changes (i.e., expands) with new information and experiences. Major shifts in thought occur when the level of dissonance surrounding a particular area becomes too great. Further research functions by providing carefully proposed scientific models which will create such dissonance and thus cause a person to question whether a naturalistic view is adequate.

Richard D. Tkachuck

REACTIONS

Readers are invited to submit their reactions to the articles in our journal. Please address contributions to: ORIGINS, Geoscience Research Institute, 11060 Campus St., Loma Linda, California 92350 USA.

RE: BROWN: GEO AND COSMIC CHRONOLOGY (ORIGINS 8:20-45)

I wish to compliment R.H. Brown and the editors of ORIGINS for making the data of "Geo and Cosmic Chronology" available to your readers. There seems to be a definite need for this subject matter and the style is quite fitting. All too often the Genesis creation week account is assumed to record the origin of our solar system, galaxy, etc., without critical study into the assumption.

More significant than the data itself is Brown's forthright statement of his "basic hermeneutic principle that the books of nature and the Scriptures should be consistent with each other." As thoughtful Protestants it is all too easy to fall into the error of applying *sola scriptura* loosely to everything covered by Scripture. In selecting his hermeneutic principle he chooses a principle that will be neither popular nor easy. I commend him for selecting this approach.

William M. Allen
Professor of Chemistry
Loma Linda University
Riverside, California

The review article by Dr. R. Brown on "Geo and Cosmic Chronology" is informative and puzzling. Informative in that Brown appears to be taking a major step toward amassing evidence for an old inorganic earth, something which has not been so boldly done in "apologetic scientific creationism." Brown cited several lines of evidence for the age of matter using an annotated bibliographical style. References were organized, and appropriate disclaimers were made concerning lack of reference completeness.

The puzzling nature of Brown's paper stems from an apparent lack of depth when he launches into a discussion of theological implications. Does Brown suggest that these are his own selection of the options? Further, do they reflect the review nature of his paper? Where are the references supporting these issues?

It is my view that Brown's theological issues section was not treated with any of the rigor apparent in the rest of his article. Its presence raises serious questions about the necessity of the "addendum" to an otherwise scholarly paper.

Charles J. Amlaner, Jr.
Assistant Professor of Biological Sciences
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College Place, Washington

RE: BROWN: SCIENTIFIC CREATIONISM? (ORIGINS 8:57-58)

I felt Dr. Brown presented a reasonable approach to the too enthusiastic expressions of some in the creationist position. Yet when I turned to page 58 and came to the word "neutral" I was caused to wonder along with another reader. Since I hold that basically all facts are either oriented with God or against God, then "neutral" seemed a strange word.

Then "it science is to be taught soundly" was a phrase that led me to wonder further since quite technically "origins" questions are formally outside of proper, orderly scientific investigations. This assertion seems realized even by an evolutionist spokesman at June 1982 Pacific section of AAAS. (By evolutionist Root-Bernstein: at least, from my reading of his paper.)

In short *if* origins are to be discussed at all in the science classrooms of America, then students should be most carefully apprised of the fact that such discussions are *outside* the purview of proper, orderly science. Rigorously such discussions are centered in metaphysics, or as Root-Bernstein expressed it: in statements of *meta*scientific nature.

John N. Moore
East Lansing, Michigan

R.H. BROWN REPLIES:

I understand your concern over my use of the term "neutral." I intended to use it in the sense of uninvolvement with biblical specifications, and as a means for emphasizing that there is a strong philosophical and scientific basis for creationism entirely apart from the testimony of the Hebrew-Christian Scriptures.

My contention is that science cannot be taught soundly if such teaching includes a one-sided view of origins. As you point out, if consideration is given to origins in scientific instruction, it must be emphasized that any consideration of origins is metascientific.

RE: NEWS AND COMMENTS: ARKANSAS ACT 590 (ORIGINS 8:46-48)

When the ACLU challenged the Arkansas law requiring a balanced treatment of evolution and creation-science, they based their argument on the claim that since creation-science got its inspiration from statements in the Bible, it must be religious. The judge followed the same line of thought, and ruled that the fact that creation-science supposes a Creator, makes it religious and therefore unconstitutional.

This petition arose from a misunderstanding of the meaning of creation and creation-science, and their relation to religion. According to Funk and Wagnall's Dictionary, religion is "a belief binding the spiritual nature of man to a supernatural being." Creationism, as a religious dogma, involves, of course, belief in God as the Creator. But creation-science does not do this. Why? That is what we wish to explore.

Millions believe, and have believed for thousands of years, that "in the beginning God created the heaven and the earth" (Genesis 1:1). And these millions are not always ignorant; they have included some of the keenest minds. Therefore it is not reasonable for anyone who may not believe in a Creator to deny the *possibility* that the creationists *might* be right. Once it is admitted that such an origin is within the bounds of possibility, it is only just and fair to investigate the matter, and to see if the facts of science might perhaps fit the creation model as well as, or better than the evolution model.

By *model* we mean a set of criteria by which we judge which mode of origin seems to be the most likely. Evolutionists set up an evolution model, around which they gather an array of scientific data that they feel support their concept of a slow, gradual development of life on the earth. Creationists set up the model around which they arrange the facts of science that they feel lend support to the theory of origin by supernatural intervention.

Correlation of scientific facts with the two models does not mean that one has an obligation to accept either view. One may admit the possibility of direct creation and admit that there is a wealth of facts supporting that concept, and yet not allow these facts to demand that he believe in supernatural origin. He might still believe evolution to be a superior concept.

On the other hand, since many sincere Christians believe in the Creation doctrine, it is only fair that when their children are brought face to face with the question of origins, they should be given a chance to know the facts on both sides of the question, and to make up their own minds as to which concept is the most satisfactory.

Both evolutionists and creationists freely admit that their views cannot be proved scientifically. Outstanding evolutionists declare without hesitation that evolution is a "way of thinking," but that the facts of science cannot prove that this way is right. The same is true for creation. Creation-science organizes the facts around the creation concept, but that cannot prove this concept to be true. All that can be done is to present the scientific evidence, and leave every individual to draw his own conclusions.

Parents rightfully object to the procedure in the public schools of presenting only one side of the question. They demand that their children be shown that there is more than one possible mode of origin of the earth and its life.

To present to the children the evidence that creation scientists have gathered in support of the creation concept *is not religious*. It is simply a study of evidences that creationists believe support the concept of origin by creation. Of course there has to be a supernatural Being to perform the act of creation, but a mere study of the evidences for this mode of origin does not demand belief in God as the Sovereign of one's life. The religious aspect of the case is another matter.

In conclusion, therefore, when the ACLU or any scientists or anyone else claim that presenting a "balanced treatment" of the two views regarding the origin of the earth and its life is religion, they are confusing religion with a mere factual presentation of the evidence bearing on the two different concepts of origin. It is only fair and just that both sides of the question should be given in an honest, open consideration, and that the children be left free to accept whichever view they feel is most satisfactory. They should not be expected to accept as truth what is only theoretical. Theory may be debatable; but everyone has a right to his own convictions, a right no one can deny. A fair presentation of both sides of the question in no way demands nor forbids a religious view.

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ARTICLES

STRATIGRAPHIC DISTRIBUTION OF VERTEBRATE FOSSIL FOOTPRINTS COMPARED WITH BODY FOSSILS

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WHAT THIS ARTICLE IS ABOUT

Fossil vertebrate footprints are distributed through much of the geologic column. Reptile and amphibian footprints are most abundant and diverse in Permian through lower Jurassic rocks. At the end of the lower Jurassic there is a sharp drop in diversity, and essentially the only footprints found in upper Jurassic and in Cretaceous rocks represent a few types of large dinosaurs. Vertebrate footprints are rare in the lower Tertiary, but mammal and bird tracks are more common in upper Tertiary rocks. The distribution of reptile and amphibian fossil footprints in the geologic column differ sharply from the distribution of reptile and amphibian fossil bones. Why are reptile and amphibian tracks so rare in upper Mesozoic and Tertiary deposits, in which the corresponding bones are abundant? It is suggested that these data are explained most naturally by an earth history model which includes a worldwide flood.

Fossil skeletons contain a wealth of information about animals that have become extinct long ago. If most of he skeleton is available, the general structure and appearance of the animal can be reconstructed with reasonable accuracy. From the characteristics of the teeth we can deduce something about the food habits of the animal. Bones and teeth can even provide much information beyond that, but can we be sure that the animal lived and died at the place where we found its fossil bones? In many cases the answer is no. When an animal dies its bones may be scattered by scavengers. If it dies near water it may be washed far downstream, or it may float in a body of water for some time before it sinks and is buried (Behrensmeyer & Hill 1980, Schafer 1972). After it is buried it may still not be able to rest in peace. At some later time the sediments in which it is buried may be eroded out, and the bones and sediments may be washed down to another basin and deposited again.

An animal's footprints in the mud cannot go through any of these processes and still be preserved. Consequently when we find a fossil animal footprint we know that an animal walked on that very spot at some time in the distant past. This is one of the characteristics of fossil footprints that makes them helpful in analyzing the history of life on earth. The study of fossil footprints and other fossilized evidence of animal behavior is called ichnology, and each type of footprint, believed to represent the tracks of one species of animal, is given a genus and species name and is called an ichnospecies.

METHODS

We quantitatively analyzed the stratigraphic distribution of fossil vertebrate footprints as revealed by data from about 800 published papers and from additional specimens in the American Museum, U.S. National Museum, Yale University Peabody Museum, and the Raymond Alf Museum. Much of the published footprint literature dates from the 19th and early 20th century, and contains considerable duplication — several different workers giving different names to the same type of fossil tracks. As far as possible we avoided this excess of ichnospecies for reptiles and amphibians by following the taxonomy of Haubold's (1971) taxonomic revision, supplemented by more recent papers.

There is a large degree of uncertainty concerning the number of species of birds and mammals represented by fossil footprints, because of the difficulty of accurate identification and the lack of any comprehensive taxonomic study. Consequently in our graphs of bird and mammal footprint diversity we indicate maximum and minimum diversity that can be derived from the literature plus observed museum specimens.

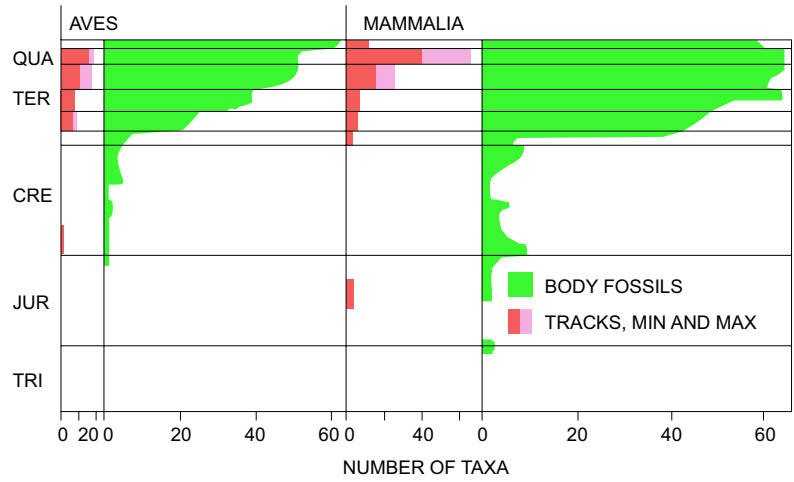
In addition to the factors noted above, there are likely to be many undescribed specimens scattered in various museums that we have not seen. However, the sample reported here seems to be adequate to demonstrate reliable trends in distribution and diversity. The patterns illustrated in this paper were evident early in the data collection process, and further literature and museum study increased the numbers of taxa, but did not significantly change the relative trends.

We compared the diversity of fossil footprints with diversity of body fossils (bones and teeth) at successive stratigraphic levels. The body fossil data are from Harland (1967).

COMPARATIVE DIVERSITY OF FOOTPRINTS AND BODY FOSSILS

Overall distribution of bird and mammal footprints correlates well with the distribution of bird and mammal body fossils (Figure 1). Mammal

FIGURE 1. Comparison of diversity of fossil footprints and body fossils of birds and mammals. Footprint diversity is given in number of ichnospecies. Various taxonomic levels are represented in the body fossil data (from Harland 1967), with families being most common. Maximum and minimum figures for the number of footprint taxa indicate the range of uncertainty resulting from the incomplete taxonomic information for many of these fossils.



footprints and bones are both most abundant in upper Tertiary deposits. The mammal footprint fauna includes one small mammal taxon in the Jurassic and one in the Miocene or Pliocene. The other mammal tracks are predominantly carnivores, ungulates (hoofed animals), and elephants. Bird footprints are never very diverse, and they are nearly limited to Tertiary deposits. The bird footprint fauna is dominated by shore bird types and large ground-dwelling birds. However, many are just identified in the literature as “bird tracks.”

In contrast to the bird and mammal footprints, the stratigraphic distribution pattern of amphibian and reptile footprints is very different from the distribution of body fossils (Figure 2). Amphibian footprints are rare after the early Permian, and reptile footprints, with the exception of dinosaur footprints, which are the most diverse and conspicuous group of tracks,

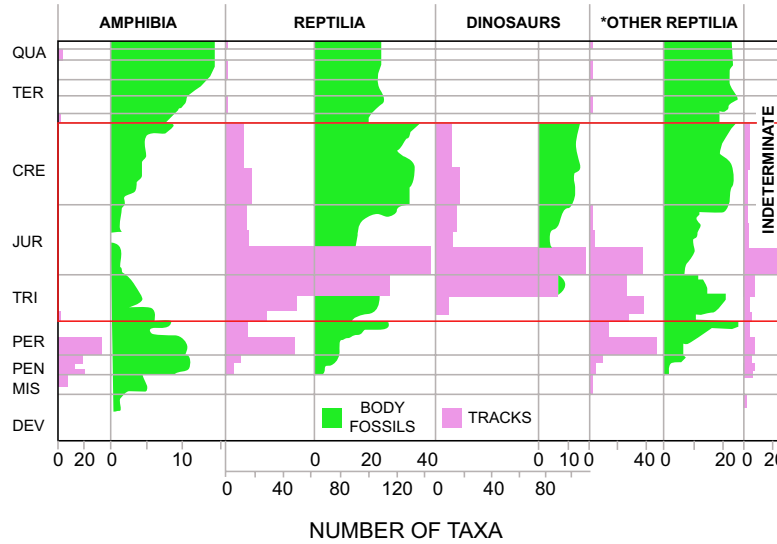


FIGURE 2. Comparison of diversity of fossil footprints and body fossils of amphibians, all reptiles, dinosaurs, and (*) reptiles exclusive of dinosaurs, and of indeterminate tetrapod footprint taxa. Footprint diversity is given in number of ichnospecies. Various taxonomic levels are represented in the body fossil data (from Harland 1967), with families being most common.

are most abundant in late Triassic and early Jurassic rocks (Figure 2). The only Cretaceous reptile footprints identified in the literature are about a dozen types of large dinosaur footprints. In contrast, amphibian and reptile body fossil diversity is greatest in the Cretaceous and Tertiary, when corresponding footprints are rare or nonexistent.

CONCLUSIONS

If the geologic column represents sediments that have accumulated over many millions of years, and the fossils from each geologic period are the remains of animals living in successive time periods, it would be reasonable to expect that the stratigraphic patterns of footprint diversity should roughly parallel the patterns of equivalent body fossil diversity — the periods with the most kinds of dinosaur bones should have the most kinds of dinosaur tracks, for example. The bird and mammal fossil record fits that expectation quite well, but the reptile and amphibian record definitely does not. We will discuss two approaches to explaining this discrepancy.

The first approach assumes that much of the geologic column was deposited during a global flood. This model suggests that during the early

to middle part of the flood large numbers of amphibians and reptiles were moving about, and thus producing footprints. Later during the flood (upper Jurassic and Cretaceous) there were very few live amphibians or reptiles to produce footprints, except for the large dinosaurs. During the Cretaceous when the only footprints preserved were the large dinosaur tracks, there were many amphibian and reptile bodies that were being buried to produce the abundant Cretaceous body fossils. During the Cenozoic almost no amphibian or reptile footprints were preserved.

This flood model suggests that during the flood the birds and mammals were in the uplands, away from the depositional basins, because of ecological differences and/or their more adaptable behavioral response to the unusual biological crisis caused by the flood. Consequently they left almost no footprints. This model further suggests that the upper Tertiary footprints were formed after the flood when geological processes were more like those observed today.

If this flood model is correct, and the birds and mammals were living contemporaneous with the Paleozoic reptiles, why aren't there at least a few bird or mammal tracks in Paleozoic sediments? It appears that there

FIGURE 3. Unidentified, bird-like fossil footprint from Paleozoic strata. A trackway from the Carboniferous of Nova Scotia (after Sternberg 1933).

may be a few. In carboniferous deposits in Nova Scotia tracks were found that "superficially ... resemble the tracks of some of the wading birds, but of course there is little probability of their having been made by birds" (Sternberg 1933) (Figure 3). If these tracks had been found in Cenozoic deposits it seems likely that they would have been described as bird tracks. Another interesting track was found in the Permian Hermit Shale of the Grand Canyon (Gilmore 1927). It looks precisely like a bird

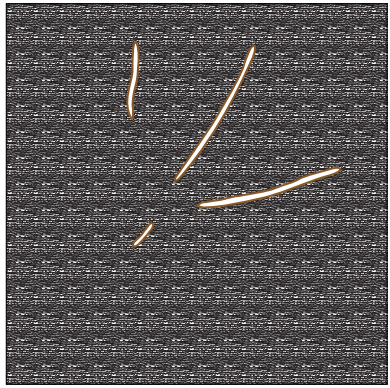


FIGURE 4. Unidentified, bird-like fossil footprints from Paleozoic strata. A track from the Permian Hermit Shale of the Grand Canyon (after Gilmore 1927).

track, but since birds are not thought to have evolved until the Mesozoic, this Permian track is just listed as an "unidentified track" (Figure 4).

Another question that arises is why reptile and amphibian footprints are so abundant in Paleozoic and lower Mesozoic sediments and so rare in recent sediments, since reptiles and amphibians are common today. Part of the answer could be that there were many types of reptiles and amphibians living earlier in earth history that no longer exist. We would suggest that another part of the answer is that the rapid sedimentary processes during the global flood were usually conducive to the burial and preservation of footprints before they were destroyed by weathering processes. Thus during the flood there would have been a great diversity of reptiles and amphibians making tracks under conditions uniquely suitable for preserving those tracks. In more recent times, with most of the Mesozoic trackmakers extinct and conditions not as suitable for preserving footprints, reptile and amphibian footprints seem to be seldom preserved.

The second approach to explaining these data is based on the conventional geologic model of sedimentation over long ages of time, coincident with the evolution of animal life. This model must assume that the stratigraphic distribution of amphibian and reptile fossil footprints is an artifact, and does not at all reflect the actual relative amount of animal activity during different geologic periods. Several factors have been suggested as potential contributors to producing this artifact:

1) In Mesozoic and Tertiary deposits containing larger, more conspicuous tracks, smaller tracks may be more likely to be overlooked, and not collected. This argument is weakened by the fact that small reptile tracks are abundant in Triassic and Early

Jurassic rocks, when dinosaur tracks are also at their peak of abundance. It also does not explain the near absence of amphibian and reptile tracks in Early Tertiary deposits, which have no dinosaur tracks and few bird and mammal tracks to divert attention from the smaller tracks.

2) Smaller, shallower tracks would be destroyed more easily by weathering or by slumping of waterlogged sediment than the larger tracks. However, this factor should have affected the entire geologic record, not just the post-Jurassic deposits.

3) Older rocks tend to be well-indurated (firmly cemented), while younger rocks are more likely to be relatively unconsolidated, and thus less suited to preserve footprints. However, many of the Cenozoic footprints are quite well-preserved, including delicate bird tracks. Also this factor does not explain the sharp drop in footprint diversity after the lower Jurassic.

These factors may play a role in biasing the published footprint record, but they do not seem adequate to explain the sharp contrast between the abundant footprints of amphibians and small reptiles in Permian to Lower Jurassic rocks, and their near absence in younger rocks.

The only explanation that this model provides for the bird-like Paleozoic tracks is that they must have been made by unknown types of Paleozoic reptiles with bird-like feet.

We conclude that these data are most easily explained by the global flood model. Does this mean that they should be taken as proof of the flood? No, it does not mean that. Science rarely makes its decisions on something that could be called proof, but it makes its decisions on the perceived weight of evidence. This is particularly true when studying unobservable events from the past history of our earth. Our footprints can neither prove nor disprove the flood model. The question is, into which model do the data make the most natural fit? It appears that the footprint data make a very natural fit with a global flood model.

LITERATURE CITED

Behrensmeyer AK, Hill AP. 1980. Fossils in the making. Chicago: University of Chicago Press. 338 p.

Gilmore CW. 1927. Fossil footprints from the Grand Canyon. Second Contribution, Smithsonian Miscellaneous Collections 80(3):1-78.

Harland WB, editor. 1967. The fossil record. Geological Society of London. 827 p.

Haubold H. 1971. Ichnia amphibiorum et reptiliorum fossilum. In: Kuhn O, editor. Handbuch der Palaoherpetologie, Pt. 18. Stuttgart and Portland, OR: Gustav Fischer Verlag. 124 p.

Schafer W. 1972. Ecology and palaeoecology of marine environments. Chicago: University of Chicago Press. 568 p.

Sternberg CM. 1933. Carboniferous tracks from Nova Scotia. Geological Society of America Bulletin 44:951-964.

ARTICLES

THE GENEALOGIES OF GENESIS 5 & 11: A STATISTICAL STUDY

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and

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WHAT THIS ARTICLE IS ABOUT

The geneaologies of Genesis 5 and 11 contain information on birth- and death-dates of a number of patriarchs. It is possible from this information to compute the lifespan of these individuals. When the ages at death are examined for this group, it is found that they present a nonrandom picture in that certain death ages arise with greater frequency than predicted. These results are compared with current demographic data.

For centuries the genealogies of Genesis 5 and 11 have provided Christians with a chronological framework for history between creation and the time of Abraham. A unique feature of these genealogies is that they record the age of each patriarch at the birth of his presumably first-born son and the number of years the patriarch lived after that event. Genesis 5 additionally records the age of death of each patriarch, this value being the sum of the first two numbers given. In view of these numerical data Genesis 5 and 11 have been called "chronogenealogies" (Hasel 1980a, 1980b).

A persistent use of the Genesis age data has been as a basis upon which to assign a date or an approximate time for the creation. The best-known attempt of this kind was by Archbishop James Ussher in *Annales Veteri Novi Testimenti* (1650-54). In this work Ussher concluded that creation had occurred during 4004 B.C. While this date was later refined and modified by other scholars, it was to remain the generally accepted date of creation among Christians for two or more centuries (White 1896, p 249-256).

More recently extensive scientific evidence (Hare 1974, 1979; Abelson 1982) has convinced many Christians that the Genesis age data are unreliable for purposes of chronology (Warfield 1911, Geraty 1974, Horn

TABLE 1. Pregenerative and postgenerative years of 38 fathers of staff members at Andrews University.

father no.	pregenerative years	postgenerative years
1	28	59
2	26	3
3	27	44
4	35	38
5	27	52
6	41	38
7	26	21
8	26	50
9	31	23
10	22	16
11	34	55
12	28	54
13	25	29
14	28	39
15	27	43
16	24	37
17	22	31
18	29	44
19	34	52
20	29	42
21	25	39
22	24	35
23	35	50
24	23	52
25	25	32
26	20	49
27	29	44
28	21	61
29	29	26
30	27	37
31	36	50
32	33	9
33	26	48
34	29	14
35	22	43
36	24	35
37	26	49
38	26	6

1979). However, other Christians argue that regardless of the scientific objections, the most apparent interpretation of scripture (in this case that the genealogies provide an adequate basis for construction of a pre-Abrahamic chronology) stands authoritative (Brown 1977, Hasel 1980b).

With these contrasting opinions in mind we evaluate the Genesis age data without recourse to extrabiblical chronological information. We do not attempt to completely resolve the genealogy/chronology problem, but only demonstrate that these age data form a significantly nonrandom distribution in contrast to an expected random distribution of numbers.

METHODS AND RESULTS

We hypothesized that for any random distribution of pregenerative years (number of years prior to the birth of his first-born son) and postgenerative years (number of years he lives following the birth of his first-born son), the last digits of these values form a random group of numbers. To test this hypothesis questionnaires were sent to staff members of Andrews University asking for birthdates of their fathers and their fathers' first-born sons, and their fathers' death dates.

Thirty-eight questionnaires were returned with complete information. Pregenerative and postgenerative years were calculated for each of the 38 individuals represented. To handle fractions of years consistently the age of the individual at his most recent birthday was used (Bogue 1969, p 148).

Table 1 shows the pregenerative and postgenerative years of each individual in the control. The frequencies of digits "0" to "9" used as last

TABLE 2. Frequency distribution of last digits of pregenerative years of the control sample in Table 1. Observed and expected frequencies are not significantly different ($x^2 = 4.38$, d.f. = 9, $P > 0.05$).

last digit	observed frequency	expected frequency
0	1	3.8
1	3	3.8
2	3	3.8
3	2	3.8
4	5	3.8
5	5	3.8
6	7	3.8
7	4	3.8
8	3	3.8
9	5	3.8

TABLE 3. Frequency distribution of last digits of postgenerative years of the control sample in Table 1. Observed and expected frequencies are not significantly different ($x^2 = 2.91$, d.f. = 9, $P > 0.05$).

last digit	observed frequency	expected frequency
0	3	3.8
1	3	3.8
2	5	3.8
3	4	3.8
4	5	3.8
5	3	3.8
6	3	3.8
7	2	3.8
8	3	3.8
9	7	3.8

digits in the pregenerative and postgenerative years, respectively, are shown in Tables 2 and 3. Control frequencies did not vary significantly from expected frequencies (38 numbers / 10 possible last digits = 3.8 in each case) for pregenerative or postgenerative years, confirming our hypothesis that a natural distribution of ages should be random with respect to frequencies of last digits. (Note: The .05 level of significance was chosen for these as well as for the following tests).

Turning to the data from Genesis 5 and 11 (Table 4) we again hypothesized that the pregenerative and postgenerative year values should be random with respect to last digits. However, the frequencies of last

TABLE 4. The pregenerative and postgenerative years of the 20 patriarchs listed in Genesis 5 and 11 (Masoretic Text).

patriarch	pregenerative years	postgenerative years
Adam	130	800
Seth	105	807
Enosh	90	815
Kenan	70	840
Mahalalel	65	830
Jared	162	800
Enoch	65	*300
Methuselah	187	782
Lamech	182	595
Noah	500	450
Shem	100	500
Arphaxad	35	403
Shelah	30	403
Eber	34	430
Peleg	30	209
Reu	32	207
Serug	30	200
Nahor	29	119
Terah	70	135
Abraham	100	75

*"He [Enoch] was not, for God took him." Genesis 5:24 (KJV)

digits of both pregenerative and postgenerative ages show significant deviations from expected frequencies (20 numbers / 10 possible last digits = 2 in each case), implying that the data are biased (Tables 5 and 6).

An examination of Table 5 reveals that out of the 20 pregenerative ages represented, 10 have as their last digit a "0" and are thus multiples of 10. The frequency of digit "0" varies most from the expected frequency of 2 and thus contributes most to the large chi-squared value. Ages with the last digit of "5" have the second highest frequency of 4. Remaining frequencies are distributed among four other digits. Digits "1," "3," "6,"

TABLE 5. Frequency distribution of last digits of pregenerative years of the patriarchs listed in Genesis 5 and 11 (Table 4). Observed and expected frequencies are significantly different ($x^2 = 34.25$, d.f. = 9, $P < 0.0001$).

last digit	observed frequency	expected frequency
0	10	2
1	0	2
2	3	2
3	0	2
4	1	2
5	4	2
6	0	2
7	1	2
8	0	2
9	1	2

TABLE 6. Frequency distribution of last digits of postgenerative years of the patriarchs listed in Genesis 5 and 11 (Table 4). Observed and expected frequencies are significantly different ($x^2 = 26.88$, d.f. = 9, $P < 0.005$).

last digit	observed frequency	expected frequency
0	9	2
1	0	2
2	1	2
3	2	2
4	0	2
5	4	2
6	0	2
7	2	2
8	0	2
9	2	2

and “8” are not represented in the distribution. An examination of Table 6 reveals a similar pattern for the postgenerative years.

These analyses are based upon data from the Hebrew Masoretic text. Data from the Greek Septuagint reveal essentially the same pattern.

DISCUSSION

As the above tests reveal, the probability that the Genesis age data represent a random distribution of age values is extremely low. Several reasons for this biased distribution can be postulated.

A. The numbers could have been generated by the writer or compiler of the genealogies to fit a preconceived number pattern. One of the best-known attempts to support this hypothesis was by Cassuto (1961, p 251-254) who showed that each number in Genesis 5 is a multiple of 5 plus 7, the only exception

being the death age of Methuselah which is a multiple of 5 plus 14 (or 2 × 7). He postulated that this numerical series was influenced by the sexigesimal number system. Every 5 years equals 60 months. Multiples of 5 years would then be multiples of 60 months. Additions of 7 to multiples of 5 years would be equivalent to saying "somewhat longer than" the multiple of 5 years. However, there seems to be no rationale for the series of numbers required as multipliers of 5 to arrive at the data, unless it is assumed that the numbers are close to the actual age values for the individuals named. Also, Cassuto's scheme works for all the age values in Genesis 5, but not for all the numbers in Genesis 11. [See Hasel (1980b) for reviews of similar numerical schemes].

B. The numbers could reflect a relationship to the Sumerian King List (Barton 1937, p 264-272; Speiser 1964, p 42), the Ammonite Genealogy of the Hammurapi Dynasty (Malamat 1968, Hartman 1972, Wilson 1975), or other such Middle Eastern lists. On the basis of a number of unique qualities of the Genesis genealogies, Hasel (1978) argued that the appearance of any such relationship is superficial. More recently, however, Walton (1981) has demonstrated a possible numerical link between Genesis 5 and the Sumerian King List.

C. The biased age values may be due to digit preferences by those reporting age data. Demographers have shown that people exhibit preferences for ages having certain terminal digits. For example, single-year-of-age data for the 1960 population of the Philippines shows a strong preference for ages ending in "0," with somewhat lesser preferences for ages ending in "5," "2,'' and "8." Conversely, these data show negative preferences for ages ending in "9," and "1" (Shryock et al. 1971, p 204).

Our analysis sheds no light on which, if any, of the above explanations actually accounts for the data. It is even possible that more than one such explanation applies. The concept of statistical nonrandomness which we are postulating states only that the numbers appear biased, suggesting that the Genesis genealogical age data fail to provide a defensible basis upon which to construct a precise-pre-Abrahamic chronology of the world.

LITERATURE CITED

Abelson PH. 1982. Creationism and the age of the earth. Science 215:119.

Barton GA. 1937. Archaeology and the Bible. Philadelphia: American Sunday School Union.

Bogue DJ. 1969. Principles of demography. NY: John Wiley.

Brown RH. 1977. Radiometric age and the traditional Christian view of time. Origins 4(2):68-75.

Cassuto U. 1961. A commentary on the Book of Genesis. Part 1. Jerusalem: Magnes Press.

Geraty LT. 1974. The Genesis genealogies as an index of time. Spectrum 6(1-2):5-18.

Hare PE. 1974. The age of the earth: how it changed from thousands to billions of years. Spectrum 6(3-4):17-27.

Hare PE. 1979. Geologic time: the scientific evidence and the Genesis record. Spectrum 10(1):12-19.

Hartman TC. 1972. Some thoughts on the Sumerian King List and Genesis 5 and 11b. Journal of Biblical Literature 91:25-32.

Hasel GF. 1978. The genealogies of Gen 5 and 11 and their alleged Babylonian background. Andrews University Seminary Studies 16:361-374.

Hasel GF. 1980a. Genesis 5 and 11: chronogenealogies in the biblical history of beginnings. Origins 7(1):23-37.

Hasel GF. 1980b. The meaning of the chronogenealogies of Genesis 5 and 11. Origins 7(2):53-70.

Horn SH. 1979. Can the Bible establish the age of the earth? Spectrum 10(3):15-20.

Malamat A. 1968. King lists of the Old Babylonian Period and biblical genealogies. Journal of the American Oriental Society 88:163-173.

Shryock HS, Siegel JS, & Associates. 1971. The methods and materials of demography. Vol. 1. U.S. Department of Commerce, Bureau of the Census. Washington DC: U.S. Government Printing Office.

Speiser EA. 1964. The Anchor Bible. Genesis. Garden City, NY: Doubleday.

Walton J. 1981. The antediluvian section of the Sumerian King List and Genesis 5. Biblical Archeologist 44:207-208.

Warfield BB. 1911. On the antiquity and the unity of the human race. The Princeton Theological Review 9(1):1-25.

White AD. [1896] 1960. A history of the warfare of science with theology. Vol. 1. NY: Dover Publications.

Wilson RR. 1975. The Old Testament genealogies in recent research. Journal of Biblical Literature 94:169-189.

ARTICLES

THE TUNGUSKA EXPLOSION OF 1908

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WHAT THIS ARTICLE IS ABOUT

In 1908 a cataclysm occurred in the central Siberian area of Russia. Initial reports described a glowing object in the sky which crashed to the earth and exploded into flames, destroying a large forested area.

A scientific team was sent in 1921 to investigate the phenomenon. Initial theories attributed the event to meteor impact, but subsequent expeditions failed to find evidence to confirm this.

Recently, other theories have been proposed to explain the Tunguska Explosion. These include some serious proposals such as cometary collision, contact with either anti-matter or a black-hole, and a more fanciful idea such as a nuclear device from an extraterrestrial object. The cometary hypothesis appears to be most strongly supported by the physical evidence which includes mode of impact and debris remnants. The anti-matter hypothesis proposes that annihilation occurred when anti-matter came in contact with the atmosphere. A black hole with a mass of approximately 10^{23} grams could also have caused the above event. Supportive evidence for this hypothesis is not complete.

INTRODUCTION

A catastrophe may be defined as a natural event of large magnitude (energy), short duration, wide extent and low frequency. The Tunguska (pronounced: toon-goos'-ka) explosion of 1908 fulfills all five parts of the above definition and can be considered the epitome of a cosmic impact catastrophe. An understanding of this unique event and its origin could provide insight into large ancient asteroidal or cometary collisions with the Earth (e.g., Sudbury and Popigay impact structures) and possible global catastrophic effects (e.g., from flooding, tectonism, volcanism, glaciation and air blast waves). Catastrophism, a doctrine spurned by uniformitarian scientists in the twentieth century, is now being confirmed by events which have occurred in this century.

The scientific interest stimulated by the Tunguska explosion of 1908 has produced enormous speculation and controversy as to its origin. The theories offered by those who have studied the event range from the

realm of science (a meteorite, comet, or nuclear explosion) to the realm of science fiction (a black hole, anti-matter rock, or an alien spacecraft).

Each theory has protagonists promoting and defending their point of view in light of the evidence, yet, because the scientific community did not view the actual event, but only observed the devastating results (it was 19 years after the impact before the first scientist arrived on the scene), each theory contains some speculation.

Before delving into the specifics of each theory, it is important to review the actual facts of the event.

DESCRIPTION OF THE EVENT

The Tunguska explosion occurred on the morning of June 30, 1908 at 7:17 A.M. local time (0h 17m 11s U.T.) in the area of the Stony Tunguska River with the coordinates of the epicenter being 60º55' N, 101º57' E (Krinov 1966). This location is in the central Siberian area of Russia, approximately 1000 km north of the town of Irkutsk and Lake Baikal (Figure 1).

The first report of the explosion was in the Irkutsk paper dated July 2, 1908, published two days after the explosion:

> *... the peasants saw a body shining very brightly (too bright for the naked eye) with a bluish-white light....The body was in the form of 'a pipe', i.e. cylindrical. The sky was cloudless, except that low*

FIGURE 1. Area map of the 1908 Tunguska explosion event. After Sullivan 1979.

> *down on the horizon, in the direction in which this glowing body was observed, a small dark cloud was noticed. It was hot and dry and when the shining body approached the ground (which was covered with forest at this point) it seemed to be pulverized, and in its place a loud crash, not like thunder, but as if from the fall of large stones or from gunfire was heard. All the buildings shook and at the same time a forked tongue of flames broke through the cloud. All the inhabitants of the village ran out into the street in panic. The old women wept, everyone thought that the end of the world was approaching* (Krinov 1966).

S.B. Semenov, an eyewitness in the village of Vanovara about 60 km south of the explosion site, provided excellent information:

> *... I was sitting in the porch of the house at the trading station of Vanovara at breakfast time...when suddenly in the north...the sky was split in two and high above the forest the whole northern part of the sky appeared to be covered with fire. At that moment I felt great heat as if my shirt had caught fire; this heat came from the north side. I wanted to pull off my shirt and throw it away, but at that moment there was a bang in the sky, and a mighty crash was heard. I was thrown to the ground about three sajenes [about 7 meters] away from the porch and for a moment I lost consciousness....The crash was followed by noise like stones falling from the sky, or guns firing. The earth trembled, and when I lay on the ground I covered my head because I was afraid that stones might hit it* (Krinov 1966).

Through comparison of old seismograms of the Tunguska event and seismograms of the Novaya Zemlya and Lop-Nor nuclear-weapon tests, Ben-Menahem (1975) determined that the Tunguska projectile had "the effects of an Extraterrestrial Nuclear Missile of yield 12.5±2.5 megatons." This is approximately 3 orders of magnitude greater than the Hiroshima A-bomb and about one-fifth the energy of the largest hydrogen bomb explosion (McWhirter & McWhirter 1974). The height at which the explosion occurred was estimated to be approximately 7.5 km, with a total energy release of approximately 3×10^{23} ergs, 5×10^{18} ergs of which was changed into seismic energy (Ben-Menahem 1975). More energy went into the air blast than the earthquake. F.J.W. Whipple (1930) estimated the energy of the air blast wave to be 3.2×10^{20} ergs. The seismic activity measured on the Richter scale was 5.0; and the air compression wave went twice around the world, according to recordings at meteorological stations.

The projectile traveled in a southeast to northwest direction with a 60° azimuth, according to Fesenkov (1966) who made use of eyewitness accounts and an inspection of the radial symmetry of the trees at the explosion site. This direction was probably immediately prior to the

explosion; however, there are conflicting reports as to the actual line of flight (discussed later when dealing with the causal theories of the Tunguska explosion).

The temperature at the center of the fireball was estimated by one source to be up to 30 million degrees Fahrenheit (LeMaire 1980). Some storage huts in the nearby vicinity of the focus were found devastated by fire and the silverware and tin utensils within were deformed by intense heat. “Preceding the front of the shock wave there arises a heated zone whose radiating surface area is far larger than that of the shock wave itself” (Stanyukovich & Bronshten 1961). This is substantiated by Semenov who first felt the heat wave, then was thrown to the ground by the air shock wave.

The inhabitants of Central Siberia saw the fall and explosion of the meteorite over an area with a radius of 600-1000 km. Eighty million trees in the taiga (coniferous forest) were uprooted and blown down for a radius of 30-40 km (F.J.W. Whipple 1934). Some trees on the leeward side of hills were somewhat protected, yet still had their branches broken off and bark stripped to leave them standing naked, resembling telegraph poles.

After the impact, forest fires broke out and ravaged an area of 10-15 km in radius (Astapowitsch 1934). Krinov (1960) describes these forest fires as being unnatural. The trunks of trees and their branches were not burned through but were only scorched on the surface. Apparently a searing heat wave caused the scorching, yet a conventional forest fire was not present. Some trees were entirely scorched in standing position, but were bent away from the epicenter. In normal fires in the Vanovara area, trees remained vertical with fire damage occurring at the lower sections while the tree tops remained untouched. It is also interesting to note that some trees which had been stripped of bark showed no signs of scorching (Krinov 1963).

The nights following the Tunguska meteorite were anomalous. Abnormally bright nighttime illumination was reported throughout Europe and Western Russia to the extent that people could read news print at midnight without artificial lighting (Krinov 1966). The cause of the anomalous illumination of the night sky is discussed later.

The Russian government made no immediate attempt to investigate the event, due to its internal political upheavals at the time of the explosion, and because the incident occurred in such a desolate area without harming anyone. In 1921, the country’s fledgling Academy of Sciences appointed L.A. Kulik, a science worker at their Mineral Museum, to head a team of

investigators who would travel through Siberia with the purpose of gaining information concerning meteorites from the local populace.

Kulik collected newspaper articles and questioned eyewitnesses in his attempt to pinpoint the time and location of the Tunguska fall. However, due to the lateness of the year (late autumn), the expedition did not attempt to maneuver through the taiga to investigate the impact site. In his four succeeding expeditions covering 1927-1939, Kulik obtained many sensational eyewitness accounts concerning the Tunguska meteorite.

In a local newspaper, the reporter described the bolide (a bright, detonating fireball) itself as a "body of fiery appearance" and a tail (probably a dust trail) as a "radiance." Other articles described "a fiery body like a beam shot from south to north west" with "a tongue of fire" appearing in place of the fiery bolide (Krinov 1966).

One witness to the event, a train engineer, said he felt "a kind of strong vibration of the air," then heard a "roar" which he believed to be "an earthquake or some other natural phenomenon," and which frightened him to the extent that he stopped the train thinking that it had gone off the rails (Krinov 1966). In fact, when he arrived at the station, he asked for an inspection to locate the problem on the train.

Another eyewitness reported that a thousand reindeer owned by the Evenki people were killed and many carcasses burned by the ensuing forest fire. It was one of the Evenki people, Okhchen, who eventually led Kulik to the impact site (Krinov 1966).

Potapovich, who served as a guide for Kulik, told Kulik that "his brother's hut was flattened to the ground, its roof was carried away by wind [apparently some sort of tent structure], and most of his reindeer fled in fright. The noise deafened his brother and the shock caused him to suffer a long illness" (Krinov 1966). Potapovich's brother lived on the Chambe River located just outside the limit of the tree damage (Figure 2).

In the trading station at Vanovara, Kosolapov reported to Semenov (previously mentioned) "a fierce heat scorched my ears. I held them, thinking the roof was on fire...." Windows broke and the oven door on Kosolapov's stove flew off and landed on the bed across the room (Krinov 1966).

A farmer in the Kezhma area (about 200 km south of the impact site) related the following:

> *At that time I was ploughing my land at Narodima (6 km to the west of Kezhma). When I sat down to have my breakfast beside my plough, I heard sudden bangs, as if from gun-fire. My horse fell on its knees. From the north side above the forest a flame shot up. I thought the enemy was firing, since at that time there was talk of war. Then I saw that the fir forest had been bent over by the wind*

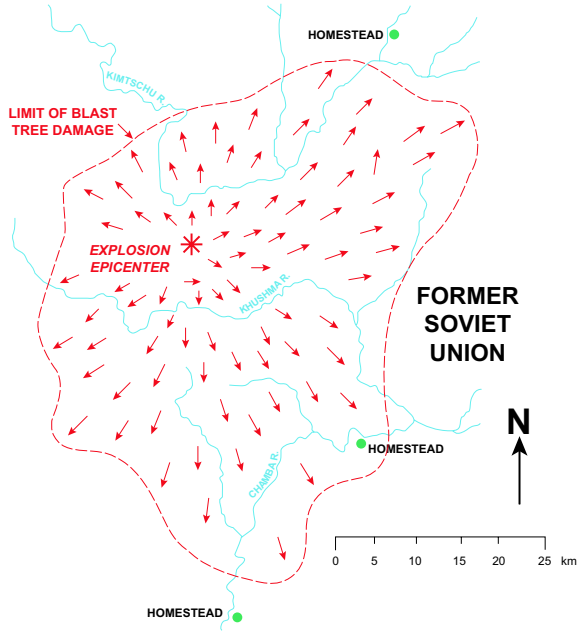

FIGURE 2. Map depicting fallen tree pattern (arrows represent direction) from explosion of 1908. This is a closeup of the impact site of Figure 1. After Sullivan 1979 and Krinov 1966.

> *and I thought of a hurricane. I seized hold of my plough with both hands, so that it would not be carried off. The wind was so strong that it carried off some of the soil from the surface of the ground, and then the hurricane drove a wall of water up the Angara [a seiche perhaps]. I saw it all quite clearly, because my land was on a hillside* (Krinov 1966).

After having obtained interesting and tantalizing eyewitness and newspaper accounts during his 1921 expedition, Kulik was anxious to reach the Stony Tunguska River region to locate the impact site of what he ascertained to be a meteorite. In 1927 Kulik was able to return to search for the Tunguska meteorite. After spending some time in Vanovara, Kulik made arrangements for Evenki hunters to guide his party to the impact site. Reaching the explosion site was an extremely arduous task.

The spectacle that confronted Kulik as he stood on a ridge overlooking the devastated area was overwhelming. He saw an area where trees up to three feet in diameter had snapped like toothpicks, were uprooted and strewn across the landscape. Upon closer examination, he located holes which he erroneously concluded were meteorite holes; however, he did not have the means at this time to excavate them.

During Kulik's three succeeding expeditions to determine the cause of the Tunguska event, his meteorite theory received no substantiating evidence. Despite tremendous hardships caused by the searing heat of summer, the coldness of winter and insufficient funds for supplies and equipment, Kulik and his party persevered to obtain evidence relating to the Tunguska explosion. Throughout his investigations and those of others covering a total of fifty years, there was no evidence of impacting iron, no impact craters, no meteorite remnant and no strewn field of particles. The only evidence left by the Tunguska bolide was toppled and burned trees. The holes that Kulik thought to be from meteorites proved to be natural depressions.

THE COMET THEORY

Due to a lack of evidence for the meteorite theory proposed by Kulik, other theories were proposed to explain the Tunguska event. Various authors (Cowan, Alturi & Libby 1965; Krinov 1960, 1966; Hughes 1976) have designated F.J.W. Whipple (1930-1934) as the initiator of the cometary hypothesis. Whipple proposed "that the meteor was essentially a small comet and that the tail of the comet was caught by the atmosphere" (F.J.W. Whipple 1934). However, in the same article only two paragraphs later, he stated: "I do not feel much confidence in this hypothesis."

A model of a comet nucleus is offered by F.L. Whipple (1950). This model consists of a large dirty snowball composed of dust and rock interspersed with water, methane and ammonia ices. Krinov (1963) and Hughes (1976) utilize this model to support their belief that the Tunguska projectile was a small comet. Yet, interestingly enough, F.L. Whipple (1975) questions such a possibility:

> *It appears unlikely, therefore, that the Tunguska explosion was produced by a bona fide active comet a hundred or so meters in dimension....more likely, however, the Tunguska object was an inactive, low-density, friable body....There is no reason to suspect that it was interstellar.*

It is an understatement to suggest that the origin of the Tunguska explosion is controversial.

There are various elements of the cometary hypothesis that explain the eyewitness accounts and the associated physical data. Probably the most important concept supporting the comet hypothesis is the nature of flight of the Tunguska fireball. Fesenkov (1962) claims, "According to all evidence, this meteorite moved around the Sun in a retrograde direction, which is impossible for typical meteorites...." Fesenkov notes that meteorites rarely hit the earth in the morning, because the morning side

faces forward in the planet's orbit. Usually the meteorite overtakes the earth from behind, on the evening side. However, comets have a wide range of orbits and velocities and could collide with the earth on the morning side, hitting head on at a velocity of approximately 60 km/sec (130,000 mph or Mach Number 180). Fesenkov (1966) demonstrates that the direction and angle of the attack toward the earth was from behind the sun; thus, the glare of the sun prevented sighting.

In addition to the evidence of the bolide's retrograde orbit was the brilliant night sky observed in Europe and Western Russia. Fesenkov (1966) points out that there was no anomalous glow on June 30, 1908, but that there was such a glow on July 1, 1908. There was no unusual illumination reported in the U.S., the southern hemisphere or in countries east of the explosion site. "The most probable explanation for the anomalously bright nights associated with the Tunguska meteorite fall would be that the meteorite was actually a little comet with a dust tail pointing away from the sun" (Fesenkov 1966). "These properties of the [dust] distribution can be explained if the cloud of cosmic particles was associated directly with the nucleus of the Tunguska comet, and pointed in a direction away from the sun" (Fesenkov 1966). This is a plausible explanation in regard to the brilliant nights observed in Europe. No other theory offered adequately explains this anomaly.

More evidence supporting a comet came to light in 1962 when technicians discovered microscopic pellets of magnetite and silicate globules, thought to be extraterrestrial, in soil samples from the Tunguska explosion site. A double spherule consisting of a magnetite pellet inside a larger silicate shell is unique to this event and thought to be the result of "rapid condensation of incandescent gas upon cooling" (Fesenkov 1966).

The final piece of evidence for the Tunguska comet explains physical observations satisfactorily. According to Whipple's model described above, the comet probably exploded prior to impact with evaporation of the components thereby leaving no remnant. By comparing the records of air waves from various sources, Ben-Menahem (1975) deduced that the height above ground where the explosion occurred was 7.5 km. There appear to have been three radiant centers made by fallen trees, according to Fesenkov (1966), which would indicate multiple explosions. F.J.W. Whipple (1930) noted that the air wave recorded on the microbarographs appears to indicate two types of waves; one generated by penetration of the object into the atmosphere, and the other generated by the explosion or explosions.

THE NUCLEAR THEORY

The similarity between the Hiroshima A-bomb devastation and the mysterious Tunguska effects gave rise to the notion that the 1908 event was caused by a man-made nuclear bomb. The fictional writings of the Soviet author Alexander Kazantsev in 1946 were the first to pick up the idea which scientists later considered. A prominent Soviet scientist, Alexei Zolotov, after a 17-year investigation, expanded the nuclear explosion theory by supposing it was caused by the visit of an alien spacecraft (TASS news release, mid-October 1976). According to Zolotov, a spaceship controlled by "beings from other worlds" may have caused the 1908 explosion. He imagined a nuclear-propelled craft that exploded accidentally due to a malfunction. Zolotov also admits to problems with the theory, realizing that safety devices would probably prevent such a mishap, and observing that the actual area of destruction was "an amazing demonstration of pinpoint accuracy and humanitarianism."

T.R. LeMaire, a science writer, continues this thought, by suggesting "The Tunguska blast's timing seems too fortuitous for an accident" (LeMaire 1980). He claims that a five-hour delay would make the target of destruction St. Petersburg, adding that a tiny change of course in space would have devastated populated areas of China or India.

> *Can we assume that the 'pilot' chose a cloudless day with excellent visibility from aloft to assure a safe drop? American Military strategy called for identical weather conditions; for a perfect strike on Hiroshima's industrial heart, the Enola Gay's bombardier was forbidden to release through a cloud cover: he had to see the target below. To maximize blast destruction, minimize radiation perils: the bomb was set to explode at a high altitude rather than against the ground. Similarly, the Siberian missile detonated high in the air, reducing or even eliminating fallout hazard* (LeMaire 1980).

LeMaire maintains the "accident-explanation is untenable" because "the flaming object was being expertly navigated" using Lake Baikal as a reference point. Indeed, Lake Baikal is an ideal aerial navigation reference point being 400 miles long and about 35 miles wide. LeMaire's description of the course of the Tunguska object lends credence to the thought of expert navigation:

> *The body approached from the south, but when about 140 miles from the explosion point, while over Kezhma, it abruptly changed course to the east. Two hundred and fifty miles later, while above Preobrazhenka, it reversed its heading toward the west. It exploded above the taiga at 60º55' N, 101º57' E (*LeMaire 1980).

Scientists who have reviewed eyewitness reports are not convinced of any course changes as the brilliant object traversed the sky. Neither are

scientists convinced of nuclear temperature. Brown & Hughes (1977) state that a temperature of two million degrees Celsius (the supposed temperature obtained if all the kinetic energy of the comet, 3×10^{23} ergs, was changed into heating the component parts) is "substantially subnuclear." Furthermore, it is entirely fallacious to suppose that the sub-nuclear temperatures cannot produce nuclear effects...." They suggest that a thermo-chemical explosion could produce the effects of a nuclear bomb.

THE ANTI-MATTER HYPOTHESIS

The anti-matter hypothesis is offered by Cowan, Alturi & Libby (1965) and supported by Gentry (1966). This theory proposes that an anti-rock composed of anti-matter was annihilated in the atmosphere above the Tunguska explosion site and caused the observed damage. Cowan et al. postulated that such an explosion would cause an increase in atmospheric radiocarbon. Upon analysis of C-14 content in a 300-year-old Douglas fir from Arizona, they believe that they obtained increased radiocarbon for the time of the event. However, the data presented in their paper appear to lack statistical significance for support of their conclusions. Furthermore, careful C-14 measurements of a tree nearer the blast fail to show an increase in 1909 (Lerman et al. 1967).

THE BLACK-HOLE HYPOTHESIS

The last theory as to the cause of the Tunguska event is proffered by Jackson & Ryan (1973). They suggest that a black hole with a mass of 10^{22} to 10^{23} g would have the necessary energy (10^{23} ergs) to have caused the Tunguska destruction. Jackson & Ryan maintain that the black hole would cause the destruction as it pierced through the earth with the ease of cutting soft butter, exiting the earth through the Atlantic Ocean.

Beasley & Tinsley (1974) refute the black-hole theory because the microbarographs that recorded the air waves of the explosion did not record air waves of an exit point in the Atlantic Ocean. This is vital to the black-hole theory because the exit of the black hole from the earth would be expected to exhibit devastating effects similar to those at its entrance.

The black-hole concept also does not explain the magnetite and silicate globules found in the explosion region, nor does it account for the anomalously bright night sky observed over Europe. Beasley & Tinsley (1974) conclude, "All the evidence favors the idea that the impact which caused the Tunguska catastrophe involved a body with characteristics like a cometary nucleus rather than a black hole."

CONCLUSION

The Tunguska explosion is indeed unique and mysterious. Of the possible causes it appears that the present consensus favors the comet hypothesis. However, suggesting a consensus is quite tenuous. Though the other theories have plausibility, they have difficulty explaining the observed event and the resulting physical evidence. Making use of the cometary hypothesis allows for the following probable scenario.

Above central Siberia on June 30, 1908, at approximately 7:17 AM local time, a small comet entered the atmosphere from behind the sun and moved in a southeast to northwest direction. The comet was composed of about 30,000 tons of water, methane, and ammonia ice with traces of silicates and iron oxides. Penetrating the atmosphere at approximately 60 km/sec (130,000 mph), the object created an intense shock wave which wrapped tightly around its nose. As it descended that sunny morning, its nucleus exploded (possibly 3 times) approximately 8 km above the Earth's surface. A huge black cloud immediately appeared following the explosion which released 10^{23} ergs of energy. A heat wave with a temperature of approximately 16.6 million degrees Celsius at the focus was generated that had a tree-scorching effect for a radius of 15 km. The heat wave was followed by air shock waves which disfigured or toppled 80 million trees occupying approximately 8000 km^2 of Siberian taiga (a radius of 30 km), and initiated a seismic wave of Richter magnitude 5, but, to our astonishment, left no crater. The dust from the tail of the comet moved away from the sun and provided anomalously bright night sky in Europe and parts of Western Russia. No trace of the comet itself was found except for tiny magnetite and silicate globules. The principal consequences were fear and awe among the inhabitants of the region, and the physical damage from the explosion. Fortunately, no human life was lost, though more than a thousand reindeer were destroyed.

Speculation will continue as to the origin of this catastrophe, yet no certain conclusions can be attained unless man has the dubious opportunity to observe and monitor such an event in the future. The Tunguska explosion directs our attention to catastrophic forces which have helped form the earth, and causes us to ask questions about the nature of much larger cosmic events. What were the global effects of enormous impact events which formed the 1-km-diameter Meteor Crater in Arizona, the 100-km-diameter Popigay crater of Siberia, and the 140-km-diameter Sudbury impact structure of Ontario? What changes in the earth's crust, atmosphere, ocean and life were caused by the release of a million times more energy than the Tunguska explosion? The Tunguska event provides a faint glimpse.

LITERATURE CITED

Astapowitsch IS. 1934. Air waves caused by the fall of the meteorite on 30th June, 1908, in Central Siberia. Royal Meteorological Society Quarterly Journal 60:493-504.

Beasley WH, Tinsley BA. 1974. Tungus event was not caused by a black hole. Nature 250:555-556.

Ben-Menahem A. 1975. Source parameters of the Siberia explosion of June 30, 1908, from analysis and synthesis of seismic signals at four stations. Physics of the Earth and Planetary Interiors 11:1-35.

Brown JC, Hughes DW. 1977. Tunguska's Comet and non-thermal C14 production in the atmosphere. Nature 268:512-514.

Cowan C, Alturi CR, Libby WF. 1965. Possible anti-matter content of the Tunguska meteor of 1908. Nature 206:861-865.

Fesenkov VG. 1962. On the cometary nature of the Tunguska meteorite. Soviet Astronomy 5(4):441-451.

Fesenkov VG. 1966. A study of the Tunguska meteorite fall. Soviet Astronomy 10(2):195-213.

Gentry RV. 1966. Anti-matter content of the Tunguska meteor. Nature 211:1071-1072.

Hughes DW. 1976. Tunguska revisited. Nature 259:626-627.

Jackson AA, Ryan MP. 1973. Was the Tungus event due to a black hole? Nature 245:88-89.

Krinov EL. 1960. Principles of meteorites. Oxford: Pergamon Press.

Krinov EL. 1963. The Tunguska and Sikhote-Alin meteorites. In: Middlehurst B, Kuiper GP, editors. The Solar System, Vol. IV: Moon, Meteorites and Comets. Chicago: University of Chicago Press, p 208-217.

Krinov EL. 1966. Giant meteorites. Oxford: Pergamon Press.

LeMaire TR. 1980. Stones from the stars. Englewood Cliffs, NY: Prentice Hall.

Lerman JC, Mook WG, Vogel JC. 1967. Effect of the Tunguska Meteor and sunspots on radiocarbon in tree rings. Nature 216:990-991.

McWhirter N, McWhirter R. 1974. Guinness book of world records, 1975. NY: Sterling.

Stanyukovich KP, Bronshten IA. 1961. Velocity and energy of the Tunguska meteorite. Doklady Akademii Nauk SSSR, earth sciences sections 140:1053-1055.

Sullivan W. 1979. Black holes, the edge of space, the end of time. Garden City, NY: Doubleday.

Thorndike JJ, Jr, editor. 1977. Mysteries of the past. NY: American Heritage Publishing Company.

Whipple FJW. 1930. The great Siberian meteor and the waves, seismic and aerial, which it produced. Royal Meteorological Society Quarterly Journal 56:287-304.

Whipple FJW. 1934. On phenomena related to the great Siberian meteor. Royal Meteorological Society Quarterly Journal 60:505-513.

Whipple FW. 1950. A comet model I. The acceleration of the Comet Encke. Astrophysical Journal 111(1):375-379.

Whipple FW. 1975. Do comets play a role in galactic chemistry and gamma-ray bursts? The Astronomical Journal 80(7):525-531.

LITERATURE REVIEWS

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THE DOGMATIC SKEPTIC

SCIENCE: GOOD, BAD AND BOGUS. Martin Gardner. 1981. Buffalo, NY: Prometheus Books. 412 p.

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Science: Good, Bad and Bogus represents thirty years of Martin Gardner's scathing articles and book reviews about pseudoscience. Often the contents of anthologies by one author are carefully selected to reveal growth and perhaps even changes in attitude and thinking over a span of years. This is not the case with Gardner's book, even though each chapter has been updated with a postscript.

In his introduction, Gardner bemoans the futility of amassing rational arguments to combat irrational ideas:

> *People are not persuaded by arguments to give up childish beliefs; either they never give them up or they outgrow them.... For these reasons, when writing about extreme eccentricities of science, I have adopted H.L. Mencken's sage advice: one horse-laugh is worth ten thousand syllogisms* (p xv-xvi).

Any reader who ignores the warning and proceeds to the rest of the book can be assured of an overabundance of wisecracks, sour jokes, and almost-vitriolic sarcasm. Of the 38 chapters (18 articles and 20 book reviews), only one — on Carl Sagan's *Broca's Brain* — comes close to saluting the accomplishments of another person (Sagan). But even this chapter deteriorates into a diatribe against Velikovsky and Protestant fundamentalism, and it becomes apparent that Gardner is merely using Sagan's book as an excuse for denouncing his cherished pet peeves and their supporters.

The first three chapters discuss "hermit scientists" (L. Ron Hubbard, Immanuel Velikovsky, George McCready Price, and Wilhelm Reich) who have already received attention in Gardner's *Fads and Fallacies in the Name of Science*, the stifling Party control on Soviet nuclear physics, and the *Ars Magna* of Ramon Lull, a 13th-century theologian who attempted

"to employ geometrical diagrams for the purpose of discovering nonmathematical truths." Thereafter, with few exceptions, the remaining chapters attack such phenomena as precognition, psychokinesis, ESP, mentalism, and the occult. Once Uri Geller, the Israeli magician who claims paranormal powers, has been introduced, his name comes up continually as the whipping boy for all the trickery, fakery and deceptive techniques employed by purveyors of belief in the paranormal.

Repeatedly Gardner expresses the plea for tighter and more specialized controls in experiments designed to investigate the validity of extraordinary claims. Believing that only a magician — a "consummate liar" (p 91) —, is trained to detect deceptions, he appeals to his own status as a knowledgeable student of conjuring for authority to provide rational explanations (e.g., fakery) for psychic phenomena. After postulating possible scenarios by which the deception *could have* taken place, he concludes that this is how it *must have* happened. As long as the possibility of deception remains, he apparently assumes the phenomenon to be fraudulent.

Needless to say, Gardner's essays have engendered emotional reactions from the targets of his verbal thrusts. Perhaps to give the readers a chance to decide for themselves, he includes some of these letters in his postscript to the chapters. He shrugs off their criticisms of his inaccurate statements as being "trivial" and merely reiterates his contempt for "Geller-gawkers." Though the book is entitled *Science: Good, Bad and Bogus*, very little is said about good science. This leads one to wonder if good science is anything that agrees with Gardner's mind-set, while bad science is anything seemingly irrational and/or fraudulent. Perhaps his essay entitled "Close Encounters of the Third Kind," which blasts the book, the movie, the director, the philosophy and writings of the technical consultant, and UFO studies, might qualify as a discussion of "bad" or "bogus" science. But why include a review of a book entitled *Four Arguments for the Elimination of Television*?

More curious are his book reviews on *The Preachers* (Oral Roberts, Billy James Hargis, Kathryn Kuhlman, Herbert W. Armstrong, and Billy Graham) and on Ruth Carter Stapleton's *The Gift of Inner Healing* (which concentrates on her personal life, ministry, and her influence on her brothers Jimmy and Billy). It is unclear as to why a popular-science writer even bothers to review books that are usually classified as "religious." Does he intend to show that science (i.e., naturalism) is the only source of truth and that religion is a pseudoscience?

Gardner cannot be accused of utilizing staid or boring vocabulary in these essays. Among his favorite adjectives (which rapidly become jaded

as one encounters them repeatedly) are: "unscrupulous," "shabby," "crazy," "foolish,'' and "silly." More colorful phrases include: "misleading assertions," "wild, preposterous claims," "conscious fudging," "knuckle-headed volume," "whopping misconception," "charming heights of claptrap," and "enormous gullibility." He deplores a publisher's failure to summon scientific evaluators "when a moronic manuscript has great potential for meeting the public's hunger for scientific hogwash" (p 112). In an essay on black holes, he shudders at "the appropriation of astro-physical mysteries to shore up the doctrines of pseudoscientific cults, or the shabby performances of psychic rip-off artists" (p 343). Pseudoscientists are defined as "eccentric ignoramuses who work in far-out fringe areas where extraordinary claims are loudly trumpeted with an extraordinary absence of evidence" (p 381), while crackpots produce "ignorant, trivial, at times pathological work" (p 233).

While Gardner has made a valuable contribution by urging caution in accepting new or unusual ideas, it probably is not necessary to read this collection in its entirety, for most chapters only reiterate what the previous ones have said. For an encapsulation of Gardner's philosophy, merely read his review of a book on psychokinesis in the 11 November 1982 issue of *Nature*. All the elements of *Science: Good, Bad and Bogus*, including the slurs on Geller, appear, and he concludes typically:

> Psychokinesis *is only the latest, but surely not the last, of a seemingly endless line of lurid books about the paranormal, hacked out by gullible believers who are incapable of distinguishing competent investigations from shabby research and anecdotal poppycock.*[1]

Gardner attempts to correct the imbalanced tone of his book by also expressing doubts about the honesty of some orthodox scientists who either deliberately faked their data or "unconsciously distorted their work by seeing it through lenses of passionately held beliefs" (p 123). These include such notables as Gregor Mendel, Johann Beringer, and Paul Kammerer. He further voices discouragement about his inability to eradicate the persistent problem of the rising interest in the occult and the paranormal. While admitting that "modern science should indeed arouse in all of us a humility before the immensity of the explored and a tolerance for crazy hypotheses" (p 246), he laments:

> *How is it that today, when science and medicine are advancing on a thousand spectacular fronts, people seem caught up in every conceivable variety of irrationalism?* (p 268).

Though blaming lack of information for the popularity of pseudo-scientific literature, he has not, unfortunately, contributed to the science education of the average citizen. He has arrogantly debunked sacred cows without providing substitute milk, and devotees of pseudoscience and the paranormal will continue to believe. One wonders why Gardner has not emphasized the positive results of scientific experiments and discoveries in his column, rather than making a career of belittling the beliefs of the pseudoscientist.

Perhaps Gardner should also consider the possibility that Jake Page, another popular-science columnist, has suggested. In a recent issue of *Science 83* he states that impersonal science has not provided solace for those who live with its "fruits ... and its handmaiden, modern technology." More scientific information alone is not enough, because those who reject science are not necessarily the uninformed:

> *... to an apparently growing proportion of educated people in this society, science as a method of discovery, as a mode of cognition, as a description of reality, is inadequate. These people are in deadly earnest, and they are saying that for many if not most of the important layers of human concern, science simply does not work .*[2]

To be more effective, Gardner, the professional debunker and skeptic, should try to find out why science alone is unsatisfactory for this large group of people.

ENDNOTES

1. Gardner M. 1982. Nuts about PK. Nature 300:119-120.
2. Page J. 1983. Ghostly persuasions. Science 83 4(1):80-82.

GENERAL SCIENCE NOTES

TEMPERATURE REGULATION IN TETRAPOD VERTEBRATES: ECTOTHERMS VS. ENDOTHERMS

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Amphibians and reptiles have often been considered to be primitive, and to illustrate steps in an evolutionary pathway to higher vertebrates, the birds and mammals. However, in a notable recent review Pough (1980) points out that the anatomy and physiology of amphibians and reptiles are as complex as in birds and mammals, but fit a different mode of life. They have a system based on low energy flow rather than the high energy flow of birds and mammals.

Birds and mammals maintain a constant high temperature by a high metabolic rate; they are called "endotherms" to specify that the source of heat is internal. On the other hand, amphibians and reptiles (and many other animals), choose a warm environment at the time of activity, and this supplies the necessary heat; they are called "ectotherms,'' indicating that the heat source is external to the animal. One consequence is that an active amphibian or reptile may use less than a tenth as much metabolic energy as an endotherm! Even when at rest the metabolic rate is only 10-20% of that of birds and mammals of similar size. Further, in nonactive periods of the day (or year), the body temperature can also drop, further reducing overall metabolic energy usage.

Part of what makes this low energy flow system possible is that most of the energy used for muscular activity is limited to anaerobic metabolism, rather than aerobic as in endotherms. Anaerobic energy stores (glycogen) are immediately available within the muscles and hence facilitate bursts of activity. But in many cases the animals would be completely exhausted by 3 to 5 minutes of maximum activity and could require several hours to completely regenerate their energy stores. At this point one might ask, "How then do they manage?" The answer is that bouts of activity are brief, interspersed with "sitting and waiting" (follow the next frog or lizard you see). In this way these animals may normally avoid the oxygen debt ensuing from continuous activity.

This might seem a high price to pay. On the other hand, consider the benefits of low energy flow (see Table 1). Small endotherms, with their large surface/mass ratio, lose heat so rapidly that they require more food per unit weight. This explains the incessant food gathering required by

TABLE 1

Costs and benefits of ectothermy and endothermy. The items listed are not mutually exclusive: some follow from others in the list. Based on Bennett & Ruben 1979 and Pough 1980.

	Ectothermy	Endothermy
Disadvantages	Rapid exhaustion	Require *much* food
	Activity restricted to brief bouts	Require *continuous* supply of food, water, and O_2
	Activity restricted to certain hours or habitats	
Advantages	Avoids cost of high basal metabolic rate	Work capacity many times that of ectotherms
	Endure shortages of food, water, or O_2	Capable of sustained high activity
	Can be elongate in shape or tiny in size	Can be active at a variety of times of day and in a wide range of habitats
	Can live in very sandy desert	

small animals such as shrews. In fact, the metabolic rate rises so fast with decreasing body size that an endotherm smaller than 5 grams would have an energy demand impossible to meet. But amphibians and reptiles, with a weight-specific daily energy requirement of less than a tenth that of birds and mammals, may have body weights of much less than 5 grams. Over 300 of 5000 species surveyed (Pough 1980) weigh less than 1 gram (!) (calculated from his Table 2). Thus amphibians and reptiles can occupy a whole size range (i.e., <5 grams) unavailable to birds and mammals.

Further, an elongate form is possible (long salamanders, lizards, snakes). To endotherms, this form would result in prohibitive loss of heat across the body surface. Again we see the variety possible in terms of thermal physiology.

Or suppose there is a food shortage. Because of their low energy approach, many ectotherms can go for months without food.

Many species of lizards and snakes can survive the extremes of the desert even in an area of shifting sand, by burrowing under. A mammal could not get enough oxygen at the depth required, and a tunnel system in this instance, which might provide oxygen elsewhere, would collapse.

What benefits do endotherms gain from their costly high energy flow system? The *resting* levels of oxygen consumption for endotherms equal the maximum levels for ectotherms, and the *maximum* levels for endo-

therms are 5-10 x the resting levels. Hence the capacity of endotherms for supporting work is many times that of ectotherms.

Birds and mammals are capable of much higher sustained speeds than ectotherms and can have a much broader behavioral repertoire than ectotherms because of the greater range of possible speeds and activities. Furthermore, there is greater independence in timing daily activity, because of constant maintenance of the high temperature that provides for maximal oxygen consumption.

In summary, here is yet another example of what has been seen before: when a phenomenon is studied with enough depth and in enough animals, it may show great design or value in its own right, rather than primitiveness or progressive evolution. It also may show more diversity in the underlying design than previously suspected — a little surviving reminder that Eden must have been a more intriguing place, even physiologically, than we had imagined.

LITERATURE CITED

Bennett A, Ruben J. 1979. Endothermy and activity in vertebrates. Science 206:649-654.

Pough F. 1980. The advantages of ectothermy for tetrapods. American Naturalist 115:92-112.

[As specific examples of current research see (a) Hulbert A, Else P. 1981. Comparison of the "mammal machine" and the "reptile machine'': energy use and thyroid-activity. American Journal of Physiology 241:R350-R356; and (b) Schall J, Bennett A, Putnam R. 1982. Lizards infected with malaria: physiological and behavioral consequences. Science 217:1057-1059].