Word & World 13/3 (1993)

On the Importance of Scientific Literacy

MARTHA LINDBECK and ANN PEDERSON
Augustana College, Sioux Falls, South Dakota

I. FRAMEWORK FOR CONVERSATION: THE THEOLOGIAN'S QUESTIONS

The doctrine of creation is the theological framework in which the relationship between God and the world is described. Christians confess that the world is God's creation. The task of theology is to discover a vision not only of God but also of God's created world. The task for the church leader is to become familiar with and knowledgeable about the world in which God is active. Faith's claims must be intelligible and applicable to life in this world we call creation. Philip Hefner states:

> The breathtaking new vision of what nature is, both physical and human nature, challenges Christian theological reflection upon nature. This challenge calls for a religious vision that is both intelligible and persuasive when facing current views of the created world.[1]

The doctrine of creation must be discerned and reformulated in light of contemporary scientific discoveries.

This article was written during the month of January which is both the season of Epiphany and the academic term in which we team teach a senior course in science and religion. Many students assume that these two disciplines have noth-

[1]Philip J. Hefner, "Fourth Locus: The Creation," in *Christian Dogmatics*, vol. 2, ed. Carl E. Braaten and Robert W. Jenson (Philadelphia: Fortress, 1984) 217.

ing to say to each other because they speak different languages. As a religion teacher on the way to a colloquium in the science building, I was once accused by a student of being headed in the wrong direction. Are these two disciplines so independent that they cannot carry on a conversation with one another? Can we change the way we know the world so that we are not confined to language games within individualized households? In learning another language we expand our own vocabularies, construct new metaphors, and learn more about ourselves and the world in which we live. When one learns the language of another culture, one of the primary pedagogical techniques is conversation. Conversation necessitates transformations that enrich the lives of both participants.

Provocative and creative ideas might emerge from the dialogue between the two distinctive disciplines of science and religion. Where might we create boundaries for constructive conversation between these two unlikely and divergent conversation partners? How do we maintain an environment where both may agree and disagree, teach and learn from the other? How does such a conversation begin? To carry on a conversation within another discipline, one must possess the desire to learn the other's language. Each must esteem the other discipline as one worthy of respect, as a defensible field of knowledge, and as a way of knowing that points toward truth. Church leaders who engage in conversation about the ways in which science and scientists understand our world have taken a significant step in becoming scientifically literate. Common vocabulary must be learned, methods must be tried, and patterns in learning how to talk with one another must be encouraged.

II. A TALE OF TWO THEORIES: A SCIENTIST'S RESPONSE

The word "light" is perhaps one of the most metaphor-laden words of the English language. Its very richness of meaning risks blinding, rather than illuminating, participants in a conversation if some preliminary groundwork is not laid. The following expression is a mixed metaphor which is meaningful in its entirety to a limited number of people.

And God said,

$$\nabla \cdot D = \rho$$

$$\nabla \times H = \frac{\partial D}{\partial t} + J$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \cdot B = 0$$

and there was light

It brings the world of science expressed in mathematical language into contact with the religious language of the Bible. Is such a conversation desirable? Could it perhaps even be fruitful? Would such a dialogue serve to prevent conflict and enhance understanding?

The magi and the shepherds lived in totally different worlds, yet both were drawn to Bethlehem, to see a child in a manger. Although they never encountered one another, they shared this event. What brought these diverse representatives of religious faith and worldly knowledge to a lowly stable in a nondescript village in the middle of nowhere?

Angels spoke to the shepherds, those of faith who worshiped God. Did the angels come robed in light? The shepherds were terrified by the sight, but they left their flocks to see this child, to behold this wonder with their own eyes. They came to the manger bearing their gifts: belief, praise, worship.

What of the magi? No angel came to them in the night and said, "Behold, I bring you tidings of great joy." Their knowledge came from their own curiosity and willingness to study the heavens and to follow the light of a star. Like so much human wisdom, their knowledge was only partial and they failed in their first effort to locate the child. Expecting a king, they went first to

Jerusalem where a king ought to be born, and had to be redirected to Bethlehem by Herod's priests. The magi came to honor this new-born king, bringing him worldly gifts of gold, frankincense, and myrrh; they returned to their own country, as had the shepherds, and neither group really ever appear in the story again.

Who are the shepherds of today? Who are the people of faith who are sent to worship this infant born in a lowly stable? And who are the magi, the people of knowledge who find their way to the stable out of curiosity? Can we bring together those people who ask questions of God and those who ask questions of nature? What new perspectives could each bring to the other's conversation? If nature is truly God's creation, must we not extend an invitation to all to participate in such a meeting? There is unquestionably risk in such an encounter; dialogue is difficult when the participants do not share a common language. One might be changed by the encounter. Is the one who is "other" feared and regarded as a threat to the present? Or is knowledge of the other welcomed and regarded as a challenge for the future? One thing seems certain—neither the knowledge proclaimed from crystal palaces nor that dispensed from ivory towers is sufficient in and of itself to understand today's world.

Today magi are called scientists, but they still search heaven and earth for answers to their questions. Astronomers, physicists, and chemists spend long nights mapping the skies, seeking to understand the stars. By pursuing such knowledge, they have learned how stars generate their light, how far away they are, how old they are, how they were born, and how they will die. The study of light brought scientists to one of the paradoxes of the twentieth century. What is the "nature" of light? For centuries scientists argued whether light was a wave as indicated by Maxwell's equations or a particle as Newton had believed. Today scientists speak a language of "wave/particle complementarity" in a world of quantum mechanics, a world of the very small whose description lies far beyond the realm of common sense. When the magi of this world journey to the manger, what gifts do they bring? What language do they speak when they tell their story?

Before we continue, it is probably time to agree on some terminology and

assumptions. From a practical standpoint, what does it mean to be "scientifically literate"? Literacy involves far more than knowing the meanings of individual words, but it must at least start there. Literacy implies the ability to listen with understanding as well as to speak intelligibly; it does not require fluency. Both theologians and scientists use in-house language among themselves which will not be appropriate to genuine dialogue with strangers. However, both also borrow liberally from the language of the other, and indiscriminate usage of particular terms opens the door for misunderstanding. Vocabulary matters! The context within which a dialogue occurs influences the meaning of the words. At its best, this conversation must be a workshop, not a seminar, a true dialogue rather than a lecture from either partner.

Science comes from the Latin word for knowledge, and the way that science currently knows the world is through observation, experimentation, and measurement. Large amounts of data are correlated by theories which serve to explain existing data and predict the results of future experiments. Science is perceived to be objective, rational, and predictable. If science existed in a vacuum, this description might be perfectly adequate. However, science is done by scientists, human beings who are influenced by existing theories, their culture, politics, and economics.[2] Scientists must strive to be "objective"—but they must recognize that there are limits to objectivity. Science must be done within a logical framework, but that which is new can be discovered only by stepping outside of that framework. Theories are changed by those scientists with creative imagination, the willingness to look at old data from new perspectives. At the beginning of the twentieth century experimental data were straining the credibility of the theories of Newton and Maxwell; that which was predicted did not agree with observation. What was showing through the cracks of the old framework was light. Although the theories of Newton and Maxwell continue to be used today, they have proven to be insufficient to explain phenomena in the worlds of the very small and the very fast, both of which involve light.

Scientifically speaking, light is electromagnetic radiation and, in general, is described by Maxwell's equations as waves. This radiation can be separated into radio and television waves, microwaves, ultraviolet rays, and X-rays. The human eye can detect only visible light, which itself can be separated into the colors of the rainbow. However, that is not "all" that light is, even for scientists. Light cannot be described as a quantitative, absolutely predictable phenomenon, even within the world of science. Such language is simply inadequate in terms of current theories. Light was chosen as the metaphor for this dialogue because the nature of light forms the roots of the two great scientific theories of our century—quantum mechanics and relativity. Light, as a metaphor, may imply brilliance and illumination, but one should view theories as massive ponderous things. Theories are never proven, but they bear the weight of tradition and, for all the open-mindedness and

[2]See Ian G. Barbour, *Religion in an Age of Science* (San Francisco: Harper & Row, 1990), for a discussion on paradigms, theories, and data.

fluidity expected of science, it is extremely difficult to change them.[3] However, they do change, and the changes of this century stretch the human imagination to its limits.

Although Einstein is most often associated with relativity, he received his Nobel Prize for explaining an experiment involving light by suggesting that light is made up of particles or "quanta." These particles are discrete bundles of energy which are now called photons. Countless experiments involving light can be explained by Maxwell's equations which treat light as a wave, but the photoelectric effect, as explained by Einstein, requires that light behave as a particle. In the realm of science, experiments answer certain questions for scientists and raise others. If light, which was thought to be a wave, can exhibit particle behavior, can something considered to be a particle exhibit wave behavior? Experiments involving electrons indicated that they did indeed act like waves under certain conditions. Although this evidence offers support for Einstein's theory, it is paradoxical behavior for the scientist who believes that matter and energy are two different aspects of the natural world. It also raises difficulties for those who wish to insist that the scientist is totally objective. The very act of observation requires that somehow the observer become participant as well.

In order to "see" the electron, a photon must be involved—measurement of a physically observable property requires participation of the observer. In the world of the very small, the energy of the photon with which one observes the system changes the system in a way that cannot be totally known. This is a basic statement of Heisenberg's uncertainty principle. If one knows exactly where a particle was at the moment of observation, one has no idea where it will be a moment later. This imposes a limit on scientific knowledge; predictions of what are known as complementary properties, such as position and velocity, cannot be made both exactly and simultaneously. Events that occur in the physical world must now be spoken of statistically, in terms of probabilities. If a chemist goes searching for an electron in the vicinity of the nucleus of an atom, there is a finite probability that it won't be there.

It must be emphasized that the discussion above applies to nature in general, but is significant in terms of measurement only in the world of the very small. Quantum effects are simply not a part of our ordinary world. If one throws a baseball at a window, the probability of observing it exhibit its wave properties as it is transmitted through the glass is vanishingly small. However, the language of quantum mechanics has found its way into the vocabulary of ordinary people. Translation and use of the language out of context and without knowledge of assumptions can and often does lead to misinterpretation and misrepresentation of what science can "know."

Such are the gifts of the magi who speak quantum mechanics. What do the

[3]See Thomas S. Kuhn, *The Structure of Scientific Revolutions* (Chicago: University of Chicago, 1970), for a general discussion of how theories evolve.

---

shepherds hear when this story is told? How do they interpret this story so that it makes sense within their world? What language do they contribute when they repeat the story? In fields such as the natural sciences in which knowledge and data are growing at exponential rates, how can the church leader become "literate"? One must become familiar with scientific discoveries and content, but literacy also requires an appreciation for the imaginative, theoretical, and creative methods of science as a valid way of knowing the world. To become scientifically literate, the church leader must practice the art of conversation. The conversation will inspire the theologian, create new visions and dreams about God's world, and transform the participants. This conversation produces a shared vision: that the world in which we live is not only worth talking about but also worth living in, caring for, and nurturing.

People do not live their daily lives in a world in which Einstein's physics makes sense. When common sense and mathematical principle conflict, one trusts that in which one believes. Aristotle discarded mathematics in favor of human reason, perceived as common sense. Newton disregarded his own laws in favor of his image of an absolute God. Einstein, however, refused to believe that the laws of nature were influenced by tradition or limitations of the human imagination. He presented the scientific world with special relativity, combining Maxwell's equations regarding light as a wave with Newton's laws which indicate that there is no unique frame of reference that can be regarded as stationary. In Einstein's theory the concepts of absolute space and time were sacrificed and the speed of light in a vacuum was recognized as a universal constant.

The implications of Einstein's theory may be appreciated by considering what is known as the twin paradox. One twin remains on earth while the other spends several years in a space ship traveling near the speed of light. When the twin in the space ship returns to earth, the two will no longer be the same age. Indeed, if the journey lasts too long, the twin on earth will not even be alive for the reunion. Although this experiment has never been performed, except in the imagination, the principle behind it has been verified in the world of the very small, with a particle traveling close to the speed of light.[4] There now exist scientists who study relativistic quantum mechanics, a language in which very few are fluent.

While Einstein was turning the world of classical physics upside down, geologists were searching for an accurate method with which to determine the age of the earth, this planet we call home. Such a clock was found in the radioactive disintegration of atoms—the unexpected immensity of this time scale measured earth history in billions of years. In astronomy, Hubble's measurements of the light from other galaxies indicated that they appeared to be rushing away from ours at velocities that increased with increasing distances.[5] The frontiers of the universe now encompass inconceivably vast expanses of time and space. The magi who

[4]Julian Schwinger, *Einstein's Legacy* (New York: Scientific American Books, 1986) chap. 2.
[5]Stephen W. Hawking, *A Brief History of Time* (New York: Bantam, 1988) chap. 3.

---

followed a star to Bethlehem two thousand years ago never imagined the story that their successors would see in the stars of the future. To today's generation belongs the story of the "Hot Big Bang," a theory about the origin and evolution of the universe as told by those who have read the story in the light of stars and not-so-black black holes.

Einstein's successor may be Stephen Hawking,[6] whose book *A Brief History of Time* presents much of the history of science in broad strokes, preserving the integrity of the field while making much of the terminology accessible to nonscientists. Hawking's history of time is a history of the universe, and this history pictures the universe as a dynamic creation, expanding, growing, changing. If the universe is now expanding, then at some time in the past it must have had a point of origin. Running the clock backwards, scientists can estimate that at some point in the past, all the matter/energy in the universe was concentrated in a single point of infinite density. This "singularity" may have marked the birth of the universe and the beginning of time. Such a "singularity" is singularly uninviting to scientists since it cannot be observed and the laws of physics cannot be assumed to apply there. How does the scientist test the validity of a theory when direct observation of the event is impossible? The strength of a theory lies in its ability not only to explain existing data, but to also make predictions about future events. While scientists cannot directly observe the actual moment of the big bang, they can make assumptions about what conditions might have been and then predict how the universe should have evolved given those original conditions. The question now is, "Does observable evidence exist today which would be predicted by the big bang theory?"

The stars themselves can provide such evidence. A star that is big enough may, as it consumes its fuel supply, eventually collapse to a point which is called a "singularity." Its gravitational attraction will then be so great that not even light can escape from it. Such a star forms a "black hole" which itself is not accessible to observation. However, the gravitational fields of black holes would have an effect on nearby stars. When Hawking combined the theories of relativity and quantum mechanics while studying black holes, he came to the conclusion "black holes ain't so black." Light may find ways to escape even a black hole. The mathematical equations that describe black holes predict that they ought to emit a steady stream of particles. This is explained using a slightly different version of the uncertainty principle: one cannot know both the exact value of the electromagnetic field of a system and the exact rate of change of that field simultaneously. Hawking's imagination has led him to the outskirts of the universe, and the only language spoken there is that of mathematics. He believes he has found a language which allows him to speak of the big bang without invoking a singularity, but in his journey to the origin of the universe, he has stepped beyond the range of verbal and/or metaphorical conversation.

[6]Ibid.

III. FRAMEWORK FOR CONVERSATION: THE SCIENTIST'S QUESTIONS

These are the worlds of today's magi. Are their stories true? Scientists are not certain. Will these stories change in the future? Probably. What do these stories have to do with shepherds? Perhaps nothing. What do they have to do with God? Perhaps everything. If shepherds and magi are attempting to find meaning in one and the same universe, they surely have much to talk about. If they speak different languages, operate from different assumptions, but share a universe, conversation seems imperative if conflict is to be avoided. If they are strangers to one another, they are surely instruments of the biblical God who so valued the stranger. If the word of God is to speak to scientists intelligibly and credibly, it must take seriously these ideas, for there are those among the magi who have come to the manger to see God as well. The magi must come in silence, for they cannot speak of God in their own language. The question of the existence and nature of God belongs to metaphysics and theology, not science.

Modern science brings the worlds of the very large and the very small into the realm of research. Nontechnical magazines such as *Scientific American*, *Discover*, and even *Time* and *Newsweek* bring the language of science into everyone's vocabulary, making relativity and uncertainty common household words. If the picture of a theologian is that of someone who holds Scripture in one hand and the newspaper in the other, then the theologian must be someone who can speak, even haltingly, the language of quantum mechanics and big bang cosmology. The images used to speak of God must be large enough to contain the entire universe and all the ideas encompassed within it. If the universe is somehow God's creation, will our respective understandings of our home as global and cosmic not be enriched by a dialogue between science and theology?

MARTHA LINDBECK is an assistant professor in the chemistry department at Augustana College with broad interests in astronomy, geology, oceanography, and physics. ANN PEDERSON is an assistant professor of religion who is currently working on related research in science and religion, feminist thought and process theology.