NEWER AREAS

Native Knowledge in the Americas

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THE WAYS IN WHICH THE NATIVE PEOPLES of the New World lived in and adapted to the environments around them have generally been categorized as religion or magic rather than science, and studies of native cultures have been the province of anthropologists rather than historians. Historians of science have acknowledged native practices but have generally relegated them to the realm of technology. G. Stresser-Péan maintains: "Though it would be misleading to call the religious systems and technical achievement of these people 'scientific,' even the most primitive among them made practical contributions that no historian of science can ignore."[1]

Religion and science are quite different ways of thought. However, useful comparisons can be made between the ways that native peoples and the western Europeans who encountered them beginning in 1492 understood the natural world. There are similarities in these different intellectual traditions that constitute a basis for a discussion of science.

Let us first discuss briefly the differences. The characterization of native Americans' thought as religious generally presupposes that they believed in a transcendent power underlying physical reality, a power not understood in rational terms but one which arouses feelings of awe and sometimes fear. The defining characteristic of religion, as the term is used here, is the sense that the forces of nature are manifestations of transcendent power that has will and volition. And indeed native American societies have so understood the nature of the world, for they ascribe self-movement, will, and choice to physical forces in nature. These attributes, then, remove nature from the realm of pure rationality. Science, on the other hand, presupposes a nature of physical forces acting according to laws. Those forces have no personal aspect but are susceptible to rational understanding because their behavior is lawful, rather than willful, and they can be understood by logical thinking.

The difference between the Europeans and the native peoples they encountered lies in their differing assumptions about the nature of the physical world. To be sure, the natural world of 1492 was alive with Aristotelian concepts of natural place, transmutation of elements under the influence of philosophers' stones, and mysterious forces of magnetism, to name but a few. However,

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[1] G. Stresser-Péan, "Science in Pre-Columbian America," in *History of Science,* ed. René Taton, trans. A. J. Pomerans, Vol. I: *Ancient and Medieval Science* (New York: Basic Books, 1963), p. 293.

Europeans increasingly regarded these forces as purely mechanical, while native people in the New World continued to view them as personal attributes of spiritual beings.

To give New World cultures a place in the history of science, we must be aware of the ways in which European and native thought diverged over time. European science was increasingly based in concepts of lawful behavior of natural forces. Native American beliefs were based on the willful behavior of those forces. The one presupposed rational ways of understanding those laws; the other sought interaction with the forces of nature through dreams, visions, and ceremonies—through intuitive and personal ways of comprehending and controlling those forces.

The common factors that characterized European and native activities in 1492, and that continue as accepted tenets of scientific activity, are those of observation of a body of physical phenomena existing apart from human beings (this assertion in itself is a statement of belief), the desire to control those phenomena and the forces behind them, and the attempt to exercise that control. The character of these attempts reflects both the common ground and the differences between these two cultures. Native cultures, with their beliefs in the personal will and volition of those forces, sought control by establishing personal relationships with them through ritual; an important aspect of this for many groups was the careful observation of natural phenomena. European scientific culture sought control through rational perception of laws of nature and the ability to predict the outcome of events, an ability also based on careful observation of physical phenomena.

The crucial point at which native and European concepts of science differed was in the role of experimentation. According to the Western view, the lawful behavior of nature will allow similar actions to lead to similar results, and thus the predictive power of science is enhanced. The native concept posits that the personal relationships of groups or individuals with spirit forces is necessary to assure desired results, and thus ceremony and ritual take the place of experiment.

Having explored these similarities and differences, we can define native American science as the activities of the native peoples of the New World in observing physical phenomena and attempting to explain and control them. This brief summary cannot take in the complexities and variations of cultural practices throughout North America at the time of European contact, and it cannot offer a definitive description of the nature of European science at that time. However, this definition of native science forms a basis for evaluating writings about native American science in the history of science.

PROBLEMS IN THE STUDY OF NATIVE SCIENCE

Many problems in dealing with science in the native cultures of the New World arise from the nature of the available sources. Since native people did not have written language, except for some pictographic or hieroglyphic forms in Mesoamerica, most studies of these cultures fall outside the province of history. Even where indigenous records are available, problems exist. For example, studies of Mayan codices have been concerned as much with problems of deciphering the writing as with their scientific and historical content. Floyd Lounsbury acknowledges the problems of interpretation in his studies of Mayan mathematics and calendrical systems; however, his contributions to an understanding of Mayan science are extremely significant.[2]

If historians of science rely on native sources, they face distinct problems of interpretation, but if they rely on sources written about native people by European observers, they face problems stemming from European contact itself. It is possible that some native practices and beliefs might have been the result of European contact rather strictly indigenous. Lynn Ceci's article "Fish Fertilizer: A Native American Practice?" raises the issue of primacy. She maintains from historical evidence that the practice of fertilizing corn hills with fish was not an indigenous practice but one learned from Europeans. Critics of her thesis argue that planting in hills was not a European custom and that although Old World cultivators might have used fish as fertilizer, it was unlikely that the custom would have been taken over by Indians whose planting methods were otherwise so different.[3]

This kind of discussion focuses on the historian's natural subject—change; it does not so much enlighten us about the nature of Indian agriculture as it raises the issue of the result of European contact on native practices. The historian without indigenous records cannot say what is native knowledge and what has been the result of European contact. More often than not, though, contact has led to the loss of native knowledge rather than its advance.

Ceci's study, by focusing on innovation, uses historical records to ascribe primacy to a discovery, thus implying that earlier invention or discovery in some way establishes a scientific achievement. This implicit assumption of the primacy of European science may also motivate accounts that describe native systems of knowledge as they existed at the time of contact but judge them as scientific by modern standards. Bernard Ortiz de Montellano in "Empirical Aztec Medicine" points out that many of the plants used for medicine have chemically active ingredients with physical effects consistent with the desired cure, but many have no such ingredients and were nonetheless used. Ortiz de Montellano indicates that the empirical basis of Aztec medicine entailed more than the purely physical effects that might be expected from herbs. However, he seems to feel compelled to justify the efficacy of Aztec medicine on the basis of chemistry rather than culture.[4]

Ortiz de Montellano is a scientist rather than a historian, and he brings the assumptions of modern science to the study of past cultures. The sources for his study, however, are seventeenth-century descriptions of Aztec culture. The historian finds problems with accounts such as these because they are ethnographic rather than historical. They are synchronic rather than diachronic: they provide a picture of a culture at one point in time rather than providing a sense of change or development in native systems of knowledge. Nonetheless, they

[2] Floyd G. Lounsbury, "Maya Numeration, Computation and Calendrical Astronomy," in *Dictionary of Scientific Biography,* ed. Charles C. Gillispie, 16 vols. (New York: Scribners, 1970–80), Vol. XV, pp. 759–818.

[3] Lynn Ceci, "Fish Fertilizer: A Native North American Practice?" *Science,* 1975, *188*:26–30; see letters to the editor and Ceci's response in *Science,* 1975, *189*:945–948.

[4] Bernard Ortiz de Montellano, "Empirical Aztec Medicine," *Science,* 1975, *188*:215–220.

may illuminate the world views of native cultures. And, incidentally, they may illuminate the world views of those who study native cultures.

The classic dichotomy between primitive and modern ways of thinking dominated the thought of anthropologists and sociologists for many years and shaped attitudes toward native peoples and their patterns of thought. Around the turn of the century, Emile Durkheim and Lucien Lévy-Bruhl formulated their theories of human culture and society along the dichotomy of primitive and modern, as Robin Horton has pointed out. In the mid-twentieth century, in *The Primitive World and Its Transformation,* Robert Redfield, an anthropologist, classified scientific thought as a characteristic of modern civilization and argued that primitive people did not make the crucial distinction between themselves and their physical surroundings that was necessary for science. Hence natives personify and respond emotionally to their environments rather than viewing them in an objective way. Writing in 1932, however, E. A. Burtt, a philosopher of science, attempted to deal with the dichotomy of primitive and civilized and to meld the scientific and religious viewpoints. His statement in *The Metaphysical Foundations of Modern Physical Science* has relevance to the definition of native science: "Possibly the world of external facts is much more fertile and plastic than we have ventured to suppose; it may be that all these cosmologies and many more analyses and classifications are genuine ways of arranging what nature offers to our understanding, and that the main condition determining our selection between them is something in us rather than something in the external world."[5]

Following Burtt's lead, studies of native science must not only deal with the results of native activities but should acknowledge as well the world views and understandings of native people concerning their relationships to the natural world. Most work on native science has been concerned only with the results of native observational efforts that are similar to those produced by Western science. However, as historians of science have begun to realize that science is not a thing sui generis and have begun to study the social context within which scientific method is used, they have attempted to investigate not only the observational results of scientific endeavors but the assumptions about the nature of the world that underlie them.

One criterion by which to evaluate writings about native American science, then, is the extent to which they are both descriptive of native practices of observation and interpretative of their cultural context. One way of approaching the subject is through ethnoscience.

ETHNOSCIENCE AND NATIVE SCIENCE

Ethnoscience is a method in anthropology that examines the boundaries of categories in systems of classification. It attempts to use precise definitions of sets of characteristics that define classes. Because ethnoscience depends upon analysis of native observations and definition of physical phenomena, it has been

[5] Robin Horton, "Lévy-Bruhl, Durkheim, and the Scientific Revolution," in *Modes of Thought: Essays on Thinking in Western and Non-Western Societies,* ed. Robin Horton and Ruth Finnegan (London: Faber & Faber, 1973); Robert Redfield, *The Primitive World and Its Transformation* (Ithaca: Cornell Univ. Press, 1953); Edwin Arthur Burtt, *The Metaphysical Foundation of Modern Physical Science* (2d ed.; London: Routledge & Kegan Paul, 1932) p. 224.

used to study native systems of knowledge in a scientific way. If we assume that the classification systems of native people must bear some relationship both to an objective reality and to their own cognitive structures for seeing the world, then ethnoscience is a useful tool to examine both the objective results of classification systems and the underlying cognitive structures that produce them.

William Sturtevant has defined ethnoscience as a method for the study of "the system of knowledge and cognition typical of a given culture," with the caveat that the term *ethnoscience* should not be taken to mean that studies of folk classifications and folk taxonomies are science while other forms of ethnography are not. Ethnoscientific studies are based on linguistic analysis, and Sturtevant sets out principles for the relationships of linguistic categories that will allow the student of a culture to examine native belief systems. The categories' proximity to or distance from those of Western science provides some insight into the cognitive structures of a world view.[6]

Sturtevant's essay raises a basic question for students of native science. Systems of categorization may indeed be an indication of the underlying preconceptions about the nature of the physical world, and they may be recognized by the outside observer of a culture on the basis of their congruence with the observer's own systems of categorization. The systems may be based on similarities and differences in an objectively real world. In that regard, the observer categorizes as "science" the explanations in the native world that match his or her own experiences and definition of science. However, the reasons why each culture adopts a particular explanation may be quite different.

Ethnoscience in its strictest anthropological sense has focused on eliciting information from native informants and discovering the native principles that determine the kind of congruences that must be present to constitute a category. In "An Ethnoscience Investigation of Ojibwa Ontology and World View," Mary Black finds, for example, that the Ojibwa (Chippewa) have higher respect for spiritual beings in their world than they do for animals. The reasons for the rankings (elicited by Black's question "Is *x* more respected than *y*?") have to do with concepts of power in the Ojibwa world view—with which beings have the ability to control the activities of other beings.[7]

Black's study is an excellent example of the method of ethnoscience. Although it would not necessarily be recognized as an exploration of native American "science," it gives insight into the way in which native people understand the physical world around them and is thus indeed an investigation of science in its broadest definition. Based on the premise that how native people categorize all the phenomena of the physical environment is important, it explores the world view of the Chippewa people through phenomena recognized by the Chippewa within a certain framework, that of control of forces of the environment. The beings who constitute the Chippewa world are manifest as objective phenomena, but their actions are understood in terms very different from those of Western science.

[6] William C. Sturtevant, "Studies in Ethnoscience," in *Culture and Cognition: Rules, Maps, and Plans*, ed. J. P. Spradley (San Francisco: Chandler, 1972), pp. 129–167, quoting p. 130.

[7] Mary B. Black, "Ojibwa Power Belief System," in *The Anthropology of Power: Ethnographic Studies from Asia, Oceania, and the New World*, ed. Raymond D. Fogelson and Richard N. Adams (New York: Academic Press, 1977).

Ethnoscience as a methodological approach is important because language is a key to understanding a world view, if one may substitute that term for cognition or cognitive studies. However, it is a technical approach that the more general observer cannot always undertake. It depends on the ability of the researcher to impose order upon the data collected.

Eugene Hunn distinguishes ethnoscience from "folk" science. He describes the first as a methodological and critical stance within cultural anthropology and the second as a domain for analysis of content within the understanding of informant and ethnographer. The ethnoscience view is etic: the observer looks at the culture from an outside perspective and attempts to apply certain general rules of knowledge to what is seen. The folk science view is emic: the observer attempts to understand the native way of describing and categorizing experience.[8]

The distinction between ethnoscience and "folk science" is not clear-cut, however. Brent Berlin, Dennis Breedlove, and Peter Raven describe their study of Tzeltal plant classification as botanical ethnography, or "that area of study that attempts to illuminate in a culturally revealing fashion prescientific man's interaction with and relationship to the plant world." Their approach is a linguistic one, and their study can be called ethnoscientific. It is also a study of the Tzeltal world view. Although one might argue with the assertion that native "interaction with and relationship to the plant world" are prescientific, Berlin and his colleagues have made a significant contribution to an understanding of native science.[9]

Not only do native categories provide an entrée into what may be perceived as universal cognitive processes, but they are also valid in and of themselves within the culture of which they are a product. They reveal the ways in which native people organize, understand, and control their worlds. In systems of classification, these ways are often based not on discrete characteristics so much as on a gestalt of the whole animal. This way of looking at the world is significantly different from Western science.

ARCHAEOASTRONOMY AND ETHNOASTRONOMY

Native classification systems deal with objective natural phenomena, and the results of those systems can be compared with Western scientific systems of classification. This comparative approach is used in other areas of native activity as well. Since astronomy is a science based on observation rather than experiment, its methods and analyses should correspond well in Western and native systems of thought. Archaeologists have presented orientation of structures as objective evidence for the observational powers of native people, and hieroglyphic records from the Maya provide systematic documentation. Archaeoastronomy is a field in which the results of the activities of native people are apparent, although the causes may not be so clear-cut; those results lend themselves to comparison with European systems of observation.

[8] Eugene S. Hunn, *Tzeltal Folk Zoology: The Classification of Discontinuities in Nature* (New York: Academic Press, 1977), pp. 3–5.

[9] Brent Berlin, Dennis E. Breedlove, and Peter H. Raven, *Principles of Tzeltal Plant Classification: An Introduction to the Botanical Ethnography of a Mayan-Speaking People of Highland Chiapas* (New York: Academic Press, 1974), p. xv.

An excellent introduction to the subject of archaeoastronomy is Anthony Aveni's *Skywatchers of Ancient Mexico*. His second chapter, "Astronomy with the Naked Eye," explains for the nonastronomer the movements of celestial bodies as they appear to the earthbound observer. Moreover, the study of archaeoastronomy in Mesoamerica has the advantage of a body of recorded evidence, and Aveni introduces the complexities of the Mayan calendar system and the ways in which astronomical data were recorded in codices. The extensive literature on Mayan astronomy and mathematics is based primarily on two codices, housed in Paris and Dresden, that survived the destruction of sources of native knowledge that occurred after the European conquest of the New World. J. E. S. Thompson has studied the Dresden codex, which contains mathematical notations describing the movements of the planet Venus and a table of lunar eclipse predictions. On the basis of information in the Paris codex, Gregory Severin postulates the existence of a Mayan ecliptic and zodiac.[10]

A major focus for scholars has been the calendar system of the Maya. Thompson has been a leader in the attempt to correlate the Mayan and Julian calendars.[11] The problem of correlation has not been resolved, but the work on it is a good example of the conjunction of Western scientific activity, which resulted in the Julian calendar system; native scientific observation, which resulted in the 365-day cycle of the Mayans known as the vague year and the 260-day sacred calendar; and the discipline of history, by which scholars have attempted to correlate the two systems through some objectively verifiable historical events.

The origin of the 260-day calendar, the *tzolkin,* has been the subject of speculation, for it had no relation to the agricultural year. Vincent Malmstrom argues that it originated from the 260-day interval between the times at which the sun passes through the zenith at the latitude of fifteen degrees north, where the phenomenon was first observed.[12] The *tzolkin* regulated religious activities and the highly deterministic astrological system of the Maya. Besides requiring observational skills, it had profound cultural significance.

The Mayan solar year, on the other hand, was reckoned through observation and divided into eighteen months of twenty days with an added five-day period. Much of the Mayan calendar system was devoted to noting and using the conjunctions between the solar and the ceremonial calendar, which occurred once every fifty-two years, a time marked with special ceremonial observances in both Mayan and Aztec culture. E. C. Krupp has described the Aztec ceremony of the "Binding of the Years," which marked the end of the fifty-two-year cycle.[13] Although claims have been made for the impressive accuracy of the

[10] Anthony F. Aveni, *Skywatchers of Ancient Mexico* (Austin: Univ. Texas Press, 1980); John Eric S. Thompson. *A Commentary on the Dresden Codex: A Maya Hieroglyphic Book* (Memoirs of the American Philosophical Society, 93) (Philadelphia: APS, 1972); Gregory M. Severin, *The Paris Codex: Decoding an Astronomical Ephemeris* (Transactions of the American Philosophical Society, 71, 5) (Philadelphia: APS, 1981).

[11] J. Eric S. Thompson, *A Correlation of the Mayan and European Calendars* (Field Museum of National History, Pub. 241, Anthropological Series, XVII, 1) (Chicago: Field Museum of Natural History, 1927); Thompson, *Maya Chronology: The Correlation Question* (Carnegie Institution of Washington, Pub. 456, Contribution 14) (Washington, D.C., 1935).

[12] Vincent H. Malmstrom, "Origin of the Mesoamerican 260-Day Calendar," *Science,* 1973, *181*:939–941.

[13] E. C. Krupp, "The 'Binding of the Years,' the Pleiades and the Nadir Sun," *Archaeoastronomy: The Bulletin of the Center for Archaeoastronomy,* 1982, *5*:9–13.

Mayans in determining the length of the solar year, it is obvious that whatever the basis for their observations, their overriding concern was the prediction of the continuation of their world, which was based on the elaborate cosmology within which they worked.

In addition to codices, archaeoastronomy is based on the observed results of native peoples' activities, that is, the orientation of structures, which provide concrete evidence of native behavior. Interest in studies of orientation began with examinations of Stonehenge and other megalithic sites in Europe. Throughout the Americas, structures of varying complexity have been identified as having specific physical orientations to points on the horizon that mark rising or setting points of the sun at its solstices or the first risings of the year of particularly bright stars at sunrise or at sunset (their heliacal risings). There are extensive ruins of early cultures in South and Mesoamerica and less extensive but no less interesting sites in North America.

Aveni has described the difference between astronomy in North America and astronomy in the tropics as one of orientation. In the temperate latitudes, the emphasis is upon observation of events along the horizon, particularly solstices and the rising and setting of certain stars. In the tropics, the orientation is toward observation of events overhead, since the movement of the stars is directly overhead. However, the difference does not hold clearly, as the series of papers in *Ethnoastronomy and Archaeoastronomy in the American Tropics,* a symposium sponsored by the New York Academy of Science in 1981, demonstrates.[14]

Studies of orientation include one by Aveni, Sharon Gibbs (a historian of science), and Horst Hartung (an architect), who have analyzed the structure of the Caracol Tower at Chichén Itzá and have concluded that its doors and windows and its base platform could be aligned with key rising points of the sun, Venus, and certain stars. They support their hypothesis with early accounts of Mayan ceremonies that corroborate the notion that the Maya actually used such orientations. Orientation on a much larger scale was examined by C. Chiu and Philip Morrison in their study of the offset street grid at Teotihuacan in Mexico. They proposed that the streets were oriented to buildings in a way that brought them into astronomical alignment with celestial phenomena overhead. In Peru, R. T. Zuidma has studied the extensive system of *ceques,* forty-one directional lines centered on Coricancha, a temple of the sun in the city of Cuzco, and marked by various natural phenomena near the horizon. The lines were first recorded by Benabe Cobo in 1653, and his historical account provides the basis for Zuidma's study of archaeological sites and natural phenomena. The lines and celestial phenomena played a role in establishing the Inca calendar.[15]

Studies in Mesoamerican cultures, the Maya and Aztec particularly, have the

[14] Anthony F. Aveni, "Introduction," *Ethnoastronomy and Archaeoastronomy in the American Tropics,* ed. Anthony F. Aveni and Gary Urton (Annals of the New York Academy of Sciences, 385) (New York: New York Academy of Sciences, 1982); Owen Gingerich, "Summary: Archaeoastronomy in the Tropics," *ibid.*

[15] Anthony Aveni, Sharon L. Gibbs, and Horst Hartung, "The Caracol Tower at Chichén Itzá: An Ancient Astronomical Observatory?" *Science,* 1975, *188*:977–985; B. C. Chiu and Philip Morrison, "Astronomical Origin of the Offset Street Grid at Teotihuacan," *Archaeoastronomy,* 1980, *2*:55–64; R. T. Zuidema, "Catachillay: The Role of the Pleiades and of the Southern Cross and α and β Centauri in the Calendar of the Incas," in *Ethnastronomy and Archaeoastronomy,* ed. Aveni and Urton.

advantage of permanent records kept by natives. For North America there are no such sources, and theories of origin must be based solely on orientation of prehistoric sites, with corroboration in historical sources being minimal at best.

One of the most studied but controversial orientation sites in North America is found at Fajada Butte in New Mexico, where a trio of stone slabs, resting against a rock face and supported by a narrow ledge, cause a narrow beam of light, a "sun dagger," to fall, on the day of the summer solstice, across the center of a spiral cut into the cliff. Anna Sofaer and others have been studying the phenomenon for several years, trying to determine whether the placement of the stones is deliberate or accidental. Jonathan Reyman has studied another site in which human effort is obvious: Pueblo Bonito in Chaco Canyon, located in eastern New Mexico. Using observational and measurement techniques similar to those used by Aveni, Gibbs, and Hartung, Reyman determined that window openings at Pueblo Bonito could have been used to observe the winter solstice sunrise.[16]

One of the most dramatic sites in North America is the medicine wheel located high on the side of the Big Horn Mountains in Wyoming. The presence of stones laid out in what are called medicine wheels has inspired the idea that native people were aware of celestial phenomena such as solstices and the heliacal rising of certain stars. John Eddy has investigated the astronomical alignment of the Big Horn medicine wheel and concluded that the builders of the wheel (a simple circle of rocks with a central point, twenty-eight spokes, and five stone cairns around the outer rim) aligned their structure with heliacal rising points of certain stars and the solstice points of the sun. Eddy tested his hypothesis by sighting the rising of the summer solstice sun over the point of alignment of two of the stone cairns.[17] The remoteness of the site and the fact that the ancient people who built it were not agriculturalists but hunters raise questions of interpretation. Any attempt at explanation of the wheel's origins remains speculative.

Following Eddy's lead, Thomas and Alice Kehoe examined a number of sites in Saskatchewan where patterns of boulders indicate human construction efforts. They found at two sites significant evidence of orientation along a north-south axis that would indicate the sun's rising at the summer solstice. They also learned from Blackfoot Indians that there were calendar men who marked the days for certain ceremonies, and that sun dance lodges had a north-south orientation like that of the stone constructions, although the Indians denied there was a connection. They concluded that the stones could indeed be a kind of calendrical system.[18]

The Pleiades have been an important point of reference for astronomical systems in many cultures. The Aztecs watched for the passage of the Pleiades through the zenith as the marker of the end of one cycle in their calendar and the beginning of a new cycle. They celebrated the occasion (which occurred

[16] Anna Sofaer, Volker Zinser, and Rolf M. Sinclair, "A Unique Solar Marking Construct," *Science*, 1979, *206*:283–291; Jonathan E. Reyman, "Astronomy, Architecture and Adaptation at Pueblo Bonito," *Science*, 1976, *193*:957–962.

[17] John A. Eddy, "Astronomical Alignment of the Big Horn Medicine Wheel," *Science*, 1974, *184*:1035–1043.

[18] Thomas F. Kehoe and Alice B. Kehoe, "Stones, Solstices, and Sun Dance Structures," *Plains Anthropologist*, 1977, *22*:85–95.

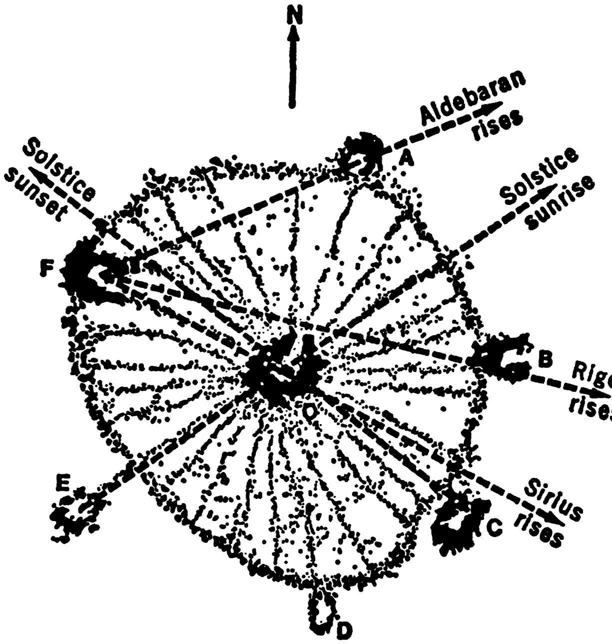

Diagram of Big Horn Medicine Wheel with superimposed arrows indicating observed astronomical alignments. From John A. Eddy, "Astronomical Alignment of the Big Horn Medicine Wheel," Science, *1974,* 184 *(4141):1040. By permission of the publisher. Copyright 1974 by the AAAs.*

once every fifty-two years) by kindling a new fire in the breast of a sacrificial victim. The passage of the stars indicated that indeed another cycle had begun, and the world would continue. Although the explanation does not fit the scientific model, the observational techniques that it inspired led to an understanding of certain objective phenomena.

The Pleiades were an important marker for a number of North American tribes who practiced agriculture, because their appearance and disappearance coincided with the beginning and end of planting seasons. Lynn Ceci describes the phenomena in "Watchers of the Pleiades: Ethnoastronomy Among Native Cultivators in Northeastern North America." The Pleiades also figure in a highly speculative but fascinating attempt to understand the astronomical beliefs of a North American Indian tribe, Von Del Chamberlain's study of the Pawnee.

Chamberlain has used a body of ethnographic information and oral tradition and one permanent record, a star chart inscribed on a finely tanned hide. The ethnographic accounts, both from native Pawnee and nonnative sources, emphasize the role of the stars in the daily lives of the tribe. The Skidi band of Pawnee located their villages in conformity with patterns of the stars. Ceremonies invoked the morning and evening stars to bring their favor on the people. And the Pleiades were used to mark planting seasons. The star chart, with crosses painted on the hide, reproduces recognizable star clusters—the Big and Little Dippers, the Pleiades, and others. Chamberlain speculates that the Pawnee built and oriented certain of their earth lodges with the opening toward the east and the smoke hole opening overhead in such a way that they could observe solstices through the doorway and the passage of certain stars overhead. He must speculate, because there are no longer Pawnee earth lodges built in the traditional way for everyday use, only written descriptions. He asserts the possibility, not the actuality, that the Pawnee were consciously aware of the orientations he describes. The star chart and the rich body of tradition he cites, however, are good evidence for his arguments.[19]

Stephen McCluskey's studies of Hopi astronomy demonstrate the persistence of observations along the horizon in a contemporary Indian culture. He has had the advantage of observing at first hand the correlation of astronomical observation and ceremonial systems, a connection that can only be a matter of speculation for such things as medicine wheels. His field work with the Hopi has allowed him to note the activities of the sun watchers, men who go to certain places to observe the movement of the sun along the horizon as it nears its solstice points. The solstices are still used to mark the time for the beginning of certain ceremonies in the Hopi yearly cycle. The role of the sun watchers in various Pueblos has been documented. McCluskey has demonstrated the correlation of their activities with both the seasonal cycles of frost that determine the agricultural year and the activities of their ceremonial year.[20]

A rather esoteric preoccupation in archaeoastronomy (and yet one that occupies a noticeable part of the literature) is with the possibility that Indians in North America recorded in some way the great supernova of 1054. The existence of records contemporary with the event in China and not in Europe has led to the speculation that some of the rock art of North American Indians, particularly the conjunction of crescents and circles, can be interpreted as a record (and thus independent corroboration) of the supernova.[21]

If archaeoastronomy deals with the objective results of native observation, ethnoastronomy deals with the cultural premises behind the observations. The system of thought that inspired Mayan and Aztec astronomical observations was based on religious beliefs rather than on observation for its own sake. Aveni makes this point in a review article on Mayan archaeoastronomy. David Kelley has argued that the astronomical system of the Maya reflects their religious system. He maintains that the identification of gods with celestial bodies in various codices and their relationships with each other indicates a knowledge of the mechanics of eclipses. He also acknowledges that the thesis is a controversial one. Johanna Broda has explored the influence of culture on Mayan science in "Astronomy, *Cosmovision,* and Ideology in Pre-Hispanic Mesoamerica." She relates the Mayan and Aztec calendar systems, which are very similar, to the structure of their societies, which were very hierarchical. She maintains that the fatalism apparent in the astrological system based upon the calendar (and perhaps the basis for the calendar) is an expression of the highly structured and authoritarian social system. Gary Urton has drawn similar inferences from the perception of contemporary Quechua Indians concerning the heavens. They see animal formations in the dark areas of the Milky Way, which can be called constellations, since they move regularly overhead. Urton finds in this concept

[19] Lynn Ceci, "Watchers of the Pleiades: Ethnoastronomy among Native Cultivators in Northeastern North America," *Ethnohistory,* 1978, *25*:301–317; Von Del Chamberlain, *When Stars Came Down to Earth: Cosmology of the Skidi Pawnee Indians of North America* (Los Altos, Calif.: Ballena; College Park, Md.: Center for Archaeoastronomy, 1982).

[20] Stephen C. McCluskey, "Historical Archaeoastronomy: The Hopi Example," in *Archaeoastronomy in the New World: American Primitive Astronomy,* ed. A. F. Aveni (Cambridge: Cambridge Univ. Press, 1982).

[21] John C. Brandt and Ray A. Williamson, "The 1054 Supernova and Native American Rock Art," *Archaeoastronomy,* 1979, *1*:1–38; Seymour H. Koenig, "Stars, Crescents, and Supernovae in Southwestern Indian Art," *ibid.,* pp. 39–50.

evidence of a system of classification that organizes the physical world of the Quechua, celestial phenomena, animals, and, by extension, other aspects of the world as well.[22]

A native account of astronomical phenomena in a North American Indian tribe is the basis for Berard Haile's study "Starlore among the Navaho." Haile worked extensively with the Navajo during the early 1900s, and his knowledge of Navajo culture was extraordinary, as was his working relationship with native people. His small volume on starlore is based on what he learned in his examination of the extensive body of knowledge encompassed in Navajo chants, elaborate ceremonies based on mythology and aimed at curing illness. Navajo starlore describes the way in which the heavens came to be as they are. This is mythology, and yet it is an intriguing example of a native system of explanation that expresses reality in Navajo thought. It seems that some of the stars had been carefully placed on the floor of the hogan of creation by Black God, one of the Navajo deities, and thus constituted constellations (some of which correspond approximately to Western ones). However, Coyote, a trickster and practical joker in Navajo cosmology, came along to pick up the deerskin containing the stars and blew them into the sky, thus accounting for the seemingly random distribution of the stars in the heavens. The story indicates that the Navajo were keen observers of the heavens, that they picked out certain patterns of stars against a background of seeming randomness, and that they had a system of explanation for certain distinctive groupings of stars, for example, the Pleiades, against the randomness of other stars.[23]

Studies of archaeoastronomy and ethnoastronomy indicate that the native people of the New World were keen observers of the natural world. Observation of the movements of the stars, the sun, and the moon, and knowledge of their predictive power was common among native people in North America. If the nature of the heavenly bodies was a personal one, the results of their actions were predictable. The Hopi knew that when the Sun returned to his home in the south and rested there briefly, their ceremonies would cause him to leave his home and begin his journey to the north, bringing warmth and promoting the growth of crops. They also knew that the Sun moved at times more quickly and at times more slowly through the sky relative to the lunar months, by which they timed most of their ceremonies, and they could predict the conjunction of solar and lunar events for ceremonial purposes, as McCluskey has pointed out.[24]

Aveni and Urton, in their introduction to *Ethnoastronomy and Archaeoastronomy in the American Tropics,* describe the purpose of the conference whose proceedings it contains as an exploration

> in a comparative perspective, [of] the traditions of thought and logic whereby American Indian cultures in the tropics organize cycles and phenomena perceived

[22] Anthony F. Aveni, "Archaeoastronomy in the Maya Region: A Review of the Past Decade," *Archaeoastronomy,* 1981, *3*:1–16; David H. Kelley, "Astronomical Identities of Mesoamerican Gods," *ibid.,* 1980, *2*:1–54; Johanna Broda, "Astronomy, *Cosmovision,* and Ideology in Pre-Hispanic Mesoamerica," in *Ethnoastronomy and Archaeoastronomy,* ed. Aveni and Urton (cit. n. 4); Gary Urton, "Animals and Astronomy in the Quechua Universe," *Proceedings of the American Philosophical Society,* 1981, *125*:110–127.

[23] Berard Haile, *Starlore Among the Navaho* (Santa Fe, N.M.: Museum of Navajo Ceremonial Art, 1947).

[24] McCluskey, "Historical Archaeoastronomy" (cit. n. 20) p. 53.

> in their terrestrial and celestial environments. If these systems of knowledge are found to be similar to the system of those cultures located in northern temperate latitudes, then we will learn something of the cognitive unity of mankind. If they prove to be dissimilar, then we will be reassured of the human capacity for change and adaptation to diversity.[25]

The first possibility, to learn of cognitive unity, is the aim of the anthropological view. The second, to discover change and adaptation, is closer to the interests of the historian. Although the evidence is certainly not definitive in favor of either view, archaeoastronomy and ethnoastronomy provide intriguing ways of examining not only the physical results of scientific activity but also some thing of the cultural systems that produce that activity.

ETHNOBOTANY

The discovery of the Americas opened up to Europeans a vast new world of plant and animal life (among which native people were generally included). The intellectual tradition of natural science studies in Europe readily subsumed the exploration of the New World. Although the works of early observers treated the Indians as subjects rather than scientists, they include much important information about Indian uses of the environment, particularly plants. They have been extensively used in ethnohistorical studies of Indian tribes.

Spanish explorers provided accounts of Mesoamerican natural lore. Philip II of Spain sent his personal physician, Francisco Hernandez, to collect information in the new realms. Hernandez produced a major compendium of descriptions of plants, including Aztec knowledge of their forms and uses. The work did not reach the public until much later. Hernandez's sixteen manuscript volumes were deposited in the Escurial in Spain and destroyed by fire in 1671. An abbreviated version was published in Italy in 1628 by the Accademia dei Lincei (with a second edition in 1651). Fra Bernardino Sahagún, a Franciscan priest, compiled a vast amount of material from native Aztecs, but his *Historia general de las cosas de Nueva España* was intended to serve not as a treatise on natural history but as a guide to native superstitions so that they could be countered by the Catholic Church. His monumental work was not available to scholars until a partial version was published in 1831; several editions have appeared since.[26]

In North America, interest in native flora and fauna led to works such as John Josselyn's *New England's Rarities Discovered,* which recorded Indian uses of plants; Le Page du Pratz's extensive description of the flora and fauna of the lower Mississippi Valley region, in which Indians were described among the plants and fishes and animals; and Dumont de Montigny's description of the wonders of French Louisiana. The English naturalist William Bartram was probably the most systematic and scientific observer of North American flora and fauna (including Indians).[27]

[25] Aveni and Urton, intro. to *Ethnoastronomy and Archaeoastronomy,* p. 7.

[26] Francisco Hernandez, *Rerum medicarum Novae Hispaniae thesaurus, seu Plantarum animalium mineralium Mexicanorum historia* (Rome, 1628); Bernardino Sahagún, *Historia general de las cosas de Nueva España,* 5 vols. (Mexico: Editorial Pedro Robredo, 1938); and Sahagún, *General History of the Things of New Spain,* trans. Charles E. Dibble and Arthur J. O. Anderson, 13 parts (Santa Fe: Monographs of the School of American Research and the Museum of New Mexico, 1950–1965).

[27] John Josselyn, *New-Englands Rarities Discovered: In Birds, Beasts, Fishes, Serpents, and*

The long tradition of observing Indians and the natural environment carried over into studies in anthropology. Observations of Indians and their knowledge of plants and animals in their environments were popular in the first third of the twentieth century. A number of these studies contained the prefix "ethno" with some appended scientific category. Thus one finds J. P. Harrington's *Ethnogeography of the Tewa Indians,* Leland C. Wyman and Flora L. Bailey's *Navaho Indian Ethnoentomology,* Edward F. Castetter and Ruth Underhill's *Ethnobiology of the Papago Indians,* Junius Henderson and John P. Harrington's *Ethnozoology of the Tewa Indians,* and, among an array of ethnobotanies, W. W. Robbins, J. P. Harrington, and B. Freire Marreco's *Ethnobotany of the Tewa Indians* and Huron H. Smith's "Ethnobotany of Menomini Indians."[28]

These studies follow a general pattern—a brief ethnographic description of the tribe followed either by a narrative discussion of uses of plants or animals or by a list of their names (most often the Latin classification, but also the English, or sometimes native, name). There is occasional mention of some kind of native classification system, for instance, Smith's simple statement that the Ojibwa had one.[29] These studies generally do little more than fit native knowledge into Linnaean categories and describe uses of plants and animals.

Considerably more can be learned about classification systems when ethnographers and botanists collaborate. James Teit's field notes on the Thompson River Indians of Canada were edited by Elsie Viault Steedman, a botanist, and the introductory material includes a discussion of linguistic terms and how they indicate general terms for uses and similarities of form. Leland Wyman, a physician, and Stuart Harris, a botanist, worked together on the ethnobotany of the Navajo Indians. Although they correlated native knowledge of plants with botanical classification systems to develop Navajo species and genera, they also acknowledged the existence of the Navajo system that categorizes primarily by male and female, terms that designate not physical sexual characteristics but qualities associated by the Navajo with maleness and femaleness. One of the most extensive studies of native plant uses was done by Frances Densmore

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Plants of that Country; Together with the Physical and Chyrurgical Remedies wherewith the Native Constantly use to Cure their Distempers, Wounds, and Sores . . . (London, 1672); Antoine S. Le Page du Pratz, *Histoire de la Louisiana, Contenant la Découverte de ce vaste Pays, sa Description géographique; un Voyage dans les terres; l'Histoire Naturelle; les Moeurs, Coutumes & Religion des Naturels, avec leurs Origines* . . . , 3 vols. (Paris, 1758); Jean François Benjamin Dumont de Montigny, *Mémoires Historiques sur la Louisiane, . . . le climat la nature & les productions de ce pays; l'origine & la Religion des Sauvages qui l'habitent leurs moeurs & leurs coutumes &c.* 2 vols. (Paris, 1753); William Bartram, *Travels Through North & South Carolina, Georgia, East & West Florida, the Cherokee Country, the extensive Territories of the Muscogulges, or Creek Confederacy, and the Country of the Chactaws* . . . (Philadelphia, 1791).

[28] John Peabody Harrington, *The Ethnogeography of the Tewa Indians* (Twenty-ninth Annual Report of the Bureau of American Ethnology to the Secretary of the Smithsonian Institution, 1907–1908) (Washington, D.C.: GPO, 1909); Leland C. Wyman and Flora L. Bailey, *Navaho Indian Ethnoentomology* (Univ. New Mexico Publications in Anthropology, 12) (Albuquerque: Univ. New Mexico Press, 1964); Edward F. Castetter and Ruth Underhill, *The Ethnobiology of the Papago Indians* (Univ. New Mexico Bulletin, Biological Series, 4) (Albuquerque, N.M., 1935); Junius Henderson and John Peabody Harrington, *Ethnozoology of the Tewa Indians* (Bureau of American Ethnology Bulletin 56) (Washington, D.C.: GPO, 1914); Wilfred William Robbins, John Peabody Harrington, and Barbara Freire-Marreco, *Ethnobotany of the Tewa Indians* (Bureau of American Ethnology Bulletin 55) (Washington, D.C.: GPO, 1916); Huron H. Smith, "Ethnobotany of the Menomini Indians," *Bulletin of the Public Museum of Milwaukee,* 1923, *4*:1–174.

[29] Huron H. Smith, *Ethnobotany of the Ojibwa Indians* (Milwaukee: Public Museum of the City of Milwaukee, published by order of the trustees, 1932).

among the Chippewa (Ojibwa) of northern Minnesota. Although Densmore was an ethnomusicologist, she enlisted the aid of botanists and chemists to determine the classifications and chemical components of plants. She provided both native and scientific name, although she made no attempt herself to correlate native plant names with the Linnaean system. More recent studies by Nancy Turner have taken a new approach in ethnobotany. Turner and others have been interested in the food value of plants and have tested nutrients by scientific experiment. They have shown the extent to which native foods were more than adequate to the dietary needs of native people on the Northwest coast.[30]

Descriptions of native plant uses have been heavily oriented toward uses for curing. The work of Wyman and Harris, mentioned just above, is a good example. Ethnobotany has contributed much to knowledge about native medical practices. Daniel Moerman, in *American Medical Ethnobotany: A Reference Dictionary,* has made the attempt to describe systematically uses of plants for medicine in North American native tribes. Drawing on the content of twenty-one ethnobotanical studies and using a computer, he has correlated symptoms or conditions and the plants used to treat them. He points out the chemical components of plants that would cause reactions in the body. Moerman's bibliography is an excellent source of material on ethnobotany. Bernardo Ortiz de Montellano's description of "Empirical Aztec Medicine", already discussed, is a good source for Aztec ethnobotany.[31]

However, studies of native American medical practices other than herbal remedies have tended toward the incredulous, claiming that they were based mainly on trickery, or the too credulous, claiming that American Indians were repositories of knowledge of marvelous cures which have unfortunately been lost as Indian cultures have changed. Although history of medicine is a distinct undertaking in the history of science and not totally within the scope of this essay, several sources in the extensive literature on native American health are worthy of mention. Virgil J. Vogel's *American Indian Medicine* is a survey drawn from historical and ethnographic sources. Although it errs on the side of credulity, it brings together in one place a wide range of material. The appendix lists plants used by native tribes and indicates which have been included in the *United States Pharmacopia,* the standard reference work on drugs; it is a useful reference source, as is the bibliography. In the end, though, Vogel is a compiler, not an analyzer of native practices.[32]

[30] James A. Teit, "Ethnobotany of the Thompson Indians of British Columbia . . . , based on field notes by James A. Teit," ed. Elsie Viault Steedman, *Forty-fifth Annual Report of the Bureau of American Ethnology to the Secretary of the Smithsonian Institution, 1927–1928* (Washington, D.C.: GPO, 1930), pp. 441–552; Leland C. Wyman and Stuart K. Harris, *Navajo Indian Medical Ethnobotany* (Univ. New Mexico Bulletin, Anthropological Series, 3.5) (Albuquerque, 1941); Wyman and Harris, *The Ethnobotany of the Kayenta Navaho: An Analysis of the John and Louisa Wetherill Ethnobotanical Collection* (Albuquerque: Univ. New Mexico Press, 1951); Frances Densmore, "Uses of Plants by the Chippewa Indians," in *Forty-fourth Annual Report of the Bureau of American Ethnology to the Secretary of the Smithsonian Institution 1926–1927* (Washington, D.C.: GPO, 1928); Nancy J. Turner, "A Gift for the Taking: The Untapped Potential of Some Food Plants of North American Native Peoples," *Canadian Journal of Botany,* 1981, *59*:2331–2357; Turner and Harriet V. Kuhnlein, "Two Important 'Root' Foods of the Northwest Coast Indians: Springbank Clover (*Trifolium wormskioldii*) and Pacific Silverweed (*Potentilla anserina* ssp. *pacifica*)," *Economic Botany,* 1982, *36*:411–432; Turner, "Economic Importance of Black Tree Lichen (*Bryorica fremontii*) to the Indians of Western North America," *Econ. Bot.,* 1977, *31*:461–470.

[31] Daniel R. Moerman, *American Medical Ethnobotany: A Reference Dictionary* (New York: Garland, 1977); Ortiz de Montellano, "Empirical Aztec Medicine" (cit. n. 4).

[32] Virgil J. Vogel, *American Indian Medicine* (Norman: Univ. Oklahoma Press, 1970).

More useful are works that attempt to analyze these practices. Erwin Ackerknecht's collection of essays in *Medicine and Ethnology* is important because of its analytic nature. Ackerknecht is interested in native medicine worldwide, and he uses American Indian examples in addressing important questions, such as the role of shamans in curing. His approach is firmly based in Western psychological practices. He is, however, well aware of the nature of native beliefs and appreciates both the emic and etic views in regard to native medicine. Francisco Guerra's work on Aztec medicine employs a more strictly historical approach. Guerra bases his study on the material collected by Sahagún. His intent is to provide a cultural context for Aztec curing practices.[33]

An example of the melding of historical and Western medical approaches—one might say an ethnohistorical study of disease and curing—is an article by Charles Hudson, Ronald Butler, and Dennis Sikes on arthritis. The association of animals and disease, notably deer and arthritis in the southeastern United States, is based in cultural beliefs about the association of angry animal spirits and diseases as punishment. There is evidence for the possibility of transmission of diseases between animals and humans.[34]

Medicine is in many ways an art rather than a science. It is an art at which native people of the Americas were highly adept. Native medicine involved knowledge of the physical effects of natural substances on the human body and was also based on the ways in which people understood the actions of forces in the world around them as they affected their well-being.

AGRICULTURE

An important aspect of health is diet, and the development of stable food supplies through agriculture played an important part in the development of native cultures. Agriculture is another area of human activity in which observation and prediction play basic roles, and thus it represents another common ground between European and native science.

Agriculture figures prominently in the biological exchange between the Old World and the New—the diffusion of animals, foodstuffs, and diseases between continents. That subject has been treated by Alfred Crosby in *The Columbian Exchange: Biological and Cultural Consequences of 1492,* although he gives greater attention to the consequences in Europe than to those in the New World. Among the most important exchanges were those of domesticated crops.[35]

Domestication of crops is one of the most significant agricultural accomplishments ascribed to New World cultures. Richard Yarnell has discussed native uses of plant resources in the upper Great Lakes region, using archaeological techniques to identify plant remains and to indicate their role in the diet of the native inhabitants of the area. Yarnell thinks that the early people in this region

[33] Erwin H. Ackerknecht, *Medicine and Ethnology: Selected Essays,* ed. H. H. Walser and H. M. Koelbing (Bern: Hans Huber, 1971); Francisco Guerra, "Aztec Medicine," *Medical History,* 1966, *10*:315–338.

[34] Charles Hudson, Ronald Butler, and Dennis Sikes, "Arthritis in the Prehistoric Southeastern United States: Biological and Cultural Variables," *American Journal of Physical Anthropology,* 1975, *43*:57–62.

[35] Alfred W. Crosby, Jr., *The Columbian Exchange: Biological and Cultural Consequences of 1492* (Westport, Conn.: Greenwood, 1972).

may have domesticated some plants such as sunflowers. Corn is generally considered the triumph of Indian agriculture. The most extensive work on the development of corn is that of Paul Manglesdorf who deals with the genetic relationships between teosinte, which has been considered the ancestor of corn, tripsacum, another genetic relative, and domesticated corn. Manglesdorf says that teosinte is a hybrid of corn and tripsacum which subsequently crossed with corn to produce modern varieties. He denies that Indian people were consciously practicing breeding techniques to produce new strains of corn, although they were and are careful to preserve certain strains.[36]

Indian agricultural techniques included burning areas to clear fields and to promote the growth of wild plants. Henry T. Lewis has described the practices of the California Indians, who burned off chaparral areas in the foothills of the Sierras to promote better browsing grounds for deer and so improve their own hunting. Indians in the eastern woodlands use fire in a similar manner to control deer hunting and the forest cover, as Calvin Martin recounts. By periodically clearing the understory of forest land, Indians assured that they could move easily in their hunting grounds. More directly representative of agricultural technique is swiddening, the clearing of fields by fire; Mayan use of this technique is discussed below.[37]

Agriculture represents control over or the ability to predict environmental forces—rain, frosts, and supplies of water. Its stability depends ultimately upon control of water, and several native peoples practiced irrigation. Emil Haury has studied the archaeological remains of the extensive irrigation systems that allowed the rise of a sizeable community of Hohokam farmers in Arizona around A.D. 800. Michael Glassow has examined the Colorado Plateau region of the western United States, showing the patterns of field cultivation and water control that made the development of agriculture possible.[38]

Too much water can be as much of a problem as too little. William Denevan has discussed the use of raised planting areas in Mesoamerica, where lowland tropical areas were often flooded. The most notable example of this kind of control was the *chinimpas,* artificial islands created in swampy areas around Lake Tezcoco and in the lake by the Aztecs. The rich bottom mud from swamps and lakes was brought to the surface to create the floating gardens noted by the Spanish. Two other scholars who have focused on the role played by water control in Mayan agriculture have concluded that the Maya were not as dependent on swidden agriculture as earlier studies have led us to believe. B. L. Turner has maintained that lowland reclamation techniques allowed the Maya to practice intensive agriculture in lowland regions and so perhaps to support larger populations than possible with swidden agriculture. Turner thus calls into

[36] Richard A. Yarnell, *Aboriginal Relationships Between Culture and Plant Life in the Upper Great Lakes Region* (Univ. Michigan Anthropological Papers, 23) (Ann Arbor: Univ. Michigan Press, 1964); P. Weatherwax, *Indian Corn in Old America* (New York: Macmillan, 1954); Paul C. Manglesdorf, *Corn: Its Origin, Evolution and Improvement* (Cambridge, Mass.: Belknap Press of Harvard Univ. Press, 1974), pp. 35, 64.

[37] Henry T. Lewis, *Patterns of Indian Burning in California: Ecology and Ethnohistory* (Socorro, N.M.: Ballena Press, 1973); Calvin Martin, "Fire and Forest Structure in the Aboriginal Eastern Forest," *Indian Historian,* 1973, 6:38–42.

[38] Emil W. Haury, *The Hohokam: Desert Farmers and Craftsmen* (Tucson: Univ. Arizona Press, 1976); Michael Glassow, *Prehistoric Agricultural Development in the Northern Southwest: A Study in Changing Patterns of Land Use* (Socorro, N.M.: Ballena Press, 1980).

doubt the theory that increased population with resultant increases of swidden agriculture and concomitant deforestation and decline of agricultural productivity led to the collapse of Classic Maya civilization between 790 and 950. Ray Matheny has investigated agricultural systems in both the highlands and lowlands of traditional Maya territory. He has concluded that there were significant agricultural practices beyond the swidden techniques generally attributed to the Maya, and that they were capable of terracing and water management in highlands and of raised-bed and ridge farming in marshy, low-lying areas.[39]

TECHNOLOGY

Where human activity focuses on control of the environment rather than prediction of changes in it, it is usually called technology rather than science. Although native practices may have been relegated to the realm of technology, they are obviously based on the ability to predict events, as in the case of agriculturalists who used the stars to indicate planting seasons. However, native knowledge was generally more practical than theoretical.

In certain areas technology of a highly sophisticated sort played an important role in Indian cultures. Ethnographic studies of native American cultures have included much information about the material culture of native people, and their technologies have been well presented. The Andean region of South America is particularly renowned for its unexcelled examples of weaving techniques and metalworking. Both have been extensively studied as examples of material culture. However, a recent and intriguing study goes beyond the purely material to a study of Andean values systems as they are exemplified in metallurgy. Heather Lechtman discusses the concern of cultures in the Andean region with form as well as substance. She analyzes techniques of gold plating and the importance of investing external forms with cultural meaning. The plating of shapes with gold reflected cultural values associated with those forms and thus gives additional meaning to the technology involved. An intriguing combination of technology and mathematics is represented by the *quipu,* the knotted cord that was a record-keeping and possibly mnemonic device of the Incas. Marcia and Robert Ascher argue that the *quipu* may be evidence of sophisticated mathematical ability as well as of sophisticated weaving techniques, although their interpretation is problematic.[40]

Form and meaning in native American cultures are more directly related than in contemporary American culture. Symbol, myth, and ritual certainly played more important roles in native cultures than they do in American society today. Mythology and ritual in Indian cultures have been associated with religion, as natural law has been associated with science. Studies such as Lechtman's can

[39] William M. Denevan, "Aboriginal Drained-Field Cultivation in the Americas," *Science,* 1970, *169*:647–654; Pedro Armillas, "Gardens on Swamps," *Science,* 1971, *174*:653–661; B. L. Turner, II, "Prehistoric Intensive Agriculture in the Mayan Lowlands," *Science,* 1974, *185*:118–124; Ray T. Matheny, "Maya Lowland Hydraulic Systems," *Science,* 1976, *193*:639–645; Matheny and Deanne L. Gurr, "Ancient Hydraulic Techniques in the Chiapas Highlands," *American Scientist,* 1979, *67*:441–449.

[40] Heather Lechtman, "Andean Value Systems and the Development of Prehistoric Metallurgy," *Technology and Culture,* 1984, *25*:1–36; Marcia Ascher and Robert Ascher, *Code of the Quipu Databook* (Ann Arbor: Univ. Michigan Press, 1978).

reveal the reasons behind technology, and an understanding of Inca culture may finally provide a clue to unraveling the meaning of the *quipu*.

FUTURE DIRECTIONS

Ethnohistory, ethnoscience, and the various ethnobotanies, ethnogeographies, ethnoentomologies, and other "ethno" studies indicate the wide range of disciplines and interests that have been involved in the study of native cultures of the New World. The studies have often been purely descriptive of the ways in which native people perceived, predicted events in, and controlled their environments.

Historians of science have increasingly been interested in the social and cultural context of scientific activity. Anthropologists have always been interested in the cultural context. The problem of combining the diachronic and the synchronic approaches of the two fields has already been mentioned. The possibilities for development, however, are rich. Native cultures in the New World had ways of organizing metaphysical concepts and physical reality into cultural wholes, as Lechtman has demonstrated for metallurgy and Kelley and Urton have demonstrated for astronomy.

Students of native science in the future must look to the native view of the world to understand the activities that they would classify as scientific and to understand that there are many activities that can be classified as scientific within an appropriately broad framework. They can look for elements of control and prediction not only in archaeological remains but also in mythology and ritual. They can realize that the activities of native people can be judged by criteria that do not necessarily reflect only the Greco-Roman, Judeo-Christian, Western scientific world view of modern society.

For those who wish to pursue such studies, the major source of bibliographic information on ethnographic studies of North American tribes is George Murdock's *Ethnographic Bibliography of North America*. It is divided by major cultural areas, subdivided by tribal groups, and includes both books and articles, current to 1975. Still a standard source of citations to ethnographic descriptions, it will provide good background for any serious student of North American tribes who wishes to examine their science. Mark Barrow, Jerry Niswander, and Robert Fortuine have compiled a bibliography of medicine that will also be useful. Richard Ford, whose work in American Indian ethnobotany has been very important, has published an overview of that topic. Stephen McCluskey's article "Archaeoastronomy, Ethnoastronomy and the History of Science" is a cogent discussion of the need for resolving distinctions between "primitive" and "scientific" world views. It also lists major sources in the field.[41]

Since there is no commonly accepted definition of native American science,

[41] George Peter Murdock, *Ethnographic Bibliography of North America*, 5 vols. (New Haven, Conn.: Human Relations Area Files, 1975); Mark V. Barrow, Jerry D. Niswander, and Robert Fortuine, *Health and Disease of American Indians North of Mexico: A Bibliography, 1800–1969* (Gainesville: Univ. Florida Press, 1972); Richard I. Ford, "Ethnobotany: Historical Diversity and Synthesis," in *The Nature and Status of Ethnobotany*, ed. Richard I. Ford (Anthropological Papers, Museum of Anthropology, Univ. Michigan, 67) (Ann Arbor, 1978), pp. 33–49; Stephen C. McCluskey, "Archaeoastronomy, Ethnoastronomy, and the History of Science," in *Ethnoastronomy and Archaeoastronomy*, ed. Aveni and Urton (cit. n. 4).

pertinent studies are scattered in a variety of disciplinary journals—*Antiquity* (for archaeological studies), *American Anthropologist, Ethnohistory, Economic Botany,* and *Archaeoastronomy*. There are two journals by the latter name, one an offshoot of the *Journal for the History of Astronomy* and the other the specialized publication of the Center for the Study of Archaeoastronomy at the University of Maryland. There is a journal devoted specifically to ethnobiology (*The Journal of Ethnobiology*).

The various approaches to the study of native American science should continue to produce new information, and a greater appreciation of the many forms of native investigation and explanation of the natural environment will produce exchange of ideas among scholars adopting these approaches. The field needs new directions in research toward understanding cultural systems of thought about the physical world and its explanation. Ultimately, the study of the history of native American science can meld archaeology, anthropology, and history and can enrich the history of science with a way of seeing culture as a system of belief that influences the responses of people to the understanding of the natural phenomena around them.