On a clear, cold predawn morning in Arizona, a Hopi man leaves his home and walks some distance to a rise of land near his village. He settles himself at the top of the rise to watch in the growing light for the sun to make its first appearance above the eastern horizon. The Hopi sun watcher on this morning is carrying out a duty that his ancestors were carrying out in 1492 when Columbus first sighted land from the deck of the Santa Maria, and when Francisco Coronado first arrived in the country of the Pueblo peoples in 1540. Throughout the months before the winter solstice, the sun watcher sights the progress of the sun along the horizon, observing its points of rising by natural markers such as hilltops and valleys, and, in the present, by the point of rising over the roof of the Hopi Cultural Center on Second Mesa.

The sun watcher’s observations of the sun’s movements allow him to tell the leaders of his village when the sun will reach a certain point in its travels across the sky. There, the sun has reached the extent of its southernmost journey and will rest before it resumes its travels back across the sky toward its northern house. The observation of the winter solstice is a key to the timing of the Soyal Ceremony, which celebrates the first appearance of the kachina spirits in the villages. The kachinas, the spirits who bring rain and fertile crops, are an essential part of Hopi life. The solstice is also the predictor of the change of the seasons that is crucially important to people who depend on agriculture for their subsistence. It is essential to know the time of the last killing frost so that planting may begin.

In Pueblo towns the chief priest had among his duties the responsibility for tracking the movements of heavenly bodies, particularly the sun. This idealized picture of a cliff dwelling by a nineteenth-century American anthropologist includes a tower kiva from which such observations were made. Courtesy of the National Museum of the American Indian.
A tool for straightening the wooden shafts of arrows. While straighteners were present in all parts of the Americas, this one (made of ivory) was found by archaeologists in western Alaska. Courtesy of the Field Museum of Natural History.

The sun watcher’s observations allow him to predict the future actions of the environment—that is, that cold weather and frost will cease and that plants will be able to grow. The sun watcher can tell not only when the sun reaches the extreme points of its path across the sky; he can also tell where the moon stands in relation to the sun during the year. He can tell when the moon will appear each month, and what time of night it will rise. By observing not only the points of solstice but the relationship of the moon to the sun throughout the yearly cycle of the seasons, the Hopis demonstrate, as they have for centuries, a sophisticated understanding of celestial relationships that have been integral to their own subsistence patterns, because they predict planting and harvesting seasons.

Prediction in 1492 was also an essential aspect of science as it was understood by the Europeans who first arrived in the New World. The same kind of sophisticated celestial observations that governed Hopi agriculture allowed Columbus to find his way across the uncharted waters of the Atlantic. He simply did not know about the landmass that stood in the way of his passage to India. But his skill at navigation was based on a tradition of systematic observation of nature that characterized both the Hopi Indians and the European explorers in 1492. The science that brought Columbus to the New World stemmed from an intellectual heritage of inquiry about how the natural world worked. In that respect, Columbus and the Hopi sun watcher shared a common belief—that there were patterns in nature that were important. Those patterns allowed people to predict what future events would happen in their worlds.

Although there were similarities in the traditions of observation of natural phenomena that allowed the Hopi sun watcher to know about the turning of the sun and Columbus to reach America, there were significant differences in the ways that each explained the reasons for the sun’s motion. To the Hopis, the sun was a being who acted of his own will, albeit in predictable ways. To Columbus and the intellectual tradition predominant in Europe in 1492, the sun was a physical object moving according to predictable patterns that never varied. But to both Columbus and the Hopis, the sun revolved around the earth. And the idea that physical bodies could have will was very much a part of European science. The intellectuals of the time explained falling bodies in terms of natural place, an Aristotelian belief that objects fell because they had an inherent desire to reach their natural place (the center of the world). And natural place explained gravity.

The terms “science” and “technology” in the modern world carry the learning of the last five centuries of knowledge and experience. They mean many different things now than they did in 1492, and the practices of the Native Americans of that period cannot be judged by present-day understandings of those terms. The science and technology of the New World in 1492 must be understood in the context of what Europeans understood about the world then. It was full of intangible forces that acted on things. Philosopher’s stones could transmute base metals into gold. Invisible fluids could move between objects to influence their behavior. To the common and uneducated people of Europe, the world was alive with spirits who lived in the woods, and witches and others had powers to manipulate the forces of the world to cause illness or bad luck.

The real divergence of Native American and European beliefs about the nature of the world came after 1492. In Europe, the rational traditions of the Greeks came increasingly to mean natural laws. They melded with Christian beliefs in an omniscient, omnipotent, and omnipresent God, and nature ceased to be spiritual and became increasingly material and governed by the will of that God.

In 1492, although their ways of understanding the natural environment may have differed, both Europeans and Native Americans had similar ends in view—to be able to control the outcome of events in the world around them. Knowledge of the environment came from systematic observation of a body of physical phenomena that existed apart from human beings (a statement of belief in itself), and that knowledge allowed humans to exercise a measure of control over the forces of nature and to predict the outcomes of situations and their own actions.

One way of controlling the environment is to utilize human energy more efficiently through the use of machines, what one generally calls technology. Native people of 1492 used the same kind of simple machines that Europeans did, although they did not theorize about why they worked. Many machines
in Europe were more complex, but they were based on the five simple machines of classical Greek mechanics: the wedge, the inclined plane, the level, the pulley, and the screw. The point of a machine is that it increases the force exerted on it. On the Northwest Coast of North America, there were examples of mechanical devices. Gigantic cedar trees were sometimes felled by chipping cavities into their sides with an adze (an application of the wedge) and setting a slow fire therein. The trunk burned through until the tree toppled. Cedar is straight-grained and splits easily. To split cedar logs into planks, Indian men would open a small split in the side of a log and then drive in a series of wooden wedges to widen the split until a plank could be peeled off. A simple pulley was used in a Plains Indian medical technique. To reset a dislocated joint, a man would tie a rawhide rope around the affected limb, throw the rope over a tree branch, and pull on it—a generally effective method of exerting sufficient force to pop the joint back into place.

Some of the techniques for making things were simply and sheerly ingenious. To build canoes, Haida craftsmen smoothed the outside of a giant log to the appropriate shape, burned into it with slow fires, and chipped away the charred wood to form the canoe. At the crucial stage of hollowing the shell to a uniform thickness, very small pegs of the desired length were driven through the outside, and as the carver smoothed the inside, he could tell that he had reached the desired thickness when the tops of the pegs appeared.

Beyond this use of technology, Europeans and Indians of 1492 shared the practice of systematic observation of natural phenomena. They predicted the outcome of events on the basis of those phenomena. While European intellectuals of the fifteenth century looked for ultimate causes whose results could always be predicted, the native peoples exercised control over the forces of nature by establishing personal relationships with spirit beings through ceremonial actions or visionary experiences or dreams. These personal relationships allowed people to call on the spirits for assistance in obtaining desired results. To Europeans, the natural world was ruled by laws; to native people, it exercised will. To both, it was the object of careful observation which led to ability to predict the outcome of events. Native American science in 1492, then, constituted the activities of the native peoples of the New World in observing physical phenomena and attempting to explain and control them.

The major point at which European and native science diverged was in the matter of experimentation. It would not have occurred to the Hopis to cease their ceremonies to see if the sun would indeed continue north rather than turning in its path. However, by the late seventeenth century, European scientists believed that they could test the outcomes of events by controlling the circumstances and observing the results. Modern science is concerned with proof of scientific hypotheses—that is, their power to predict the outcome of a set of circumstances controlled by the experimenter. Native people believed
that their personal relationships or the formal relationships of their groups with spiritual forces would bring about results. Thus, the ceremony performed by the Hopis at the instance of the sun watcher’s observations of the solstice actually caused the sun to turn in its journey and return across the sky.

Another principle of twentieth-century science is the importance of uniformity in nature. European science by the eighteenth century was concerned with similarities of things and events that would indicate natural order. However, to native people, importance was attached to the unusual, the mutable or changeable.

A. Irving Hallowell, an anthropologist working in Canada in the 1930s, asked a Saulteaux (Ojibwa) Indian man, “Are all the stones we see around us alive?” and after the man had thought about the question a while, he replied, “No, but some are.” To Hallowell as a scientist, it is the “all” that was important. He was looking for a generalizable principle. To the Saulteaux man, it was the “some” that were significant—those rocks that exhibited some unusual behavior, that were observed to move of their own volition, or to speak to people. These attributes were signs of special spiritual power. These actions reinforced the idea of the reality of spiritual beings acting in nature.

This is not to say that Native Americans were not interested in the similarities of things, or that they did not put things into categories. It is simply to say that things that were unusual were of greater interest than things that were similar.

The ways in which people classify things indicate what qualities or characteristics are most important to them. Aristotelian categories of earth, air, fire, and water reduced the diversity of phenomena to a few elemental forms and qualities. The modern system of scientific plant classification, the Linnaean system (devised by Carl von Linné in 1735), is generally accepted as a significant achievement in Western science. It divides plants into categories based on sexual characteristics and other morphological features.

Indians were also interested in similarities of form and function, and one can find many examples of New World naming systems that classified things or indicated similarities. The categories that native people devised were based on systematic observation, as were European systems. The difference was in the elements that were considered similar.

Plants were closely observed and widely used, and there were many examples of classificatory names. The Navajos characterized plants as male and female, depending on characteristics such as size and hardness or softness of stems and foliage. The system was based on analogy to personality traits distinguishing men and women, rather than on the idea of the physical sexual characteristics of plants.

The Aztecs used three major categories of plants: trees (quauhtli), bushes (quaquauhizin), and herbs (xihuitl). Plant names generally included a word or suffix that indicated whether they were food (quii'il), ornamental (yoohitl), medicinal (patli), or economic, or plants used for building, clothing, or material objects, for which a number of suffixes were used. The Thompson Indians of British Columbia named some plants according to their use, as ililu'nál, "cough medicine," or cucxuxura, "grizzly bear berry," one eaten by grizzly bears. They also recognized categories in the fact that certain plants generally grew together, and they could predict the presence of them together. Thus, they named the wood betony "companion of willow weed," because they found it with the willow.

Indian classifications were not always based on physical properties. The Navajos put bats in the same category as insects because of an origin tradition in which insects and bats had lived together in a previous world. The badger was classified with the wolf, mountain lion, bobcat, and lynx (which were grouped as predatory animals) because he was their friend.

Classification systems were important to native people, and they revealed the results of careful observation and thinking about the nature of the world. The categories in those systems were more likely to be based on their usefulness to humans or associations with other beings in the physical world than to simple physical form. Contemporary science judges the validity of Native American classification systems by how well the Indian names distinguished among animals and plants of different genera and species—that is, how closely native people recognized the same features that scientists do. The Tzeltal Maya in Chiapas, Mexico, for example, distinguished relatively few of the modernly designated botanical categories of plants in their environment. They did, however, distinguish a number of different kinds of beans within a single currently known species. They also lumped numbers of species together in single names. In other words, they found many differences in plants that were important to them, and very few in those that were not.

The observation of plants directed the Native Americans’ attention to their immediate surroundings and the cycles of life and death of living things. They noted the conjunction of those cycles with events in the sky above them, and they regulated their own lives by the movements of the sun, moon, and stars. The systematic observation of the movement of celestial bodies constituted one of the most dramatic facets of Native American scientific activity.

In 1492, astronomy in Europe was primarily the basis for astrology—that is, the prediction of human events. The earth was the center of the universe. The Copernican doctrine of the sun-centered universe had yet to be proposed. The movements of the earth and the planets were observed against the background of the fixed stars with their distinctive patterns that constituted the zodiac. Observations were oriented toward events occurring overhead, and those events were thought to have a significant impact on the lives of humans on the earth.
A bone handle from Mexico covered with marks of day signs designating particular dates, probably birthdays or other important family events. In 1492, calendrics were important regulators of daily life throughout Mesoamerica. Courtesy of the Milwaukee Public Museum.

In the Americas, at the same time, the horizon was the main reference point for observation of celestial events. Although some observations of zenith events—those directly overhead—took place, the horizon was still the most important marker. We can infer this fact from the numerous orientations of physical structures or their parts to events occurring on the horizon, and it distinguished Native American from European astronomy.

The horizon-based system of observation led to practices such as those of the Hopi sun watcher. Throughout North and South America, people built structures that aligned with certain points on the horizon where important celestial events took place. These structures allowed for observation of regularly recurring phenomena. In the ruins of pueblos dating back to at least A.D. 1200 in the present-day U.S. Southwest, there is evidence of Indian knowledge that the sun moved in relation to the earth in regular cycles. Casa Rinconada, a large circular kiva in the Chaco Canyon region of northwestern New Mexico, has twenty-eight niches spaced equally around the interior of its stone wall. It also has six somewhat larger and irregularly spaced niches below those. At the time of the summer solstice, for four or five days around that date, light from a window placed high on the northeastern side of the kiva shines on one of the six niches.

Some of the curiously placed corner windows of the ruins of Pueblo Bonito in Chaco Canyon have also been examined as possible observation sites for solstices or other celestial phenomena. Although the condition of the ruins makes it hard to determine exact alignments, the unusual placement of the windows draws attention to them. It seems that they were there for a specific purpose, and when the light of the rising sun at the summer solstice shines directly through a window into the room beyond it, the purpose becomes clear. The window was placed to alert the occupants of the dwelling that a crucial point in the year had arrived.

On Fajada Butte, near the large pueblo ruins in the canyon, is another apparent pre-Columbian observation site. There, three large rock slabs rest on a small outcropping and lean against the side of the butte. In 1989, one of the slabs shifted slightly, but prior to that time, on the day of the summer solstice, a thin dagger of sunlight passed through the exact center of a spiral design carved into the butte's side behind the rocks. At the winter solstice, two daggers of light just grazed the sides of the spiral. Whether the placement of the stone slabs was deliberate or accidental, the spiral in the rock is definitely of human origin, and the conjunction of light and shadow with the spiral made the sun dagger a solstice marker.

On a bluff among the Big Horn Mountains in Wyoming there is another site, also obviously the product of human activity. Known as the Medicine Wheel, it consists of a ring of piled stones or cairns, some twelve feet in diameter, from which twenty-eight stone spokes radiate to an outer stone circle abutting six other piled-stone cairns. The point of the rising of the summer solstice sun can be observed along a line sighting from one of the outer cairns across the center cairn. Other lines along the spokes of the wheel serve to sight the rising of the bright stars Rigel and Aldebaran, which precede the solstice by a matter of weeks.

Constructions such as the Medicine Wheel are evidence that systematic observation of the stars and knowledge of celestial occurrences allowed people to predict important events. If the Indians of North America did not have written languages, they recorded their observations in other ways. The Medicine Wheel both predicted and marked the summer solstice.

There are remains of many medicine wheels in North America. Two sites in the territory of the Blackfeet in modern Saskatchewan show evidence of the placement of stones similar to that of the Medicine Wheel in Wyoming. The orientation of lines of boulders and stone cairns on Moose Mountain points to the summer solstice. Other alignments toward the rising of Sirius and Al-
debaran can also be observed. The Blackfeet traditionally had calendar men who used bundles of sticks to mark the time for certain ceremonies, and although contemporary Blackfeet elders deny knowledge of a connection between the stones and the solstice, these boulders might have been placed to help the calendar men correlate their stick counts with the solar year. The coincidence between the orientations and the knowledge of calendar men that allowed the timing of the ceremonies may indicate the observational powers of the Blackfeet.

The sun is the largest and most observable of celestial bodies, and the solstices are crucial events in the lives of agricultural people because they mark the changing of seasons. But other celestial bodies were used as markers as well. The Pleiades were an important point of reference for astronomical observation. The Pleiades appear in the sky in the fall, and they remain in the night sky in the Northern Hemisphere until the spring, when they disappear below the horizon. The dates of their first and last appearance depend upon the latitude of the observer. However, their presence corresponds generally with the planting seasons of agriculturalists. They appear at about the time of the first killing frost, and they remain in the sky until about the time of the last frost. They are thus a distinctive marker of the seasons.

At approximately 42 degrees north latitude, the Seneca communities in present-day New York State observed the first rising of the Pleiades by the middle of October. They timed the beginning of their traditional Midwinter Ceremony by the passage of the Pleiades directly above the central longhouses of their villages. This event happened in early February, and it predicted the beginning of their planting season. The Pleiades disappeared from the night sky in about mid-May. The type of corn grown by the Senecas required approximately 120 days of frost-free weather to appear and mature. The zenith passage of the Pleiades in mid-February marked the midpoint of the frost season. The disappearance of the Pleiades from the sky about May 5-19 and their reappearance around October 10-15 encompassed a period of 153 to 163 days, a comfortable margin for the growth of corn.

The Pleiades were observed by agricultural people throughout North America, and various explanations were given for their origin. A charming story related by Sauk and Fox Indians in the heart of the continent told of six brothers, and the youngest brother's little dog, who were hunting one day. They began to chase a particularly large and strong buffalo. As they pursued the beast, they suddenly realized that they had left the earth and were running up to the sky. But it was too late to stop, and so they had to continue the chase forever. The six bright stars of the Pleiades are the six brothers, and the faint seventh star is the youngest hunter's little dog. The story is myth rather than scientific explanation. It is important because it reveals how Native Americans related to the phenomena of their world on a personal basis. It embodies, however, an understanding of the importance of the appearance of the Pleiades as a significant, predictable event in nature.

The Aztecs observed the Pleiades for a different, but equally important, reason. Their zenith passage marked the end of one of the significant cycles of the Aztecs' calendar system. When the Pleiades passed directly overhead at midnight in the final year of the 52-year cycle called the Calendar Round, a ceremony named toxiuhmolpilia, or "Binding of the Years," occurred. The event was marked by a period of sweeping and cleaning and disposing of rubbish, the putting out of old fires, a ceremonial procession to a temple in the city of Tenochtitlan, and a human sacrifice; the victim's chest was cut open and in the cavity a new fire was kindled. New fires were then lit throughout the empire, and the Aztecs were assured that their world would continue. The 52-year cycle marked by this ceremony was a conjunction of two different Aztec calendrical systems—one of which had no connection with the seasons—that were profoundly important in Aztec life.
Although explanations of the origins of heavenly bodies varied significantly among the different peoples of the Americas, the physical reality of the phenomena of the sky existed for all of them. Recognizable cycles in the sky corresponded to cycles in the peoples' lives, and, as stated, were particularly crucial to agriculturalists. But among some societies, the passage of time itself became important, and observations of complex cycles of celestial events were recorded.

Chichen Itzá is a Mayan site in Yucatán dating to about A.D. 800. There, a curiously shaped and partially ruined tower, the Caracol, resembles closely a modern astronomical observatory. It is a circular tower rising two stories above a flat-topped base. Sir Eric Thompson, the eminent Mayanist, described it as "a 2-decker wedding cake on the square carton in which it came." It has four outer doors oriented toward the cardinal directions, and inside is a circular corridor, from which four doors open into yet another round corridor. That inner one surrounds a central core within which is a spiral staircase leading to the top of the tower. Near the top, three shafts (originally six) pierce the thick walls. These shafts serve as observing sites. They align with the vernal and autumnal equinoxes, when the sun rises in the midpoint of one or the other of two shafts. The appearance of the Pleiades in the fall and their disappearance on the date of the vernal equinox can be observed from the tower. In addition, the alignments, corresponding to the most northern and southern risings of Venus on the western horizon, allowed prediction of the heliacal rising—or the first appearance of the star in the sky just before sunrise—on the eastern horizon. The importance of these observations reflected the significance of the planet in the lives of the Mayas.

The appearance of Venus as the morning star at sunrise or the evening star at sunset is impressive. After the sun and the moon, it is the brightest object in the sky. Its movements are closely related to those of the sun, but it is elusive in that it disappears for periods of time. The Mayas called Venus noh ek (great star) and chac ek (red star), and they followed its movements through the sky closely. They knew that Venus completed its apparent orbit around the sun in 584 days, although the concept of physical bodies spinning in endless space was foreign to them. Venus was a deity, not only to be observed but prayed to and propitiated with sacrifices. They knew that Venus was present in the sky as the morning star for 236 days, invisible then for a period of 90 days, that it reappeared as the evening star for 250 days, and was invisible again for a period of 8 days. That the Mayas knew these things about Venus we know from examination of one of the few surviving records written in the Mayan pictographic language, a codex now housed in Dresden.

From a handful of such codices, scholars have tried to reconstruct the calendar system devised by the Mayas and later appropriated by the Aztecs. That system constituted a significant intellectual and scientific achievement. It also comprised a system of thought much different from that of the Europeans who arrived in the New World in 1492, who subsequently destroyed most of the codices that preserved Mayan knowledge.

The fragments of their knowledge that still exist lay out numerical systems that present-day scientists can recognize because they resemble those of twentieth-century science. They tell virtually nothing, however, about the premises from which the makers of the calendars proceeded. Similarly, a ceremony like the Binding of the Years explains something of the importance of cycles to the Aztecs, but the processes of deduction from observed events cannot be reconstructed. From the numerically recorded results of these systems, we must work backward to try to reconstruct the systems on which they were based. Whereas modern mathematics works from premise to result, we must work from result to premise.
The Mayan calendar system counted time by two systems. One was a sacred calendar of 260 days (the tzolkin) formed by the interlocking of a series of 20 named days (as we name the days of the week) and a series of 13 numbers (as we count 29, 30, or 31 days in a month). Since the 20 named days had to go around 13 times to get back to the beginning of their cycle, there were 260 days in this sacred year.

The origin of the 260-day year, unique among calendar systems, is obscure. One theory is that it is based on the major interval between two zenith passages of the sun—260 days. Observation of this 260-day interval can be made near the Mayan city of Copán in present-day Honduras, which is at approximately 15 degrees north latitude. Here the sun passes directly overhead at intervals of 260 and 105 days. It is important to keep in mind that the 365-day year is an arbitrary convention, since the earth actually completes its path around the sun in somewhat over 365 1/4 days. The insertion of a leap day every four years is necessary to keep the calendar aligned with actual seasons, and even so, periodic adjustments of several days have been made throughout history. The Mayan calendar had no such arbitrary adjustment, and over time, the calendar months drifted through the seasons. That is, by a modern calendar system, the month of May would at some point occur in midwinter. For the Mayas near Copán, the passage of the sun overhead at intervals of 260 and 105 days was an absolutely predictable event. They were also aware, however, of the number of days that their calendar was ahead of or behind the seasons, and they knew that it took 1,508 of their calendar years for it to realign with the seasons.

The two zenith passings divide the solar year into periods of 260 and approximately 105 days, and the latter period was the typical planting season. For this reason, the tzolkin may indeed have had some correlation to the environment, although its purpose in the lives of the Mayas was, and remains,

The Mayans tracked the passage of time with two major calendars that operated simultaneously. In their everyday activities, they followed the 260-day calendar on the left. Each day sign was the combination of a number, from 1 to 13, with a day glyph, one of 20 such. (In this example, "8 Ben" is followed by "9 Ik." In the lower left are indicated the names for groups of days (kin, uinal, tun, etc.).) On the right is a 360-day calendar, used apparently for ceremonial or political purposes, in which the day signs were each composed of one of 18 numbers and one of 20 glyphs. Here, too, both parts of the day sign changed every day. For this second calendar, a 5-day interlude called an uayeb occurs at the end of each 360-day cycle. Each day sign functioned like a horoscope for the Mayas. In addition, points at which the two calendars converged were regarded as cosmic junctures which required ritual renewal. The most important of these occurred at the end of 52 years, when the two calendars coincided. There was also the "great cycle," made up of 100 52-year cycles. The Mayas' first Great Cycle is still in progress.
A pottery jar in the shape of a squash, probably Mochean. One of the earliest New World domesticated plants, squash came in many varieties and had many functions, from food to containers and ornaments. Courtesy of the Field Museum of Natural History.

more important for prediction of events in a person's life—that is, for its astrological significance. Other theories relate the 260-day year to the cycle of the planet Venus, to the 260-day gestation period of the human female, and to the base 20 numerical system of the Mayas. Whatever its origin, it was profoundly important to the Mayan calendar system.

The Mayas also had a year that corresponded roughly to a solar year—the 365 ¼ days that it takes the earth to return to its same position relative to the sun in its revolution. That year was marked by 18 named months, each consisting of 20 numbered days. At the end of the cycle, a period of five days was added. These days had religious significance since they were an addition to the regular cycle, and they marked a period of uncertainty before the next cycle of months and days began. But, again, it must be remembered that the Mayas did not attempt to keep this calendar in line with the seasons by inserting a leap day every four years. Indeed, the calendar gained time on the seasons without any correction. Generally translated as the Vague Year, its purpose was not to keep time for seasonal planting activities. Rather, this Mayan calendar followed progressions of days through cycles. The Vague Year's purpose was more likely to mark certain ceremonial or political events. Since it was not concerned with strict correlation with the seasons, it indicated concerns beyond those of pure subsistence.

Another major cycle was made up of the respective revolutions of the sacred and calendar years. Like two interlocking gears, the 260-day tzolkin and the 365-day solar year began at a certain point and revolved against each other until that same point was reached again. It took 18,980 days (or 52 years) to complete this cycle, which was known as the Calendar Round. The Round gave a unique identity to each day in the cycle, and it made it possible to record unique historical events.

Finally, the Mayas had a day count, by which they reckoned the absolute number of days in their history. As Europeans reckoned their era from the birth of Christ, so the Mayas reckoned theirs from an event far back in time. The uncertainties of interpretation of the Mayan hieroglyphic system have made it difficult to know precisely what that first event was or to correlate it with certainty with the Europeans' calendar. However, using best estimates from interpolations of the Mayan calendar, their day count went back to approximately the fourth millennium B.C. A specific date that has been proposed for the beginning of the Long Count is August 11, 3114 B.C. It is far earlier than the accepted beginning date of precursors of the Mayas among whom the intellectual tradition of the calendar system started. But the number of days in the Long Count is certain from pure mathematical manipulation. What we may well have is a native record of what can be described as mythic time—that is, a count back to a point before anything literally within human memory or written record.

One of the most intriguing aspects of the Mayan astronomical system was the importance of Venus. Its synodic period of 584 days was observable from the earth as two cycles. The orbit of Venus is closer to the sun than that of the earth, and so when the three bodies begin from a common point, Venus is visible from the earth for a period of time, then disappears behind the sun as it seems to speed ahead of the earth, and reappears for a time before it, the earth, and the sun reach the same point in the sky once again. The Venus table in the Mayas' Dresden Codex recorded time periods that corresponded to the number of days that Venus was visible from the earth as the very bright morning star. Although the numerical values in the table were consistent in recording the 584-day cycle of Venus, they did not correspond closely with the actual intervals of the planet's disappearance in the sky. Several conventions were designed to bring the numbers and the actual dates of sightings into alignment. But it is clear that the Venus table corresponded with some reality other than purely physical observations. It appears likely, too, that the Venus table served as a marker for ceremonial or political events.

The Mayas also observed the cycles of the moon. These cycles comprised one of the most obvious celestial phenomena, but it was also obvious that they did not correlate with the cycle of the sun that constituted a solar and seasonal year. The Hopi sun watcher recognized that fact. Various calendar systems use moon cycles to record important events. The Christian celebration of Easter, for instance, is timed to the first Sunday after the first full moon that follows the vernal equinox. The Mayas not only observed the cycles of the moon but recorded one of their most dramatic features, the periodic eclipses.
Observations of the moon in modern scientific terms are complicated because it has phases and it appears in different parts of the sky in its different phases. Eclipses are likely to occur at certain points in the conjunction of the moon's orbit around the earth and the earth's orbit around the sun. The plane of the moon's orbit around the earth is inclined about 5 degrees from the plane of the orbit of the earth around the sun. If one could envision a juggler spinning rings around a central point, with the sun and moon as points on the rings, these intersecting orbital planes become clear. The conjunction of these planes at certain points, called nodes, produces the condition where the shadow of the earth blocks the sun's rays that illuminate the moon, creating a lunar eclipse.

The Dresden Codex contains a table in which two numbers, 6,584 and 177, predominate, and an occasional 148 appears. The first number corresponds to the number of days in the saros cycle—similar patterns of eclipses that repeat, beginning every 6,584 days. A period of 177 days is equivalent to six cycles of the moon, at the end of which it is possible for the orbits of the earth and moon to cross each other in a way that causes an eclipse. A person observing the night sky on a regular basis would see a full or partial eclipse of the moon after some sequence of periods of 177 days, or within a period of days that could be broken down into sequences of 177 and 148 days.

Although their own reasons for observing celestial phenomena were religious and political, rather than scientific, the Mayas demonstrated their keen interest in and sophisticated observation of those phenomena. In that they moved beyond a concern with the purely physical phenomena of seasons, they became scientists in the European sense. Their interests and knowledge became more abstract but never divorced from religious beliefs. Their records, particularly the Long Count, show their concern with lengthy periods of time. And it is only over very long periods that observation of the skies allows men (and we will have to assume, given what we know of Mayan culture, that the observers were men) to record the extended cycles of the sun, moon, and planets. How many repetitions of a pattern did it take to lead to the conclusion that, indeed, a pattern existed? In tables of numbers that correspond to average intervals of celestial conjunctions, the Mayan codices indicate that their writers were well aware of patterns in the conjunction of celestial events. They recorded them, and they regulated their lives by certain of them. And if their reasons were not scientific, the records they left are.

The astronomical records of the Mayas were kept in numerical form. Our knowledge of their mathematical system derives from their calendar system. The written records of the Mayas, hieroglyphic inscriptions on stone stele or in codices, show the use of mathematics only in calendar systems. There are no records of other forms of mathematical records. The mathematics of the system were lodged in a base-20 system of counting. Numbers proceeded as units up to 20, and by powers of twenty thereafter, as we count by 10s, 100s, 1,000s, etc. Except that because the numbers explain the calendar system, the third number stood for 18 units rather than 20—the number of months in the calendar year, rather than the number of days in the month.

Rather than using digits from 1 through 9, the Mayas employed dots and bars to indicate numbers. One dot stood for 1 and five dots made a bar. For numbers from 2 through 19, dots or dots and bars were combined. Numbers above 19 were indicated by the placement of sets of dots and bars, higher-order numbers being indicated by groups of dots and bars written one above the other. Numerals written in this system were used for counting and addition.

Some scholars have asserted that the Mayas understood the concept of the zero—that there was a position in a sequence of numbers that was empty. The expression 101, for example, means that there is no multiple of 10 to count. Although it is true that the Mayas used a symbol to show that one sequence of 20 was complete and another was beginning, scholars do not agree that it constituted a true mathematical zero. The zero is mathematically important in the manipulation of numbers such as in multiplication and division. The Mayas were concerned primarily with counting in long sequences, although they certainly understood the multiplicative power of 20. There is no evidence that they used their numbers for mathematical manipulation such as multiplication or division of different numbers, or that they used them in record keeping other than calendric.

Much of the Mayan calendar system and its mathematics, derived largely from the Olmecs and other earlier Mesoamerican peoples, became, in turn, part of the intellectual legacy of the Aztec peoples of 1492. The Aztecs may have put their inherited numerical system to uses other than calendar counts. Evidence from Aztec codices indicates the recording of amounts of tribute received from subject nations and the notation of areas of land. Again, the evidence is only for counting, although it is possible to infer algorithms for computing land areas.

To Native Americans in 1492, abstract numbers were not as important as the passage of time, the gathering of tribute, or the recording of land. In the Inca empire, mathematical knowledge was recorded in quipus, a system of information storage relying on a number of strings tied in patterns (see page 236). Generally, a series of strings hung from a main cord, and some of them might, in turn, have dependent strings. The strings were often of different colors, which recurred in sequences. On each was a series of knots, again tied in distinct groups. If one views the quipu as an elaborate coding device, perhaps analogous to a Chinese abacus, it is obvious that the variables of color sequences, number of knots, number of dependent strings, and patterns of knots could convey an immense amount of information. But, even if one assumes the quipu to be a highly sophisticated code, the problem is that no one has
The chief auditor and treasurer of the Incas holding a quipu. This drawing is by Felipe Guaman Poma de Ayala, the native Peruvian chronicler of Incan life. Quipus, which consisted of a train of knotted strings of varying colors, were used for accounting and calculation and were essential to the administration of this Andean empire.

yet broken it. There is no Rosetta Stone to provide a translation of the meaning of quipus into a language recognizable to European-based science.

The quipu as a series of knotted strings may have had a larger analogy in Inca culture in a system of geographic locations encoding observations of celestial phenomena. Early Spanish chroniclers of the Inca empire, writing primarily to record its overthrow, reported the existence of a unique calendar system. Around the city of Cuzco, there were 328 huacas, or shrines, which were aligned in 41 directions along ceques, or lines radiating out from the Temple of the Sun and reaching to the horizon. Although the numbers varied somewhat, there were approximately eight shrines along each ceque. This system might have functioned like a giant quipu laid over the city. One could imagine the ceques as strings radiating from a central knot, and the huacas as knots on each string. This imaginary quipu divided time into units, because the sun traverses the arc of distance on the horizon between any two lines in a set time. The system may have worked as a calendar, and also probably organized the space around the city into political units from which certain groups of individuals came to a central plaza to blow horns and announce the arrival of a “month” when they had special responsibilities.

The system of ceques and huacas, with its values of 41 and 328, obviously did not correspond to the 365 1/4-day solar year of modern astronomy. The numbers did correspond, however, to certain aspects of the lunar year, raising the important point that for many cultures the moon was as important a marker of time as the sun because of its waxing and waning. The aspect and movements of the sun in Cuzco, a tropical city, varied less dramatically from day to day than they did in more extreme latitudes. The sun passed high overhead during the greater part of the year. The moon was the more variable of celestial bodies and, thus, the lunar cycle may have been much more important for marking units of time.

Evidence for the importance of certain numbers in the Inca system of ceques and huacas has been inferred from two pieces of fabric, one woven in a very complex design of circles and squares, and the other in rectangles. The intricacy and symmetry of the pattern in the weaving has attracted the attention of contemporary scholars familiar with the mathematical and astronomical systems described in historic accounts of the Inca empire.

The first piece of fabric is actually two pieces separately woven and sewn together. Each piece has ten rows of 36 circles, and the diagonal rows of circles across the pieces are of different colors. The diagonal arrangement of elements in the fabric divides the circles into groups that add up to 365, the approximate number of days in the solar year. The second fabric has rectangles in patterns that can be added together to make the number 28, which is close to the average number of days (29.5) in a lunar month. The calendar system that one can infer from the ceques and the huacas appears to have been based on sidereal lunar months—the period of time at the beginning and end of which the moon appeared in the same position with respect to the stars. The phase of the moon might be different, but its position was the same, relative to the stars. The system seems also to have contained references to synodic periods—when the moon returned to its same position relative to the sun after it had completed a phase.

At the same time, the ceques as imaginary lines stretched to a very real horizon. The observation of the passage of the sun along that horizon may have marked certain crucial events such as solstices. The reconstruction of this system of astronomical observation can never be certain because many of the huacas have been destroyed over time, but the possibilities for its interpretation are intriguing.

Native American systems of knowledge are often encompassed in sources that do not conform to Western ideas of written language. Hence, they have seemed undecipherable to Europeans. Astronomical knowledge, for instance, may be read from the physical remains of buildings such as Chichén Itzá’s Caracol tower. The technology of building thus becomes an expression of Indian knowledge preserved in stone.
At Uxmal, another Mayan center in Yucatan, there are buildings whose walls do not form right angles and whose doorways make odd patterns in walls. The art of construction is impressive, with corbeled arches, sculptured friezes, and carefully fitted stonework. The building identified as the Nunnery at Uxmal is quadrangular in shape, but all its sides differ in length and meet at different angles. If some scholars preoccupied with the perfection of Euclidian geometry have ascribed the strange angles of the building to sloppy workmanship, others with a different perspective have attributed them to alignments with the rising and setting of celestial bodies. The Mayas who built the complex at Uxmal were capable of laying out parallel walls with an accuracy comparable to that of modern buildings. But in the Nunnery, doors and walls align not to right angles but to sight lines that appear to indicate risings and settings of the planet Venus.

Uxmal is evidence of the ability of Mayan builders to lay out structures along their own survey lines and accommodate different angles in their construction techniques. The buildings indicate a highly developed Indian architectural technology as well. Corbeled vaults cover buildings. These served the same purpose as the curved arch with keystone, a characteristic European building technique. The monumental structures at Uxmal, as at many other sites in Mesoamerica, include elaborate detail in carved façades, pillars, and fascias.

In North America above the Rio Grande, building technology was not as sophisticated, but it certainly allowed for the development of large-scale complexes, including the Mississippian temple-mound centers and the pueblo towns, both in what is now the United States. The most impressive dwellings in North America north of the Rio Grande were those at Chaco Canyon, in New Mexico. Pueblo Bonito was an apartment complex of some 800 rooms, parts of which rose to a height of four and five stories. The building technique was straightforward. Slabs of rock were laid in courses to form walls, which were often braced with logs, either set within the walls or as supporting rafters between them. The corner windows of some rooms may have served to indicate the rising of the solstice sun. If the building's construction was not particularly innovative, it served its numerous inhabitants well while they lived there, and it far outlasted their occupancy.

High on a ridge of a great mountain chain in Peru was another city, Machu Picchu, built by a civilization that probably predated and was ancestral to the Inca empire. Perched at an elevation of some 10,000 feet between two peaks in the Andes about fifty miles from Cuzco, it was a remarkable feat of Indian design and engineering. The city was a walled citadel, surrounded by terraced plots of cultivated land and watered by mountain springs that were channeled through a stone conduit supported in part by an aqueduct that passed above a moat: and dipped under a wall into a series of fountains and basins through-
habitants of Machu Picchu was their development of a system of carving their granite building blocks and slabs with interlocking ridges and projections that fitted them together. They often followed the terrain and laid walls in irregular but carefully joined sections rather than in regular courses. Such walls, almost like jigsaw puzzles, became single units. In a mountainous area where earthquakes were fairly frequent, although not as severe as they were at lower elevations, the walls were very stable.

The mountain fortress of Machu Picchu is evidence of a highly organized society, where time and materials were available in abundance. That society was a precursor to the great Inca empire that ruled the central Andes in 1492, an empire that tied together its parts with an elaborate system of paved roads and religious shrines stretching out in linear patterns to its horizons.

Quipus, huacas, and ceques give glimpses of a highly sophisticated system of preserving information. Woven strings and woven textiles can also serve as a system of writing. The sophistication of textiles in Mesoamerica may represent as complex a system of knowledge as metallurgy in Europe. Knotted string encoded information. Cloth was required as tribute, a sign of its value in an exchange system. Cotton armor and cotton slings were instruments of war. The technology of cloth was as important to the Incas as the technology of metals was to Europeans.

The art of weaving cloth reached a high point in the Incan empire prior to the European conquest. The Incas had domesticated llamas and alpacas both as beasts of burden and as sources of wool. They hunted the vicuña for its coat. The domesticated llama served as a source of coarse wool to be woven into utilitarian garments and bags as containers for storage. The alpaca provided a finer wool, and the vicuña had the softest and finest coat. Cotton was also raised or traded with neighboring groups. To the Incas, fabric was probably more important than ceramics for storing things. It became readily associated with the status of rulers, who wore the finest garments. Given the number of yards of finely woven thread necessary for the finest garments (the average diameter was 1/125 of an inch), one can appreciate the amount of time devoted by workers in Inca society to preparing the materials and spinning the thread. Some 125 separate shades and tints have been identified in Inca textiles, evidence of the sophistication of dyeing techniques and knowledge of the mordants used to set the dyes. All of the major weaving techniques known in Europe in 1492 were known to the Incas—tapestry, brocade, gauze, and double cloth. Peruvian weavers also had a distinctive technique, interlocking warp.

The use of spindles, looms, wool fibers, and dyes appeared by about 500 B.C. in cultures on the coast of South America that were antecedent to the Incas. The technology of cloth had undergone a long period of development by 1492.

One of the hallmarks of technological development in Europe was the use of metals. The course of Western civilization had changed because northern Hittite invaders used iron weapons to overcome the bronze-armied Mesopotamians. Although the historical formulation is too simple, it dramatizes the importance of metalworking in human history. Knowledge of metalworking existed in the New World, but the ends to which it was put differed greatly from those in Europe (which, in 1492, included significant weaponry). In North America, raw copper ore was beaten into ornaments by native people around the Great Lakes, where the ore could be found on the ground. But this use was very primitive compared with the technologies of metalworking in South America.

If the Incas were sophisticated weavers, they were also superb goldsmiths, as were their predecessors, the Mochicas, and various other peoples who dwelled farther north in such places as present-day Colombia and Panama. The main technique for creating artifacts with golden surfaces involved smelting an alloy of gold, silver, and copper called tumbaga. The ingot was then beaten and annealed. The process produced copper oxide, which was removed with an acid solution. By progressively removing the copper, the process brought the gold to the surface of the increasingly thinned sheet metal. The silver was then removed with a paste of iron sulfate and salt. The gold remained in a granular state at the surface of the metal sheet, and it was heated and burnished to produce the shiny golden surface characteristic of Andean metalwork.

The technique described destroyed much of the copper and silver substrate in the original alloy. Obviously, such a technique was not thrifty with mate-
In this eighteenth-century illustration, Antonio de Herrera depicts Central American hunters armed with lances driving wild javelinas (a variety of wild boar) into a net.

...re-form metals. It was the power to transform the very essence of material and imbue it with religious significance, giving it an inner form that was more important than the outer one.

This concern with the inner forces that gave meaning and life to outer forms was the essence of Native American science. The development of agriculture in both Europe and the New World in 1492 was scientific, because it was based on the power to predict events—the growth of crops—and technological, because it allowed people to control forms of energy.

The main sources of energy available to native people in the New World in 1492 were the sun and their own physical effort. If the sun was the main motive power for human activity, then part of that activity was using human energy to produce the greatest return from the environment in the form of food. There were many techniques which Indians employed to achieve this control. One of the most prevalent was the use of fire to promote new growth and provide increased browsing areas for wild animals that were a source of food. In California, for example, Indians systematically burned off areas of chaparral (the low-growing píon/juniper/scrub oak shrubbery) that was the characteristic cover of the Sierra foothills. Through these deliberately set fires, and also through natural fires caused by lightning, the brushy undergrowth was kept thin so that the fires were not very intense. They served to burn back the older growth without killing the shrubs themselves, and this hastened the production of fresh and tender new growth that was especially attractive to deer. Contemporary animal biologists have shown that deer feeding in fired areas produce more and healthier offspring than those in other areas.

On the North American plains, fire drives were used for buffalo hunting, and they also caused the growth of new grass in the burned-over areas. This periodic burning not only replenished the browse for the buffalo but held back the perimeters of forests and maintained the extent of grasslands.

On the Atlantic coast of the present-day United States, early European travelers and explorers described the parklike aspect of the forests. Stands of trees shaded grassy areas that the Indians maintained by periodic burning. The brushy understory, characteristic of the New England forests today, was burned off frequently enough to prevent its providing accumulated tinder for very hot fires. Consequently, burns took place without damaging the large trees, and new grasses grew back to provide forage for the deer that were hunted there. The parklike environment made it easy for hunters to move through the forests and use their bows without hindrance.

Control of animal feeding areas by fire was important for hunters, since game animals were essential to their diets. The domestication of plants and animals, however, was another matter. Domestication means bringing some living thing under the control of human beings. In the Native American understanding of the world, all living things had their own lives and wills, and...
they acted independently of men. This understanding probably accounted for the relative lack of domesticated animals in the New World. The Andean peoples of South America domesticated the llama and the guinea pig, but these were not primary food sources. In North America, the dog was domesticated and used as a burden bearer, and occasionally dogs were eaten as part of ceremonial meals, but, again, dogs were not a primary food source.

The domestication of plants and animals implies certain scientific principles. In all cultures where domestication has taken place, it has been based on observation of the actions of plants and animals, human ability to predict those actions, and human intervention to control them. In Europe, the domestication of plants and animals meant that they were deprived of spirits and means of independent action. In the New World, domestication of animals was minimal, and domestication of plants was achieved through an interaction of humans with the spirits of the plants.

The term “camay” for the inner essence of Incan goldwork has a parallel in the Navajo concept of inner forms. Every outer form or active physical phenomenon had its inner form that motivated it. All living and moving things, thus, had a spiritual sanction. In the European sense of science, agriculture is the most concentrated use of human energy to control the environment to produce food. It falls within our contemporary definition of science because it entails systematic observation of plants, prediction of their future action, and deliberate intervention in the processes of nature to select and promote certain things. It depends upon an understanding of the outcome of events—such as that seeds will reproduce their own kind. People observed that new plants grew more readily where they had dug or pulled roots and disturbed the soil. They knew that the clearing of areas by gathering or by controlled burning promoted new growth. They brought water to wild plants or dug them up and replanted them somewhere else. When they gathered plants, they selected them for specific characteristics. By selecting certain plants and controlling their environments with fire and water, they altered them and made them dependent upon human action for reproduction. That Native Americans domesticated such plants as sunflowers and chenopodium is shown by the differences in the size of the seeds of the wild species and domesticated species.

In 1492, Indians in many parts of the Americas had domesticated and were cultivating an immense number of plants. The list of their crops unknown to Europeans at the time contained numerous products that have since become familiar throughout the world: maize or Indian corn, white and sweet potatoes, manioc, squashes, beans (kidney, navy, and lima), cacao, pumpkins, peanuts, avocados, tomatoes, pineapples, tobacco, and chili peppers. In the Andes, some 3,000 different types of domesticated potatoes were being grown. Other New World crops included chenopodium, quinoa, amaranth, jicama, pacay, yacón, cranberries, and guayaba, lucuma, pepino, cherimoya, pitaya, canistel, sapote, and papaya fruits. Both fossilized seeds and some that are still viable have been found in archaeological sites. Ceramic reproductions of many cultivated foods, from manioc and maize to beans and peppers, have been discovered in pre-Columbian tombs along the Peruvian coast.

Plants domesticated in the northeastern part of North America included sunflowers, sumpweed, goosefoot, maygrass, and giant ragweed. All were grown as foods, though today they are considered weeds because of their invasive nature in cultivated fields and their ability to withstand a wide range of environmental conditions. Another North American domesticate is the Jerusalem “arichoke.” Squashes, tepary beans, gourds, and devil’s-claw were domesticated in the Southeast of the present-day United States. The gourds were used as containers, and the fibers of the devil’s-claw were employed in making baskets.

Maize, or Indian corn, had become the major food source for numerous peoples throughout the Americas long before 1492. Maize was descended from teosinte, a wild grass that at least 7,000 years ago began to be modified in...
yellow—were the result of selection and the careful preservation of seeds.

The relationship between humans and corn was a symbiotic one, a fact that became evident in the religious significance of corn in ceremonial activities in the American Southwest. Pueblo peoples used corn mothers (perfect ears of corn) in ceremonies, and gave perfect ears, representing corn mothers, to children at birth. The life cycle of the corn mirrored the human life cycle. The continuation of life for the Hopis depended as much on their appropriate relationship with the spirits of corn as on their ability to domesticate and select varieties that would survive in their harsh environment. Just as planting with a digging stick allowed each seed to be placed deep into the soil in order for the long taproot to reach moisture, so the Hopi snake dance was essential to the growing of the crops because the snakes handled by the dancers were released to carry the respect and wishes of the people to the spirits deep in the earth.

Although the Hopi agriculturalists dealt with the need for moisture by modifying the corn, many other Pueblo people devised irrigation techniques to control water. In the Chaco Canyon region, where several communities began to flourish about A.D. 920, dramatic expansion of the culture was made possible by sophisticated water control systems. The Chaco River, actually a seasonally flowing stream, had formed the canyon, and people had probably lived there for hundreds of years, but the region now became a major center of population. Prior to 900, the Chaco River had flooded seasonally, and crops had been planted on the floodplain. Water had also collected in natural basins along the rim of the canyon, and in heavy rains had run over the rim and down the sides of the canyon. By about 900, however, the river had cut its way so deeply into the canyon bottom and become so entrenched that it would not flood. If the inhabitants of the canyon were to grow crops, they had to devise irrigation techniques. These included earthen dams to contain the stream's waters, diversion walls and canals to bring the water to the fields, and sluice gates to control the flow. Additional diversion walls were built along the slopes of the main and side canyons to channel the runoff water into canals. Bordered and gravel-mulched gardens preserved the soil moisture.

Today, the remains of nine major Pueblo towns are located along a nine-mile stretch of lower Chaco Wash. In the surrounding area were four other pueblos, ranging from 60 to 100 rooms each, and at least fifty small villages of 10 to 20 rooms. At its peak, the population may have been close to 15,000 people. During the great building phase in Chaco Canyon, from about A.D. 1020 to 1120, perhaps 100,000 pine trees were cut down for construction uses and firewood. After 1120, however, virtually no new building took place, and by about 1120, the population of the canyon had drifted away, and the towns and villages were virtually abandoned. The most likely explanation for the exodus was a great drought in the San Juan River basin that lasted from 1130 to
The Indians in the New World were able to control their environments through the technology of fire, agriculture, and irrigation. But they also had a sophisticated understanding of the wild plants that grew around them. They depended on plants not only for food, shelter, and material for baskets and clothing but also for curing sickness. Since plants were considered living beings that shared with humans the ability to grow and change and reproduce, to live and die, they could affect human beings, and through use and systematic observation, native people were well aware of the effects of plants on the human body.

Animal behavior probably provided them with clues to the effects of plants. Scientists in Africa observed chimpanzees swallowing the leaves of *Aspilia* plants whole. They presumed that this constituted a medicinal use, since the chimpanzees chewed other plants that they used for food. Analysis of those particular leaves showed that they contained a chemical, “thiurubine A,” which is an antibiotic. Similar active components have been found in South American species of *Aspilia*, leading to the possibility that New World monkeys might have been observed making similar use of their leaves.

Born in Milan, Girolamo Benzoni traveled through Spain’s American colonies in the sixteenth century and published a report in 1565 which was sharply critical of the Crown’s treatment of both Indians and African slaves. Here, Benzoni presents a sympathetic portrait of a native healer tending to a patient who is lying in a hammock.
The greatest similarity between modern practices and those of the native people of the New World in 1492 is in the field of medicine. Despite sophisticated technology and understanding of the processes of the human body, physicians in contemporary society still work partly in the sphere of science and partly in that of belief. Powerful drugs have potent effects on the human body. Native American healers knew from observation that plants caused significant changes in the body. And, indeed, much of the medical practice of fifteenth-century Europe was based on the use of medicinal simples, or plant medicines. Plant medicines from the New World have proved effective by modern medical standards. A hormone extracted from stoneseed, a plant used by Paiute Indian women as a contraceptive, suppresses gonadotropins in the ovaries of laboratory mice and thus interferes with the ovulation cycle. The tepactli prescribed in Aztec medicine as a diuretic and as a treatment for gangrene contains plumbagin, which is an antibacterial agent, particularly useful against staphylococcus.

The point, however, is not to judge herbal medicines by the standards of modern medicine, or the efficacy of chemical properties, but to recognize that native people experienced and assessed the powers of plants in consistent ways. Certain plants always produced certain results. To the Indian, the cause was not chemical, but the inherent spiritual power of the plant as a living being.

Medicine is a combination of science and belief. Science is also a matter of belief. In 1492, European scientists believed that objects sought their natural place, and that the philosopher's stone would transmute base elements into gold, and that plants had the power to cure illness. Native American scientists believed that plants could cure, and that golden objects could be imbued with power, and that all things had their proper places in the great scheme of the world.

The essence of science is an understanding of the world, but the premises of modern science have changed significantly from 1492 to the present. From natural place to black holes, from humors to superstrings, the enterprise of science has sought an always elusive truth. To Native Americans in 1492, the world was alive with forces that could be understood in certain ways. They observed the world around them, and they knew its patterns and its effects on their own lives. Systematic observation of the environment and prediction of the effects of forces in the environment allowed native people in the New World to adapt to a wide range of conditions and evolve their relationships with the natural world.

On the eve of Columbus's landing in the New World in 1492, the native people of the Americas maintained a delicate balance with the resources of their world. That balance between control and faith was soon to be disrupted. Confronted by invaders from the Old World, it would be overcome by the onslaught of European diseases, plants, and animals introduced into the New World environment and by beliefs that dismissed as pagan superstition the systems of knowledge that constituted the science of the Indians.