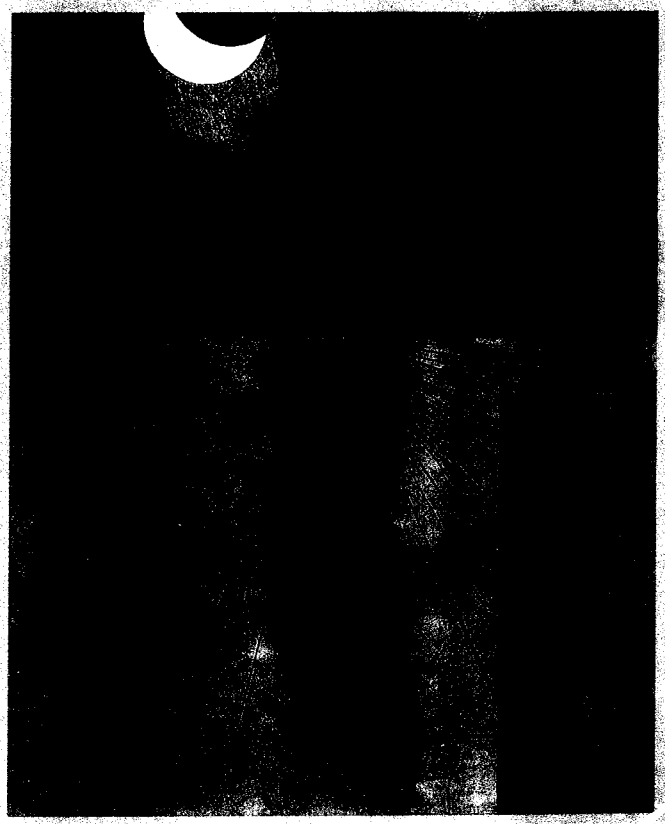
"A fascinating book about what makes time tick." —*A.L.A. Booklist*

EMPIRES OF TIME

Calendars, Clocks, and Cultures



ANTHONY AVENI

Lemons and Oysters. Georges Braque. The Phillips Collection, Washington, D.C.

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THE BASIC RHYTHMS

First the tide rushes in, plants a
kiss on the shore,
Then rolls out to sea and the sea
is very still once more.

—"Ebb Tide"

METAPHOR is a figure of speech by which the meaning of one word is transferred to another. Our century is dominated by computer and mechanical metaphors. We use terms like *network, input, feedback, gridlock,* and *information flow* to describe social situations and interactions as if to imply that society is a system that functions according to the laws of physics. But in the lyrics above from a popular song of the 1950s, the tide becomes the metaphor to describe the love one person experiences for another.* Like our emotions, the tide waxes and wanes from one extreme to another. Or, is it like the feeling of being torn apart by circumstances after coming together? For artists and poets, the changeability of human feelings finds expression in the way the waters rise and fall, not just over a day, but even from moment to moment, for the beat of each wave that breaks upon the shore imitates in microcosm the slower rhythm of ebb and flow that makes up the eternal tidal harmony.

*Actually *time* and *tide* are derived from the same Anglo-Saxon root word, *tīd*, meaning "season," "hour."

Tracking Down the Sense of Time

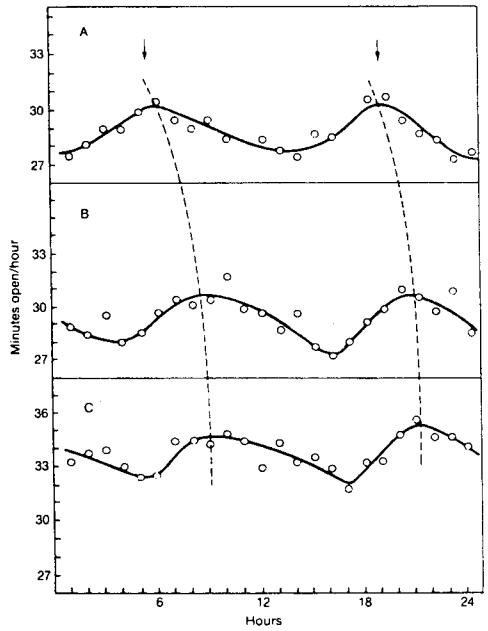
I am engaging in this romantic talk to show that we use nature's behavior as a model to describe something we feel. In the passage from that old song, we feel time not only as an endless flow of metronomic beats but also as a kind of rhythmic surge, a recurring pattern we can trace to our very roots, to an age before we could even call ourselves human beings—when we came out of the sea.

It is well known that the life cycles of marine organisms respond to the ebb and flow of the tides. The periodic inundation and exposure that results from tidal flow controls changes in temperature, pressure, agitation, salinity, and feeding conditions. Take oysters. When the sea is high, they open their shells for a longer period of time than when it is low: not much longer—it is too dangerous; only three or four minutes more per hour. Just enough longer to take safe advantage of the fresh source of nourishment brought in by the turning of the tide.

In the early 1950s, biologists pulled about a dozen oysters from New Haven harbor and shipped them to Northwestern University in Illinois for study.[1] The oysters were submerged in their original harbor water and kept in total darkness. To explore their feeding patterns, the researchers tied to the shells fine threads that could activate recording pens every time the oysters' muscular movements caused the hinged shells to part or come together. Just as expected, the oysters continued to open and shut their shells as if they still were snug on the bottom of their home harbor, even though they had been displaced to another time zone more than a thousand miles to the west. Then, after about two weeks, something strange happened. Gradually the hour of maximal opening of the shells began to drift from day to day. Now, anyone who lives near the shore knows that the high- and low-water marks shift gradually from day to day. Tides are synchronized not with the place of the sun in the sky; rather it is the moon's schedule of appearance that matters, and the moon runs about 50 minutes, or eight tenths of an hour, later than the sun's cycle. On the average, successive high and low tides occur nearly an hour later each day. We would expect all oysters to open and shut on a 24.8-hour schedule. But, the biologists in Illinois were witnessing a daily drift that corresponded to a different beat. After four weeks of recording and analyzing the data, they had determined beyond any doubt that the oysters had

restabilized the rhythmic opening and closing of their shells to the tidal cycle that would occur in Evanston, Illinois, had there been an ocean in that location. For the rest of the time the oysters were observed, they continued to maintain this new cycle (figure 1.1). It was as if they had gradually adjusted their life's pace to correspond to the time when the moon was overhead as seen from Northwestern University rather than from New Haven harbor. Could this lowly form of life actually feel the moon's presence through the sealed walls

FIGURE 1.1 Oysters adapt to a new time standard. The average number of minutes per hour their shells are open is plotted (*vertically*) against the hour of the lunar day (*horizontally*) for fifteen oysters transported from New Haven, Conn., to Evanston, Ill., and maintained in constant environmental conditions: (*A*) for the first two weeks in Evanston (arrows indicate time of high tide in the oysters' home waters); (*B*) for the next two weeks; and (*C*) for the last two weeks of the study. The time of maximum shell opening gradually shifts to, and then stabilizes at, the times of upper and lower transits of the moon across the local meridian, as the dotted line suggests. SOURCE: F. A. Brown et al., *The Biological Clock* (Englewood, N.J.: Heath, 1962), p. 25.



of the laboratory? (Think of that the next time you start to douse a plate of oysters with the stinging pungency of a few drops of Louisiana hot sauce!)

If you are impressed with the sagacity of a brood of New England mollusks, consider the even lowlier potato. Experimental biologists have charted its metabolism by measuring the rate at which it uses oxygen.[2] They removed the sprouting eyes of potatoes and placed them in hermetically sealed containers shielded from outside fluctuations in temperature, pressure, humidity, and light intensity. But the deprived spuds kept the same rhythmic cycles they had before they were snatched out of their natural environment. Peak consumption of oxygen occurred at 7 A.M., noon, and 6 P.M. every day. And when the unseen sun was gone from the sky, oxygen consumption fell to the standard nighttime low. There were annual changes, too. When it was summertime outside the container, the noontime peak was lessened; and in wintertime, it became enhanced.

As insignificant a link as it may seem in the great chain of being, a blindfolded potato still knows not only the time of day but also the season of the year! Furthermore, the rates of potato metabolism were found to correspond to the barometric pressure outside the containers in a most unusual way: they indicated what the barometer read, both yesterday and the day after tomorrow. While we can understand that yesterday's pressure changes might make for alterations in humidity and temperature that can be connected in turn to today's oxygen consumption, it is difficult to comprehend just how information can be conveyed to an imprisoned potato which enables it to adjust the height of its noontime oxygen consumption peak by just the correct amount to correspond to the barometric pressure two days later. A meteorologist removed from his usual post in front of a TV weather map and sealed away in a container could hardly be expected to do as well in predicting the weather.

Of all the rhythmic time cycles in biological organisms, those of the honeybee probably are the most well known and certainly among the most elaborate. Like many other scientists, the German biologist Karl von Frisch initiated his studies, back in the 1930s, quite by accident. One of his colleagues told him that whenever he breakfasted on his terrace, he noticed that the bees seemed always to be there at the right time to anticipate the savory taste of the jams and marmalades that often were set out. They showed up whether or not sweets were at the table. How could a bee acquire this punctuality? Was there within itself, a sort of built-in clock that goes off at the right hour, or did the insect receive clues from the outside environment?

To try to find the answer, von Frisch set up a series of experiments.[3] Food sources were set out in different directions at different times of the day. When bees coming straight out of the hive darted immediately to the food source, it became clear that somehow information about the location of that source was being transferred back to the hive by incoming members of the bee community. Peering inside the hive, von Frisch discovered that the transfer mechanism was a kind of round dance performed by a foraging bee shortly after it arrived back at the hive to dump a load of nectar. It would dance rapidly in a narrow circle, completing half a course in a clockwise direction, then would run along the diameter, and finally complete the other half loop in a counterclockwise sense—a sort of figure eight (figure 1.2). As the bee danced, spectators tagged along after it in great excitement, touching the tip of its wiggling abdomen with their feelers as they went. Cleaning itself off, the forager-communicator then left the hive and returned directly to the food source, only to be joined moments later by attentive comrades.

What information had been conveyed through this curious round dance? How did the bees watching the dance know where to proceed? These questions continued to puzzle von Frisch and his co-workers for a long time. Surely, it was not the sense of smell that caused the bees to arrive at their target, for they showed up regardless of whether the experimenters laid out honey or sugar water. And the bees certainly could not *see* the dancer perform, for the comb on which all the action took place was sealed away in darkness. Any information about orientation must have been picked up by other means—for example, by touch, inside the hive. The experiments continued.

When von Frisch varied the distance to the feeding place, he discovered that the farther away the source, the longer the dancing bee took to complete a dance loop—from forty runs a minute for a source just a few hundred meters away, down to just a few turns a minute for a feeding place situated several kilometers from the hive. And, if the source was nearby, the communicator-bee seemed to wag its abdomen much more rapidly during the straight diametrical portion of the dance. Did this action reflect that the dancer had consumed more energy when running a long way from the hive? Perhaps a tired bee

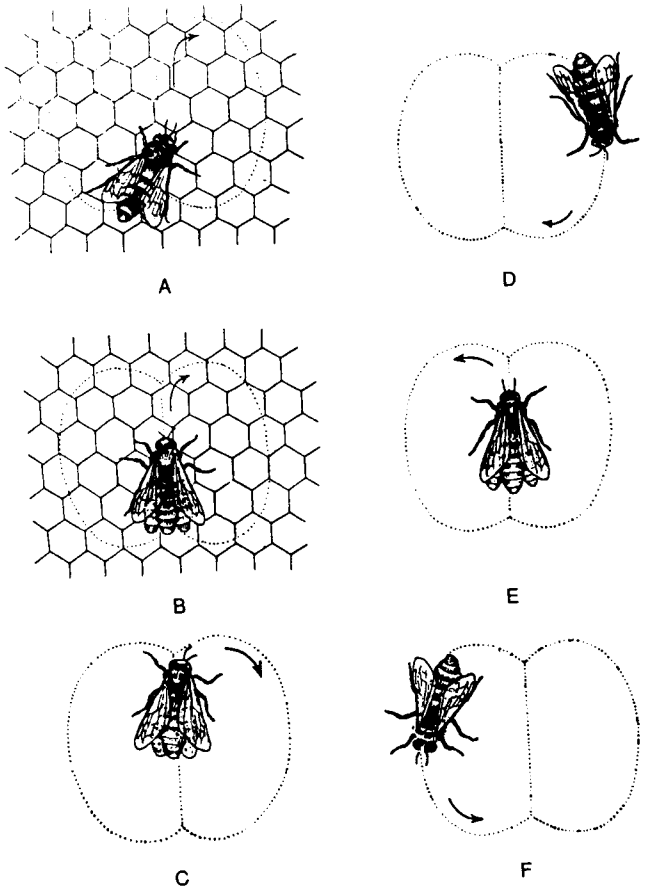


FIGURE 1.2 The wagging dance of the forager bee that has just re-entered the hive. The long axis of the kidney-shaped course gives the direction of the food source, while the intensity of abdominal wagging on the straight run (*b* and *c*) tells the distance. There is little question that the bee's sense of timing comes from the sun. SOURCE: K. von Frisch, *The Dancing Bees* (New York: Harcourt Brace, 1933), fig. 43, p. 117.

automatically conveys information about the distance to a food source because it has less energy in reserve and consequently performs a much slower dance. But what about direction? If the companion bees know how far to fly, how do they know which way to take off?

This information is conveyed in a most remarkable way. Actually the bees were navigating by the sun. Von Frisch discovered they had developed a brilliant way of measuring the angle between the food source and the sun as projected from the hive. On a horizontal comb

surface, the angle between the straight portion of the dance and the bearing of the sun is the same as the direction between the sun and the source as seen from the hive. In other words, if a food source lies 40 degrees to the left of the sun as viewed from the hive, then the bee conducts the straight portion of its dance at a 40-degree angle to the left of the direction of the sun, which, it will be remembered, cannot actually be seen from the dance floor. What if the comb surface is vertical? Then the forager bee performs the dance so that the angle to the food source is measured from the vertical instead of from the direction to the sun. In our example, the straight portion of the bee's dance would be 40 degrees east of vertical. Von Frisch could not fool the bees by changing the orientation of either the nectar or the hive. They always made a "beeline" directly to the feeding place once informed about direction and distance via the wagging dance.

If bees know when to turn up at a feeding place, they must possess some sense of time. And, because they convey information by marking off the angle of the sun, it would appear likely that they are cued in to this timing sense directly by the sun. The bee learns that when the rays of the sun arrive from certain portions in the sky, it is time to forage. Von Frisch even trained his bees to become attuned to several different foraging times each day. But this idea of environmental cueing has its problems, for bees, like potatoes, when totally isolated from all outside periodic changes, continued to behave the same way. They appeared at a feeding spot at the time of day for which they had been trained, even when they were exposed to constant artificial light, temperature, and humidity. After years of experimentation with time sensing in the honeybee, von Frisch concluded that "we are dealing here with beings who, seemingly without needing a clock, possess a memory for time, dependent neither on a feeling of hunger nor an appreciation of the sun's position, and which, like our own appreciation of time, seems to defy any further analysis."[4]

We can say the same of potatoes that adjust to the forthcoming barometric pressure and of oysters that manage to convince themselves that they live in a nonexistent ocean just west of Chicago. But where is the elusive rhythmic clock for which von Frisch was searching?

Cycles of about a day's length possessed by nearly all living organisms are called *circadian rhythms* (from the Latin *circa*, "about," and *dies*, "day") and have been recognized in Western culture at least since the time of Aristotle. Twenty-four centuries ago, he observed that certain plants raised and lowered their leaves on a regular day-night

schedule. But it was not until the age of controlled scientific experimentation (twenty-two centuries later) that we began to probe the detailed nature of this biological clockwork. In 1729, the French scientist Jean de Mairan conducted the first controlled light-dark experiment on plants in a laboratory.[5] He found that the daily periodic oscillations of plant leaves persisted even when the plants were isolated from the natural environment. This so-called de Mairan phenomenon has been observed in practically all living forms from humans down to one-celled organisms. In all cases, the cycle is close to, but never precisely the same as the earth's rotation period (generally it varies between 23 and 27 hours for different kinds of organism). Furthermore, most subjects can be trained after several days to adapt to a new artificial period through environmental control.

Mice are particularly cooperative. Biologists have weaned them away from their normal morning activity of running on a wheel by subjecting them to a single hour of artificial daylight and then keeping them in the dark for the remaining 23 hours of the day.[6] As the graph in figure 1.3 shows, after several days of such exposure, the mice adopted a routine: they would always run the wheel immediately after the hour of exposure to the light. After several weeks, the mice were allowed to "run free": that is, they were taken out of the artificial periodic environment and kept in darkness all the time. Under these conditions, wheel-running activity often persisted for several days and occurred at the same time of day to which the mice had become "entrained," to use the biologists' terminology; but then the mice began to become "disentrained," and their activity period drifted slowly toward times slightly earlier in the day. This free-running rhythm had a shortened but astonishingly precise period of 23.5 hours. (Notice the straight sloped line in figure 1.3 that fits the time of initiation of wheel activity from the 60th day forward.) Also, the length of time the mice spent running in the wheel became a little bit longer during this stage of the experiment. After 90 days, the biologists tried to switch the mice to a new period by exposing them to light 18 out of 24 hours per day. Released to run free after the 130th day, the mice were active for longer intervals; nevertheless, they kept to a rhythmic cycle that once again corresponded precisely to something less than a day. These experiments not only demonstrate the complicated nature of circadian rhythms, they also raise a fundamental question: Is a sense of time built into all organisms, or are we really being driven by the earth clock outside us?

In our world there is little to be gained by marching to the tune of

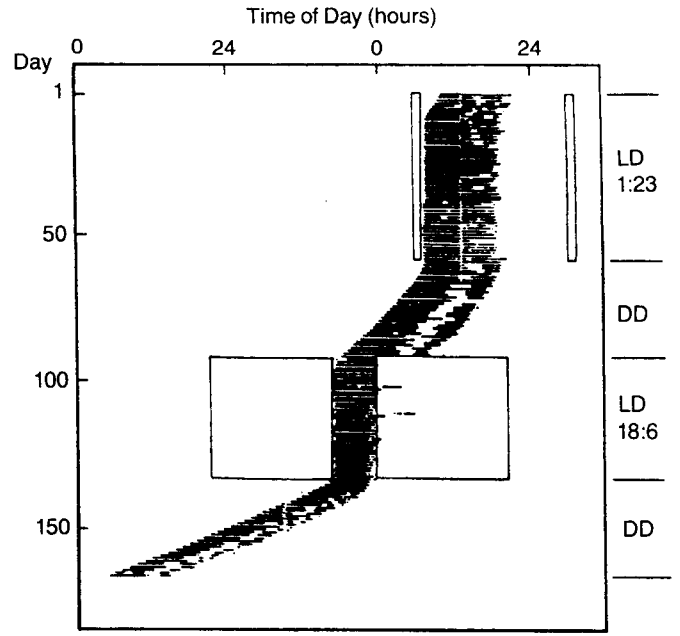


FIGURE 1.3 A mouse's circadian clock. The free period of daily wheel running (*dark horizontal streaks*) by a mouse is followed over several months. For the first 60 days, the mouse is subjected to 1 hour of light and 23 hours of dark each day (*long vertical bars*), with the result that it runs on the wheel soon after being exposed to light. When kept in constant darkness (between the 60th and the 90th day), the mouse's activity period seems to slip backward through the 24-hour day. Following entrainment to a regimen of 18 hours of light and 6 of darkness (90th to 130th day), the mouse is once again left in total darkness; as a consequence, wheel running experiences another backward phase shift (after the 130th day). SOURCE: M. Moore-Ede et al., *The Clocks That Time Us* (Cambridge, Mass.: Harvard University Press, 1982), fig. 2.8, p. 48.

a different drummer. Little wonder that most biological rhythms are virtual duplicates of nature's basic periods—the day, month, and year, all of which have their celestial origins in the rotation of the earth and the movement of the sun and the moon. To rephrase my question: How is the connection between life cycles and celestial rhythm established? One theory, the hypothesis of the internal timer (or the endogenous hypothesis) suggests that because these rhythms persist when the organism is deprived of functioning within the natural environment, every piece of living matter must be its own timer. In other words, every living thing has the capacity to develop its own internal, chemically based timing system. This idea makes good sense because the theory of evolution teaches that the mechanisms of natural selec-

tion favor the survival of the organism that achieves an adaptive advantage. Having evolved over millions of years, the oysters that "know" when to keep their mouths shut (or open) get fed; the rest become losers. Every successful class of organism needs to inherit and further develop an accurate biological clock so that it can know when to anticipate environmental change better than its competitors.

In stark contrast, the exogenous hypothesis of time sensing proposes that all biological timing depends on cosmic stimuli. Organisms oscillate with natural geophysical frequencies because they respond directly to changes in the forces of an all-pervasive environment. While experimenters may *think* they have totally isolated their potatoes and their oysters by shielding them from light and changes in barometric or thermal conditions, these organisms have subtle ways of sensing what is really happening in the world outside. For example, they might be responding to changes in the geomagnetic field or electrical charges in the air, to shifts in the intensity of background radiation, or even to tides in the earth's atmosphere that rise and fall on a daily as well as a monthly basis. How else can we explain the way the New Haven oysters adjusted themselves to the invisible moon over the nonexistent harbor in the middle of the Great Plains? Exogenists believe that oysters have a way of sensing the difference between the gravitational pull of the moon when it is directly above and below them, thus causing high tide, as opposed to when it lies on either horizon and consequently produces a lower watermark.

We already know that honeybees have good gravitational sense because they make use of it in their navigational system. How else could the forager who dances on the vertical comb convey the location of food to its hivemates unless it were able to translate the angle between food source and sun into the angle between food source and the vertical? The bee substitutes the direction of the pull of gravity for the direction to the sun. To mark the direction of the pull of the moon, the principle is the same: one need only be more sensitive, more attuned to the environment. Time, the giver of all rhythm, must originate from the outside: time sensing is hidden away in that secret communication between animal and nature that we dismiss casually as "instinct." So say the exogenists.

But consider the punctual fruit flies, or *Drosophila*, who, unlike the oysters, seem to behave as if the whole time-sensing scheme operated internally rather than externally. All of the adults emerge from

the pupal case at the same time of day—close to dawn. When reared under normal alternations of light and dark for several generations and then suddenly switched to a constant light-and-temperature situation, succeeding generations of *Drosophila* continue to burst out of the pupa stage and go on to the mating stage precisely when it is dawn outside. Furthermore, the fifteenth generation of flies is just as punctual as the first, none of them ever having seen the natural light of day. Given this sort of experimental evidence, it is difficult to get away from the idea that the clock lies in the fruit fly, that the sense of timing is inherited genetically. Indeed, some experiments on this species even support the idea that there might exist a biochemical clock-gene built into the molecular structure of all living tissue. But how does it work?

Erwin Bünning, a German biologist who conducted many experiments on *Drosophila*, is responsible for framing the hypothesis of how the internal timing mechanism operates in a way that seems to be capable of embracing the photo-periodic responses of a wide variety of living organisms from bee feeding to plant-leaf movements (though he originally intended that it be applied only to leaf movements in certain plants).[7] The mechanism consists of two phases of about one-half day each that alternate. In the "light-loving" phase, the energy falling on a body will enhance growth and activity; while, during the "dark-loving" phase, it will inhibit it. True, organisms draw energy from outside sources, but they convert it by strictly internal means into useful activity (or inactivity). This idea sounds bizarre, for it seems to treat living organisms as if they were self-operating electrical appliances like coffeemakers or clock radios that switch themselves on and off and operate by alternating currents.

I shall not venture into a discussion of all the experiments that led Bünning to his hypothesis, except to say that it had become clear to him in the lab that all circadian rhythms could be broken down into two opposing half-cycles. There seemed to be definite periods when Bünning's plants would respond only to light treatment, after which they would react only to dark treatment. This Jekyll–Hyde pattern of behavior can have but one origin. Had the organism, over its millennia of evolution, internally adapted itself to the alternating day-night cycle of nature?

The ultimate test of the internal-external controversy about time sensing would be to remove a rhythmic organism from all conceivable geophysical influences—say, by taking it into space and putting it into

solar orbit far away from the earth—and see what happens to it. Surprisingly, given all the money spent on the exploration of space, no such experiment has ever been conducted in detail. But biologists have taken the next best alternative: they have conducted experiments in an environment where most day-dependent variables can be eliminated—at the South Pole and on a rotating turntable that compensates for the earth's rotation. Hamsters and cockroaches were run there, plant leaf movements were timed, even fruit flies were bred in a turntable laboratory. The results of these experiments weighed heavily in favor of the internal clock hypothesis. The organisms went right on functioning as if the earth's rotation were still present in the environment. But the exogenists, as might be expected, still argue that the test organisms could have harbored a subtle sense of the diurnal variations in spite of all the biologists' attempts to shield them. For example, could not the organisms have taken their cues from the 24-hour movement of the geomagnetic pole around the geographic pole? Endogenists claim to have blocked that escape route by conducting separate tests in which they demonstrated that plants reared in the vicinity of powerful magnets differ in no way from those cultivated under normal conditions. But experiments with laboratory magnets do not prove the case to everyone, and the controversy rages on.

Today even the most stubborn internalist would concede that there are some exogenous effects on biorhythmic activity; and the tenacious externalists, who in today's world of genetically based research have been relegated to an active, vocal minority, have been forced to admit that some sort of biological clock does indeed exist within all of us. Still, the environment is the ultimate source, the giver of time—or *zeitgeber*, as biologists call it. It is the environment that entrains all biological organisms to oscillate in the first place. Tide, temperature, season, and moonlight—all represent the primal input that drives us to execute our clockwork, both chemical and genetic.

In the present context, I am not terribly concerned with the debate about whether life's sense of time is better explained internally or externally; whether it is a direct response to nature or has been nurtured over countless generations of evolution. Rather, I have used oysters and bees as a way of attempting to establish that all living things, regardless of where they stand on the ladder of biological complexity, respond to environmental change in surprisingly sophisticated and detailed ways. And though I write in an artificially lighted room, and

you likely will read what I write in a heated or an air-conditioned enclosure, we both are tied directly to the environment outside. Yet we never sense time directly. There is no single organ to monitor time the way the eye detects light, the ear responds to sound, or the tongue to taste. Nevertheless, all living organisms sense time by responding to phenomena that change.

A Multitude of Inner Rhythms

This undeniable sense of timing over which we have been puzzling is as inherent in humans as it is in all the lower organisms; but, paradoxically, knowing ourselves appears to be more difficult than understanding how other life forms express their time sense. The extent to which human time is either *biological* or *psychological* seems to be the root issue.

More than a hundred functions are known to oscillate within our bodies each day, and we share most of them in different degrees of variability with all mammals. At the short end of the time spectrum, there is the $^1/_{10}$-second oscillation of brain waves on an electroencephalogram, the 1-second basic cardiac rhythm, the 6-second respiratory cycle, and the various sleep stages leading up to the 24-hour sleep-wake period. Our body temperatures also fluctuate on a twenty-four-hour cycle, being highest toward evening and lowest toward morning. At the longer end of the time scale lies the 28-day menstrual cycle and the vestige of a 365-day cycle of hibernation.

Physiologists have their own language for dealing with these phenomena, and its electronic metaphors (italicized in this and the next paragraph) suggest how they think our bodies and brains operate. A *pacemaker* is some entity within the body which is somehow capable of sustaining oscillations and entraining them to other bodily rhythms. Initially, the forced oscillations, or *zeitgebers*, are received through the *auditory or visual* channel before being picked up by *transducers* or *receptors* within the body. Though these transducers acquire the time-based information from nature's cues, the pacemaker is capable of measuring time in the absence of these cues. It acts as a kind of alternating-current device which sends out measured pulses of information. Biologists have adopted this information-processing model as a way of

explaining biorhythms in the higher life forms. They formulated it on the basis of experiments with whole animals, deprived of normal environmental conditions. The tactic consists of manipulating environmental parameters and then recording the resulting behavior of successive generations of animals. But when biologists try to pinpoint the location of the pacemaker within the organism, things get really complicated. Here the strategy, like that of most scientists, is to divide and conquer. When they examine the rhythm of isolated body parts (the heart taken out of body, liver cells, or blood cells), they discover that the rhythms of the whole animal are really comprised of multiple oscillations, all running together harmoniously in a perfectly *tuned* condition in the normal specimen. But are all the rhythms in an organism *driven* by a single pacemaker, or is there a hierarchical organization of pacemakers? And, if the latter, where is the *command center* in this metaphor that says, "My body is a computer"?

Most experimental biologists believe the major pacemakers in mammals are found in the hypothalamus area of the brain—at the top of the brain stem, directly behind the eyes, to be exact. The site is a tiny bundle of nerve cells known as the suprachiasmatic nuclei (SCN). In certain instances, the information channeled from *entryway* to *command post* even can be traced—from the eye, which receives the zeitgeber, along a *neural network* to the hypothalamic area—by the injection into the retina of substances that can then be followed by radiographic detection techniques.

By studying the free-running behavior of rats after subjecting them to every conceivable manner of sensory deprivation—such as blinding; removal of adrenal gland, pituitary gland, gonads—biologists find no disruption of normal activity. Only when one begins to make knife cuts in the selected areas of the brain in the hypothalamic area does a rat begin to alter its feeding and drinking rhythm drastically from the normal oscillatory cycle. Lesions that destroy the SCN appear to affect the rhythmic discharge of certain chemicals from the adrenal glands, which control eating and drinking behavior as well as the wake-sleep cycle.

In humans there is no circadian cycle more dramatic than the alternation between being awake and being asleep. We are so conditioned to passing through that unremembered instant between the drastically opposed states of consciousness and unconsciousness that any attempt to deprive us of the ability to do so is doomed to failure. On the average, we spend one third of each earth rotation asleep (by contrast, a donkey spends one seventh; an opossum, four fifths); and,

of course, we do it during the dark period. On the other hand, anyone who forgets to "put out the cat" becomes painfully aware that felines undergo alternating bouts of sleep and wakefulness, each one to two hours long. The animal "catnaps," paying no heed whatever to the day-night cycle, a condition to which it may have adapted as a result of its predatory nature. The opossum, by contrast, is awake only during morning and evening hours.

It is extremely difficult for a human being to remain awake continuously for more than two or three days. The extreme case recorded in the *Guinness Book of World Records* is eleven days for a seventeen-year-old boy who achieved his pinnacle only with constant prodding from the outside and with a special motive in mind—to set a world record.

Our strict entrainment to the earth's diurnal period is far-reaching. When you pass a night without sleep, though you are feeling extremely fatigued during the working hours, you quickly get back on track with the normal daily cycle. By midmorning, even though you may be struggling through the twenty-seventh consecutive hour of wakefulness, somehow you feel better than you did while getting through that miserable twenty-first hour during the pre-dawn or the dark part of the diurnal cycle. However, by the time you see the sun go down for the second time, you pay the price twice over by falling into a stupor. Like the experimental animals I discussed earlier, when we depart from the normal conditions of the environment, we struggle to compensate internally.

Just like the free-running rats, people deprived of the normal light-dark cycle by living in caves, or by being confined to sealed rooms under conditions of constant light, become disentrained after a couple of weeks. They alter their biological sleep-wake cycle to a period somewhat different from the usual 8- to 16-hour cycle. Psychologically speaking, they lose all track of time, often believing they have been awake far longer than has actually been the case. They even wonder whether they have slept long enough; but these concerns usually vanish after an extended period of isolation. One subject who was kept in a closed room for several weeks stated, "After a great curiosity about 'true' time, during the first two days of bunker life, I lost all interest in this matter and felt perfectly comfortable to live 'timeless.' "[8]*

*One inexplicable phenomenon resulting from nature deprivation is what I call the *six-hour phase slide* in the sleep-work cycle of practically all college students: rarely do they rise before the sun hits the meridian, and they can be seen prowling around from

We know that the percentage of time we sleep decreases with age; it begins as a prolonged affair but is nonetheless fitful in infants (as any parent knows, it takes about two years before a child is fully fixed into the nocturnal sleep cycle). In old age, somnolence becomes fitful again.

Sleep is not just a single state. Rather, it seems to be made up of subsidiary rhythms. From the rapid *e*ye *m*ovements that occur during the time that we dream, we call this period "REM sleep." We spend about one quarter of our sleep time at it. During REM sleep, there is no muscle tone—and fortunately we cannot act out our dreams as we dream them. During non-REM sleep, we do most of our tossing and turning. Muscles are active, but the frequency of brain waves slows down, passing through various substages. These two cycles, REM and non-REM, alternate on approximately a 90-minute cycle throughout the night in all human beings.

This "ultra-dian" oscillation cannot be connected with any known period in the environment; but like all other behavior during the sleep cycle, it seems to be controlled by the interaction among clusters of nerve cells at several sites within the brain, most of them within the brain stem. One such cluster seems to play a role in REM, and another in non-REM sleep. Motor inhibition, or loss of muscular control, is operated by a third area. We know of these connections because the stimulation of these areas results in one or another reaction in the sleeping patient. But still unanswered is the fundamental question of exactly how changes in the activity of different brain-stem nuclei alters the overall activity in the entire central nervous system.

While the human sleep cycle is circadian, the reproductive cycle is predominantly *circa-lunar* and *circ-annual*. Indeed, the very word *menstrual* is derived from the *menses*, or month (a contraction of *moon-th*). At 28 days' length, the menstruation cycle lies, probably not by coincidence, close to the moon's period. In practically all primates, the production of estrogen, variations in bodily temperature, the time of ovulation—all are controlled by a period that spans the interval 25 to 35 days. In southern California, the running of the grunion is a major event during the period of the year when the highest tides occur. At either the dark or the full-moon phase of the monthly

library to dormitory (and other places) long after the sun has left the sky—hardly photoperiodic creatures.

cycle, millions of females of this slender species (about the size of a big sardine) suddenly turn up on the beaches. They perform a vertical wiggling dance, burrowing their tails and half their bodies in the sand where they deposit their eggs. The males coil round them and eject sperm to fertilize the eggs. The hole is then covered with wet sand. Two weeks (or half a lunar cycle) later, the eggs hatch, just in time for the young offspring to be helped by the advancing tide back into the ocean. These moon-based cycles may be a reflection of our original ascent from the sea. Remember the oysters? Many feedings and reproductive cycles of organisms that inhabit the ocean receive their input signals from the tidal period which, in turn, is regulated by the position and appearance of the moon.

Half a billion years ago, the moon lay closer to the earth in its orbit. It has been receding ever since; and as a result, the month, measured by the period of revolution of the moon about the earth, has become longer. There is some evidence that when the lunar period was measurably different, some 350 million years ago, living organisms were entrained to that period. During that time, the so-called Middle Devonian period, the month was about a day and a half shorter, making for more months in a year—closer to thirteen, rather than the present twelve. The evidence shows up in fossil coral embedded in sandstone laid down during the Middle Devonian period. Paleontologists have examined the growth ridges in coral which are deposited on both a lunar and an annual "breeding" cycle. During the summertime, when the waters are warmer, the thickness of the chalky deposit is larger than during the winter, when the organism lies in a more dormant state. From a statistical point of view, the data suggest that the coral time clock was ticking according to a different beat than today, one that reflects the natural environment that once existed but has since undergone gradual change (see figure 1.4).

We are a long way from relating the behavior of 350-million-year-old fossil corals directly to the estrous cycle of twenty-first-century women, but the moon's rhythm could have some bearing. For early humans, the time around the full moon offered an extended period of light during which limited hunting and gathering could take place. And under the difficult conditions in which they must have lived, our prehistoric ancestors needed all the light-time they could get. It is reasonable to suppose that the dark-of-the-moon period might have been given over to sedentary activity, which included mating. To use the

FIGURE 1.4 An archaic month calendar frozen in time. A count of the horizontal growth ridges deposited during full-moon phases by this coral from the Devonian period (350 million years ago) indicates that our months once were shorter and there were 13 of them in a year instead of 12. SOURCE: Courtesy Colgate University Department of Geology. Photo by Warren Wheeler.

physiologist's lingo, this kind of lunar entrainment could have led to the development of bodily pacemakers that controlled the secretion of chemicals related to the breeding cycle. In other words, our brains constructed a lunar-analogue time clock.

The year-clock is evident in mammals that seem to have developed an annual reproductive cycle that ensures that the young will be born at the most promising time for survival; this is particularly true of species residing in temperate climates, where the change of seasons is more dramatic than in the tropics. Animals precisely measure changes in the daily light period. For example, the testes of hamsters

remain in regression during the long winter period leading up to the spring equinox. Then, all of a sudden, the weight of the testes is multiplied by 10 in just a few days. This dramatic change seems to take place just when a light period of between 12 to 12¼ hours per day is reached. It is as if the critical day length around the equinox triggers a switch within the animal whereby it anticipates the mating season and rapidly begins to prepare for it.

Now, all of this talk sounds distinctly exogenous, though most animal biologists believe that the time clock is switched on by an endogenous circadian system, something like that advocated in Bünning's two-phase hypothesis. Thus, on long days light would tend to fall on a greater portion of the cycle that would stimulate a physiological response. In fact, experiments conducted in the laboratory showed that when a light pulse fell on one of the "light-loving" phases of the 24-hour cycle, the testes became fully functional.[9]

The circadian clock is blended in with the lunar and the solar reproductive cycles in many other ways. For example, spontaneous births in humans increase dramatically between 3 and 4 A.M.; and the estrous cycle and the time of ovulation follow a 24-hour subperiod within the menstrual cycle. But what coordinates these periods?

When freed of all time cues, humans, as well as animals, seem to go through a series of stages or adjustments before becoming totally desynchronized. They behave as if two coupled pacemakers that once provided information to one another had become totally decoupled. There seems to be an attempt on the part of the organism for the first few weeks to imitate the normal period. Then, when a certain phase between two different bodily cycles, such as body temperature and sleep-wake rhythms, is reached, the organism becomes "trapped," and a new oscillation period is settled upon and followed for both. Finally, after a few more weeks, as if a switch were pulled, the pacemakers become totally desynchronized, and the two periods start to drift rapidly away from one another. In each instance, the coupled pacemakers appear to be contained within or close to the SCN neural clusters. Thus, the human clock, at least as we conceive it, seems to behave much like a machine.

We've got rhythm! There's no doubt about it. And our desire to memorize, mark, and record it—the subject of the next chapter—seems to have been bred within us right from the start, before we could even call ourselves human. Like all living organisms, we march in time to the dependable beat impressed upon us by nature's background

music. For us today, that environmental combination of tunes happens to consist of a 24-hour alternating light-dark point-counterpoint, backed up by the song of the moon, sung both in different time and in a different key. The sun chimes in with its second chorus; the music of the seasons sounds with a much lower pitch that conflates with the lunar beat to produce a kind of disharmony. All creatures of the earth automatically tap their extremities to keep time with its tunes. Ours is a beat that could have been different had the earth's past history been otherwise (see figure 1.4). Why not a 5-hour day, a 100-day year, and maybe 3 moons in the sky instead of 1? Different planet, different music. But this is the way it is here and now, at our place.

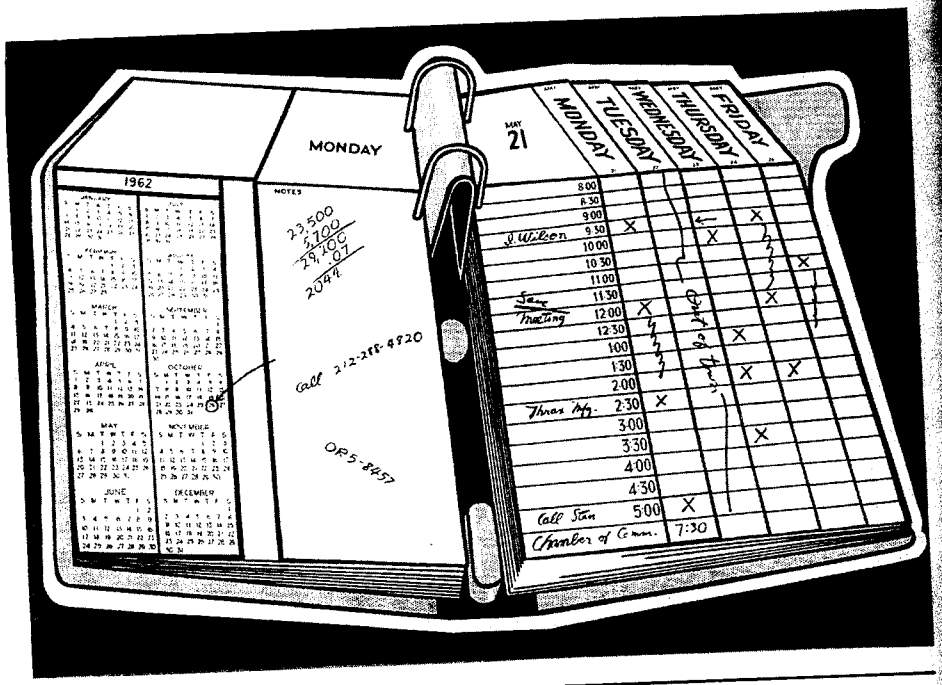
Mechanism as Metaphor

Am I a man or a violin? When my archaic ancestors finally became rational and began to become interested in the problem of accounting for their own behavior, they chose to see themselves as well-tuned instruments—machines, in fact. When we are in good working order, we happily hum away at the melody. Our pacemakers sustain and sing out every one of nature's vibrations. They sense the downbeat, capture it, and make it fit with the other beats already encoded into the body instrument.

As I have noted, the language used to describe the way we in the West think the coupled circadian oscillation works consists of neural networks, transducers, pacemakers, command posts, control mechanisms, cues, signals, and oscillators—that familiar language of information retrieval and processing in which the twentieth century is embedded. At least since the Industrial Revolution, if not from the Renaissance, when we first began to manipulate and experiment with nature, we have come to have faith in the machine, to believe in mechanism as a way of understanding. Machinery is, for us, the power tool of metaphor. After all, machine technology has helped the Western world prosper. Why not stick with a good thing and use its principles to create new ideas about how all things function? And so we try to account for natural events by inventing mental models that parallel the way things behave: the brain as a sponge, the nervous system as a public transit network, the atom as a miniature solar system, the solar

as a set of revolving spheres all linked together by a gear —as in a planetarium.

Of course, the physicist will say that the atom is not really made little round balls in orbits, and the biologist that the computer is a contemporary body metaphor. Certainly neither scientist has intention of portraying these mental fabrications as reality. The dy is *really* not a machine—no more than do atoms have a "glue" t bonds them together as molecules. The tenuous relationship ween metaphor and reality arises again in the next chapter on how ral time sensing led, in the higher forms of life, to deliberate time koning; that is, the conscious attempts by rational human beings to rk time, to remove it from its natural rhythmic casing, to mold and hion it, to develop and use it. Let me, then, turn to how, when, and y the very time we as humans—along with the corals, the oysters, d the potatoes—had been feeling within ourselves throughout evotionary history, whether by internal or external impulses, became tamorphosed in the West into something outside ourselves, an tity so strange and novel that today we must strain our senses even recognize it.



Desk Calendar. Roy Lichtenstein. The Museum of Contemporary Art, Los Angeles: The Panza Collection. Photo by Squidds & Nunns.

3

THE WESTERN CALENDAR

All the world's a stage,
And all the men and women merely players:
They have their exits and their entrances;
And one man in his time plays many parts,
His acts being seven ages. At first the infant,
Mewling and puking in the nurse's arms.
Then the whining school-boy, with his satchel
and shining morning face, creeping like snail
Unwillingly to school. And then the lover,
Sighing like furnace, with a woeful ballad
Made to his mistress' eyebrow. Then a soldier,
Full of strange oaths and bearded like the pard,
Jealous in honor, sudden and quick in quarrel,
Seeking the bubble reputation
Even in the cannon's mouth. And then the justice,
In fair round belly with good capon lined,
With eyes severe and beard of formal cut,
Full of wise saws and modern instances;
And so he plays his part. The sixth age shifts
Into the lean and slipper'd pantaloon,
With spectacles on nose and pouch on side,
His youthful hose, well sav'd, a world too wide
For his shrunk shank; and his big manly voice
Turning again toward childish treble, pipes
And whistles in his sound. Last scene of all,
That ends this strange eventful history,
Is second childishness and mere oblivion,
Sans teeth, sans eyes, sans taste, sans every thing.

SHAKESPEARE, *As You Like It* (II, 7)

TIME—we have socialized it, circularized it and linearized it, artificialized and corrupted it. In attempting to trace the origin of all time concepts, from pico-second to Great Year, that make up today's

calendar, I have found it necessary to use these descriptive terms. Our days are numbered. Take down the nearest wall calendar and flip through it. Those 12 pages represent a packet of time, a full seasonal cycle—the period of revolution of the earth about the sun. That dozen pages also represents the time it takes the sun to pass all the way around the celestial background of constellations and to return to the same place among the stars; it is also a close approximation to the time it takes the daily sunrises and sunsets to make a complete oscillation from one extreme along the horizon to the other and back again—essentially what the builders of Stonehenge were supposed to have been marking. That packet of pages we call the calendar is, like the henges on Salisbury Plain, a device invented by our ancestors to subdivide the course of the sun.

Each of the 12 calendar pages, representing a month of the year, is compartmentalized into little square blocks that number 30 or 31, except for the deviant second page. While the year is the course of the sun, the month belongs to the moon, being related to the period of revolution of the moon around the earth relative to the position of the sun—another phenomenon we don't see.

There is nothing in the universe quite like the moon. If we were freed from the fetters of indoor lighting, telescopes, and abstract scientific explanations, we all might be a little more familiar with its apparent behavior, as was Hesiod or the people who fashioned Stonehenge or *Enuma Elish*. At the beginning of its cycle, the moon is a thin, sharp-horned crescent suspended above the western horizon, its cusps always pointing away from the sun, which has already set. On succeeding twilights, it waxes, or grows, appearing at sunset farther away toward the east from where it was at the beginning of the month. It passes its quarter phase and takes on that familiar "D shape" it always exhibits when it rides high on the *meridian* (the imaginary north-south line that passes overhead) in the south at sunset. Still later in the month, it enters the *gibbous* phase, when more than half its visible disk is lighted, and can be seen high in the east late in the afternoon. After half a cycle, when it reaches the full phase, the moon is most prominent of all, rising opposite the setting sun, illuminating the sky with a flood of pale yellow light all night long.

Two weeks have passed. Now the moon begins to backtrack in its cycle, its face slowly eroding away in reverse. It passes in reverse through gibbous phase, then back toward quarter as it wanes. When you see the moon in the morning daylight hours, this is usually what it

looks like, for, having risen progressively later during the night, it remains in the sky well after the sun has come up. At month's end, the disk is reduced once again to a thin crescent, the vanishing sliver of which can be glimpsed low in the east before sunrise. Then it vanishes altogether for a couple of days as it becomes lost in the glow of the sun's light. When we see no moon, we speak of the "new" moon, but the moon is not visibly renewed until we see its crescent again in the evening twilight.

The whole process takes 29½ days—a *synodic month*. Although the cycle symbolized by any one of the calendar's 12 pages was intended originally to follow the moon's phases, some of the months we keep are now longer than others and not one matches the actual synodic lunar rhythm one can easily observe in nature. This discrepancy is a result of the convoluted, highly complex amalgam of motives that led to the formation of our calendar. Implicit in it are not only nature's rhythms but also religion, politics, and human intrigue. It is a safe bet that if travelers from another world tried to decipher our calendar, they would not stand the slightest chance of putting all the intricate pieces of the time puzzle together, however superior their intelligence.

The wall calendar contains both past and future. The days of a lunar cycle gone by, days beyond our reach except in memory stand conveniently blocked out so that one may recollect and reckon back to where one was or what one was doing at a particular point in that last lunar cycle. Next to the month past lies the month of the future—that which has yet to happen, time unreckoned, time to anticipate, time that has never existed. The unmarked calendar on my wall implies that the two are the same, that past and future do not really differ at all. But I can determine the truth or falsity of that statement when the moon recycles and I turn the page.

Any page of the wall calendar will reveal another subdivision to the time units Westerners have created: seven vertical divisions to the sequence of numbered blocks, each column with its own name. The four or five horizontal bands, called *weeks*, into which we group the moon's days constitute a peculiar time division. There is no single celestial body such as sun or moon, no obvious natural cycle to which we can directly attribute this little packet of time. Moreover, many other cultures and traditions also tally an interval of about the same general duration in their calendars.

Finally, there is the day—the simplest and most obvious unit of

time. There is a number for each one. Today is the 21st; tomorrow, the 22nd. Change numbers at midnight, and you have measured out one complete rotation of the earth on its axis—but once again that is not what our senses detect. We witness, rather, a two-part cycle, the first of which is marked by the passage of the sun across the sky from horizon to horizon, followed by an extended period of darkness, after which the sun returns to approximately the same place. (Recall that the sunrise position varies from day to day.) The day is thus really an abbreviated solar rhythmic cycle that provides a counterpoint to the longer sun cycle of the year, with the moon's beat lying in between.

Circadian, circ-annual, circa-lunar—to use the biologist's terms—are the principal cycles that make up human time. We in the West have re-envisioned on sheets of paper the very intervals to which our environment has already entrained us. No one willfully set out to create these intervals. The desire had always been to reach for the future, to set up a date-reaching scheme—a plan or model for describing patterning in the passage of events which might help people to know when in a series of measured intervals a particular event would take place. The fabrication of such a model depended upon knowledge of when a similar event had taken place in the past. Man-made calendars became both past and future time-marking devices. Still, Westerners have fashioned artificial divisions of time out of rhythms derived from living within nature's environment. We have not been content to allow ourselves to float about aimlessly on the waves of nature's ocean of time. We want to count the waves, to classify them, to package them neatly into recognizable patterns. Now, 20,000 years after having picked up a fragment of bone in one hand and a piece of flint in the other, perhaps to assist our memories, we have begun to control those waves—even to make waves of our own. We have done far more than count the moons and the suns.

On your wrist, you may see yet another mechanism we have made to control both the passage of events and the rhythm of our behavior. This device's very shape conveys the notion of the daily round of time and the natural form of the sky—unless you happen to be wearing a stylized rectangular model with distorted numerals, or a digital without hands.

Wristwatches partition time still further—the day into hours, 12 of them read twice over. The little hand is the last remnant of any direct contact between the day as we know it and the place of the sun in the sky, a pointer that shows where the sun is situated—east in the

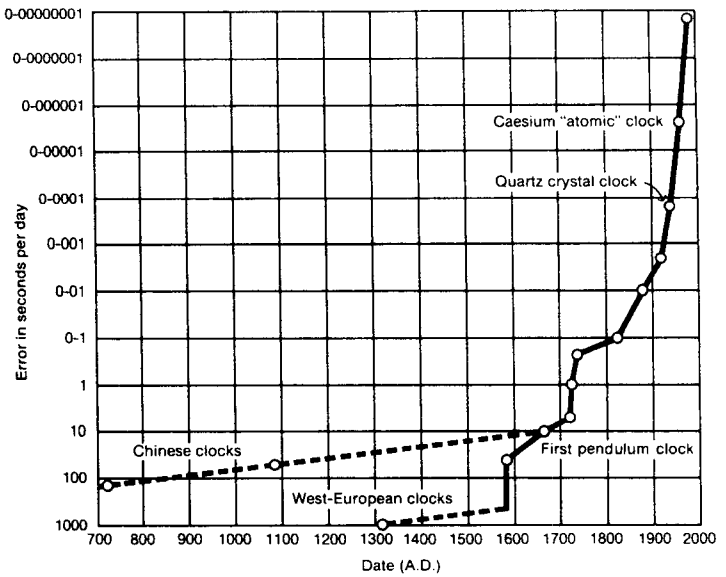


FIGURE 3.1 The progress of precision in time measurement. This plot shows the increase in the accuracy of mechanical clocks from the time of their invention up to the present. SOURCE: An updated redrawing of a graph in H. A. Lloyd, "Time-Keepers—An Historical Sketch," in *The Voices of Time*, J. T. Fraser, ed. (Amherst, Mass.: University of Massachusetts Press, 1981), fig. 3, p. 400. Copyright © 1981 by J. T. Fraser.

morning, when it points left of the 12; west in the afternoon, when it points to the right; and straight up at noontime. We also divide the hours into sixtieths called *minutes* (not tenths or hundredths the way we subdivide most things) and the minutes into sixtieths named *seconds*. Recent preoccupation with time-setting records in Olympic competition has led to watches that read to hundredths, even thousandths (not sixtieths or thirty-six hundredths), of a second. In scientific laboratories the divisions proceed to *micro* (millionths) and *pico* (billionths), even *femto* (quadrillionths) seconds. Paradoxically, we seem to have expended considerable effort trying to measure an entity we have difficulty defining (see figure 3.1). Recently Tiffany's in New York displayed a Patek Philippe Swiss watch said to be the most complicated in the world. Weighing 2.4 pounds, held together by 332 screws and exhibiting 24 hands, it performs more than three dozen different chores—among them the calculation of Easter Sunday, the times of sunrise and sunset, and the orientation of the Milky Way in the night sky. Value: $3,000,000 to $6,000,000.[1]

At the *largo* end of the time spectrum, our imagination is equally boundless. Our years grow into centuries, the centuries into millennia. The longer the time cycle, the less precisely is it defined. We have invented ages, epochs, and eras. Many non-Western calendars such as that of the Maya of Yucatan and the East Indians employ similar concepts. Scientists own the record at both ends of time's spectrum. Modern geologists and astrophysicists have conjured up the longest intervals: the lines of demarcation between them are unevenly spaced time markers that seem to be significant along the course of evolution of life, the solar system, the Milky Way galaxy, and even the entire universe.

The Day and Its Hours

Let us begin in the middle with the day and its parts, and then work up the hierarchy of cycles from short to long, concentrating on how time's parts were both conceived in our ancestors' heads and brought together. There is no need to speculate about where the day cycle came from. It is the most basic of all natural periods—the one responsible for the circadian cycles found in practically all living things. Behaviorally, little influences our lives more deeply than the variation of day and night, light and dark, sleep and wakefulness. What seems problematic about the diurnal period is where to begin and end it and how to split it up. In most cases our ancient predecessors indicated the time of day by concrete phenomena rather than by mechanical abstract devices, like marks or numbers, whose operation has nothing to do with the defining event. To express a particular "hour" of the day, one would simply point to the place in the sky where the sun could be found at that time. This is a common technique. The Konso of central Africa, for example, reckon the parts of their daylight hours approximately as follows—all of them by pointing:

9 A.M.–11 A.M.	gudada
11 A.M.–2 P.M.	guuda' guta
2 P.M.–4 P.M.	kalagalla
4 P.M.–5 P.M.	harsheda akalgalla
5 P.M.–6 P.M.	kakalseema
6 P.M.–7 P.M.	dumateta
7 P.M.–8 P.M.	shisheeba

Each interval is not numbered but, rather, is named after the activity that takes place at that time of day. Later intervals are compressed because, the people say, this is the most important time of the day for performing activities. Thus, the name of the 5-to-6 P.M. interval means "when the cattle return home." Those longer intervals during the heat of the day reflect periods of relative inactivity. While such vaguely defined boundaries and durations are in stark contrast with our regimented modern way of precisely dividing up the day, the human hour-clock is more accurate than we technology-dependent moderns might think. Though simple morning, noon, and afternoon can easily be sorted out simply by observing which side of the sky the sun is in, even 8- or 10-, perhaps even 12-, fold divisions of the day can be reckoned unambiguously simply by gesturing with the arms. Were an hour's accuracy all we ever needed, the entire world might be completely devoid of clocks today. More than accuracy, the desire for uniformity affected our Babylonian ancestors' rational way of marking time.

The invention of the simple technology of shoving a stick vertically into the ground signaled the first break away from nature which culminated in our uniform timekeeping system. The times of sunrise and sunset usually designated as beginning and ending the day are variable, and so are the lengths of daylight and nighttime hours. The partitioning of day and night into 24 hours, another human imposition upon nature, came perhaps from the division of the zodiac into 12 equal parts, each one marked by a constellation through which the sun passed over the course of one moon cycle. Because it takes the sun approximately 360 days to make a complete annual circuit through the stars, an easy system for dividing up seasonal time seems to have suggested itself: that is, intervals divisible by 6 and 12. Thus, the sexagesimal notation came to be a part of time reckoning, with 60 minutes to the hour and 60 seconds per minute, 12 hours per day and night, and so on. Spatially, the circle representing the round of the sun and its celestial course was also divided into 360 degrees. By Roman times, day and night were joined as a unit that began and ended at midnight, a more convenient time to make the transition, at least in the business world; even though midnight was a more abstract point in time than the distinctly visible sunset or sunrise. Still, the hours reckoned by the sun's shadow casting were unequal. To circumvent these nonuniformities, the ancient Babylonians invented artificial hours, which they defined as one twenty-fourth part of the day. Like the beginning and ending of the Roman day, such hours had nothing to do

with the position and rate of movement of the sun across the sky, but at least they were equal and rational; they were fair. This artificial system of time units was not practical, however, and did not achieve widespread use until the end of the Middle Ages with the glorious invention of the mechanical clock (see figure 3.2C).

In the developed state societies of Europe and America, public or shared time was the general rule. In the Roman forum, a timekeeper shouted out the noon hour as the sun passed between the Rostrum and the Grecostasis, two of its most prominent buildings. His counterpart in the ancient Aztec capital of Tenochtitlan (now Mexico City) stood in a round temple in the plaza fronting the great Templo Mayor, and announced to all citizens the opening and closing of the market, the departure of the warriors, the beginning of the games, the time to worship. Organized society demands a highly regulated daytime period in order to coordinate its principal activities. In ancient Greece and Rome, this perceived pattern of solar angles called hours was transformed into a series of crude public sundials (figure 3.2A)—objective and impersonal entities at which people could steal a glance to help keep themselves on track. (Compare the sundial from Indonesia in figure 3.2B.)

The science historian Derek Price characterizes the earliest Greek water clocks and dials as "simulacra," or simulations of how things work.[2] The original intention of the builders seems to have been the aesthetic satisfaction derived from making a device that imitated the heavens. Our first real clocks, such as the Tower of the Winds in Athens, were models of the cosmos composed and constructed to glorify the beauty and simplicity of heavenly motion, not necessarily to satisfy an appetite for precision.

Religious demands, more than the desire for quantitative science, played a major role in the increased precision that threads through much of the history of timekeeping in our culture. The Christian way demanded a controlled, disciplined life; and in the Christian Middle Ages of Western Europe, it was the strict rule that the call to prayer, particularly in the monasteries, be made at the correct time of day. In fact, the mechanical clock was the *result* of an interest in measuring time, not the *origin* of that interest. Like many artifacts emanating from Christian worship in that age of religious preoccupation, the timepiece of the Middle Ages developed into a work of beauty and complexity. Clocks became showpieces. The one-hand version used to

mark only the hour gave rise to two hands, as the hours and their parts chimed, gonged, and clattered their way into our cycle of daily activities, which now began to be submerged in the noise of still other machinery.

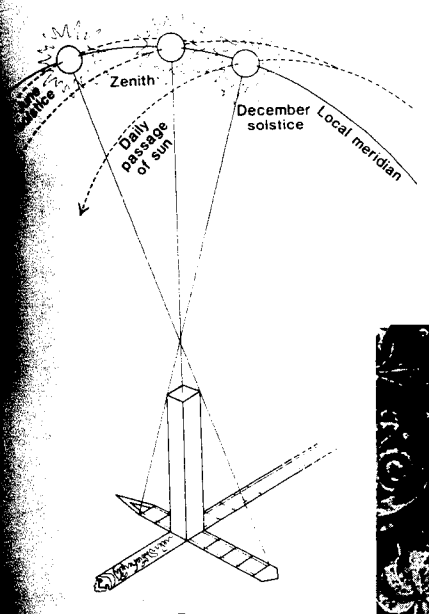
Our medieval ancestors devised other clever ways to mark time: clocks that run by gravity as water drips out of a filled tank through a tiny hole and into the base of a calibrated tank (figure 3.2C); slow-burning candles with the hours ticked off in bright colors on the banded wax; and the familiar ship's clock of sand falling from one globe to another through a tiny hole, also gravity-operated like the water clock.

"Time is money." As the secular dictates of production and trade in an expanding, interlocking market economy began to rival and surpass the sacred demands religion had placed upon timekeeping, each of these types of clock was found to have its problems. Gravity clocks start out faster, but then run more slowly; sundials do not keep equal hours, because the shadow lengthens more rapidly in late afternoon. And even if one adjusts the markers to account for the non-uniformity of "shadow time," the hours differ in different parts of the year and in different locations within the state. Should people who work shifts of different lengths be given the same pay? Why should one person be required to start work earlier than another? Or stay later? Is it possible to adopt a reliable system of uniform hours? These concerns propelled pre-Renaissance Europe farther and faster along the road of artificial mechanical timekeeping which today has come to span all units of our calendar, large and small.

By the late Middle Ages, a new kind of public time system had been created. Born out of religion, commerce, the rise of towns, and the bureaucracy that accompanied them, the "work clock" slowly began to dominate life in the thickly settled European urban communities of the twelfth and thirteenth centuries. Bells of different pitch and duration pealed from the turret that marked the center of town. They tolled when to begin and end work, when to open and close the market, when to call the people to assembly or to begin the curfew. Only in remote rural areas did folks still keep time by the natural course of the heavens, which served well enough to organize a set of daily farm activities such as milking time, meal time, market time—the way it was done in Hesiod's day or by the Konso in Africa today. This new way of marking time was automated and unnatural; it was

FIGURE 3.2 Time is motion. Some early mechanical ways of keeping track of time: (*A*) This Roman sundial from the ruins of Pompeii is an inverse map of the heavenly sphere. The shadow of the pointer moves over the marked or unnumbered bowl-shaped surface to give the hour of the day and the day of the year. SOURCE: Courtesy S. L. Gibbs. (*B*) A sundial from Java that divides years into months. The length of the month is measured by equal spaces through which passes the shadow of the gnomon cast by the noontime sun; this scheme results in unequal time intervals for the months. SOURCE: Drawing by J. Meyerson. (*C*) Depiction of a waterclock (clepsydra) in a medieval manuscript. Most waterclocks were powered by a falling float that sat in a container out of which water dripped; the float was attached to a pointer that moved over a calibrated surface. In this painting, the prophet Isaiah is shown intervening with the timekeeping process. He sets back the clock to give King Hezekiah more time to recover from his illness so that he can put his house in order: "And Isaiah the prophet cried to the Lord; and he brought the shadow back ten steps, by which the sun had declined on the dial of Ahaz" (2 Kings 20: 11). SOURCE: J. Needham, *Clerks and Craftsmen in China and the West* (New York: Cambridge University Press, 1970), fig. 78. Reprinted with the permission of Cambridge University Press. (*D*) Engraving of an early-eighteenth-century time-ball apparatus from Portsmouth, England. The dropping of the ball, usually at high noon, served as a visual time signal by which the chronometers of ships in port could be set. SOURCE: *New Philosophical Journal* (Edinburgh) 8 (1830): 290. Courtesy, editor, *Journal for the History of Astronomy.*

A



B

C

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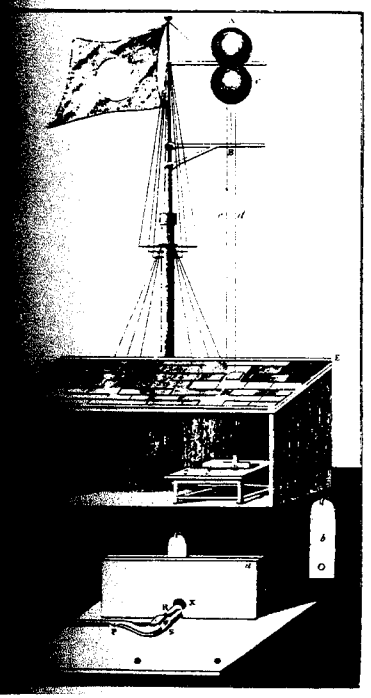


based on reason. Time had been extracted from nature and molded to fit religious and bureaucratic uses.

After the Middle Ages, Europeans moved faster toward harnessing the day. An age of discovery and exploration necessitated traveling vast distances, especially in a westerly direction. To navigate, one must keep fairly accurate time: moving across different longitudes implies keeping different times, for there is a slippage of suntime with longitude. When the rising sun is a handspan above the horizon in New York, it lies on the horizon in Chicago. At the same time in Denver, twilight has barely begun, while it is still pitch-dark in San Francisco. To chart their courses and keep track of the time, early explorers carried a ship's *chronometer*—essentially a well-balanced, accurate clock. The same requirement for a reliable, independent, and accurate means by which to track time held true for the tradesmen who journeyed with their wares between Venice, Munich, and Basel, each city having kept its own separate system of hours. Because businessmen were constantly changing their clocks, a set of conversion tables became an absolute necessity so that one could tell which city kept what system of hours, who began the day at noon, who at midnight, who at sunrise or sunset. (Noon started the day in Basel, but they called it one o'clock!) Up until the twentieth century, every respectable harbor city had its own time ball that fell once a day at noon to send ocean navigators a precise visual time signal by which to adjust their chronometers (figure 3.2D). (The famous New Year's ball in Manhattan's Times Square is a distinct survivor.)

The advent of railroads in Europe and the United States further quickened the pace of precision timekeeping and placed a heavier burden on the clockmaker who now needed to serve the demands of timetables accurate to the minute. Goods, especially perishable ones, had to arrive and depart on time so as not to be left to mold in a warehouse or to run up a huge bill. The technological burden was accompanied by a social one. Towns along the line needed to agree on a system of standard hours. Before the advent of zone time in 1883, there were two kinds of travel time: "railroad time" inside the train, and "local time" in the towns outside. The latter differed from town to town, for at a given time the angle of the sun from the meridian is the same only at a given longitude. Step one pace east or west of that line, and the natural hour changes. Even noon and midnight change. It was decided, therefore that everyone lying within a fixed distance east or west of the

nearest whole multiple of 15 degrees of longitude would keep time by that parallel. Thus, the eastern standard time zone is defined (except for a small correction) by the sun's angle with respect to the meridian 75 degrees west of Greenwich, England; while central standard time is reckoned by the 90 degree meridian, mountain standard time by the 105th, and Pacific standard time by the 120th parallel of longitude. Everyone 7½ degrees either side of these standard meridians keeps the time of that meridian, unless the line of demarcation bisects a heavily populated area, in which case it is shifted somewhat to avoid confusion. During the portion of the year when we keep daylight saving time, we simply make an instantaneous leap to the time zone directly east of us. Then, everything, including the setting of the sun, happens an hour later by clock time, giving us the illusion of having more daylight. At the other end of the cycle, the sun also rises an hour later—no real problem for most of us but an annoyance to early-rising farmers, who often object to legislation to extend daylight savings time over a wider portion of the year.

Today we live by legalized time. The continuous time differential experienced in nature has, for the sake of convenience, become discontinuous and partitioned as we move from coast to coast. On an afternoon-long intercontinental flight, it is easier to change my watch three times, in each instance either tacking on or knocking off a huge chunk of time, rather than speeding the watch up or slowing it down in a continuous manner (changing it at the rate of 1 minute for every 14 miles traveled in an east-west direction), but that is what would be required if we were to remain subject to natural time.

There is no choice: if you want uniform hours in the day, then you must cast your eyes away from the sun in the sky, and so in the eighteenth century, astronomers banished the *apparent sun* and put in its place the *mean sun*. This rational yet fictive sun moves at precisely the correct rate to compensate for the nonuniform rate of movement of that visible yellow disk our ancestors once worshiped. This fictive sun and its time, which we keep on our machines, gives us the equal hours and days we cannot seem to do without.

The Smallest Units of Time

Our smaller subdivisions of time are even more rationalistic than nationalistic when compared with the larger ones. While the clock's dial still tell us the day—the very word *dial* is named for the day—the minute and the second are total figments of our imagination. If you tune your all-band radio to WWV, the radio station of the National Bureau of Standards (2.5, 5.0, 10, 15, 20 megahertz), you can hear the seconds being ticked off officially, 86,400 of them to every earth rotation—just as the medieval clock tower in Augsburg or London chimed out bigger time bytes to our predecessors. The really persistent listener would note days, like 31 December 1987, when an 86,401st second was added, for now even the once-supposed constancy of the rate of the earth's rotation, the very day itself, has become anachronistic. Its variable length is too irregular for our needs (it changes by up to 1/1,000 of a second in some years); worse still, we cannot anticipate with reasonable certainty the rate of change of day length, though we do have some idea why the earth slows down and speeds up by almost imperceptible amounts. One cause is surely the drag effect on rotation produced by the earth's atmosphere. The same kind of friction occurs at the contact between the ocean and the surface of the solid earth—literally, the rubbing of the ocean against the solid earth. This effect is particularly pronounced in shallow bays where the tide breaking against the shore dissipates vast quantities of energy—millions of horsepower in the Bay of Fundy in Canada alone, much of it derived from the energy of rotation of the earth. Similar energy dissipation occurs at the contact points between different layers in the earth's interior. It is as if a huge brake were applied to a turning wheel, in this case the wheel of the days. Ultimately they will become longer and longer as the rotating earth clock runs down.

The modern quest for precision in timing the parts of the day has achieved revolutionary proportions late in the twentieth century. Once the clocks we were capable of building began to surpass the accuracy with which we could measure the earth's rotation, we were compelled to seek a more reliable standard. The vibration rate of a cesium atomic resonator was first installed as an alternative time standard in

the 1950s. This new "pendulum" measures out how long it takes an electron of an atom to pass from one energy state to another. But because no one can see individual atoms, such oscillations are measured only collectively and statistically. Furthermore, energy levels, even electrons and atoms themselves, are the creations of the human mind: they are microscopic metaphors we devise as a way of explaining the microcosmic behavior of nature. Thus, when we look at a line in the emission spectrum of cesium atoms, we say that a piece of matter locked away in a box behaves *as if* it consists of atoms, surrounded by electrons, certain ones of which are rapidly making the transition from one atomic orbit to another, exchanging energy with the environment as they go. When we hook up other black boxes to the one containing the cesium oscillator, we are able to tap that energy—to count the transitions or oscillations made by these moving electrons. And when we do so, we find that 9,192,631,770 of them can be used to define the international second. We do it with the obsessive accuracy of better than one part in a hundred trillion. (Expressed in spatial terms, this would be like knowing the distance to the moon to less than the width of a human hair!) Heralded as a triumph of watchmaking over astronomy, the "atomic second" became the official world time standard in 1967. It is this time unit that we usefully divide into milli-, micro-, pico-, and femto-seconds. Now I can replace my long-winded statement with a more meaningful one: the cesium atom oscillates between the two hyperfine levels of its ground state in 9.192,631,770 picoseconds.

Recently the concept of the natural oscillation of microscopic matter as a time standard has directly entered the world of everyday public time in the form of the digital watch. Here the oscillators are not individual atoms but quartz crystals energized by batteries. Typically these crystals vibrate many thousands of times a second with a remarkably steady rhythm because of their stable molecular structure. The vibrations are monitored, stored, counted, and packaged into different units of time through microchip circuitry, and then fed into liquid crystal display units that give time, day, date, and month, as well as a lot of other information of dubious digital necessity. I recently saw a watch on sale that offered times around the world, stored up to a dozen addresses and phone numbers, and intoned a diverse array of musical signals—all for only $19.95! It seems astonishing that all these feats can be accomplished without moving mechanical parts, thanks to

human technological ingenuity. Our quest for the precise time of day may go down in history as the greatest obsession of the twentieth century. Originally motivated by religion and business, rather than pure scientific concerns, our quest for the ideal model, the standard upon which to construct a rational way of marking time, has carried us from the vast cosmos down to the abstract invisible world of the atom. For the genius of our precision, we have paid a dear price. An objective outside observer might say that in the modern world time controls us, rather than the other way around. Consider what the anthropologist E. E. Evans-Pritchard once said of the Nuer tribe of central Africa:

> I do not think that they ever experience the same feeling of fighting against time or having to coordinate activities with an abstract passage of time, because their points of reference are mainly the activities themselves, which are generally of a leisurely character. Events follow a logical order, but they are not controlled by an abstract system, there being no autonomous points of reference to which activities have to conform with precision.[3]

The Week and Its Days

After the day, the week—represented by the horizontal bars on most calendars—is among the most recognizable and commonly used parcels of time and also one of the most convenient. The week seems to have developed because it was simply a sensible way of dividing up the days of the month; and of all longer time periods, it is among the few that does not vary in length. Some biologists believe the week is self-determined. The 7-day biorhythm in the human body is one of the recent discoveries of modern chronobiology. It manifests itself in the form of small variations in blood pressure and heartbeat as well as response to infection and even organ transplant: for example, the probability of rejection of certain organs is now known to peak at weekly intervals following an implant.

We are not unique in broadcasting this beat: even simple organisms, down to bacteria and one-celled animals, seem to share it with

us. There is, for example, a 7-day rhythm in the *mermaid's wineglass*, a species of algae whose configuration resembles a champagne glass with a long stem and a large flowery globe at the end. This organism can be entrained to reduce its rate of growth only when exposed to an alternating light-dark period of 7 days—no more, no less.

Does social time *entrain* biological time? We might be able to connect the faint *circa-septan*, or 7-day, periods in our biological makeup to the week cycle upon which economically motivated human beings thrive. However, we know that the Romans, to whom we owe most of our temporal habits, worked on an 8-day cycle, the last day of which was a market day. Similarly, our word *sabbath* comes from the Jewish concept of the periodic recurrence of a day of abstention from work in the cycle—the seventh day—which the Jews gave over to the worship of the deity. So important was this round of the calendar that the most famous creation story in Genesis was built around the everyday structure of social time. The creation lasts 7 days—not 3 days or 6 months. Parallels between human origin and the cycle of social life experienced by ordinary people served to emphasize the hierarchical order depicted in the creation story. The week may not be a memorial of the creation of the world; instead, the creation is a mnemonic of the work week.

There are other reasons to think that this work-rest cycle of several days' duration is natural to the human condition. Most cultures with a developed system of trade and commerce employ a cycle something like it. Five-day market weeks are kept in parts of Africa and Central America. The Inca employed 8-day weeks, at the end of each of which the king changed wives. Villagers and field workers, having spent 8 days in their fields, would come to market on the ninth day. Short market weeks of 3 or 4 days were known among the Bantu of Angola in the last century; then there are more lengthy artificial periods of time, like the 16-day market week of the Yoruba people of the coast of West Africa and the well-known 20-day week cycle employed throughout ancient Mesoamerica (which I will deal with in detail in chapter 6). The Kedangese of eastern Indonesia are the creative record setters when it comes to fabricating week cycles. They have ten kinds ranging in length from 1 to 10 days, each with its own set of names, all running at the same time. Furthermore, they seem to be able to calculate in their heads when every conceivable combination will recur in the maze of cycles that eternally preoccupies them.

Verses in the *Enuma Elish* seem to tie the week to the moon. After Marduk creates the "ornament of the night," he commands her "to make known the days" by going forth with a tiara:

> At the beginning of the month, namely, of the rising the land,
> Thou shalt shine with hours to make known 6 days.
>
> (15–16)

On the seventh day "with half a tiara"; or, according to another translation, "On the 7th day halve thy disk."[4] The implication seems to be that the 7-day cycle is a fair equivalent to a readily visible celestial phenomenon—when the moon passes from first visibility with its tiara-like crescent, to the familiar and well-defined "D-shape" quarter; then, though the *Enuma Elish* does not specifically state it, the next 7-day period might be associated with the time between quarter and full; and so on. The whole month of the phases is conveniently divisible into four quarterly periods in which the number 7 predominates. The British term *fortnight*, which stands for 2 weeks (14 nights), may have been a spinoff of this early relationship between the week and the month, an interval splitting the month into its pair of familiar half-cycles from new to full and from full to new moon. We cannot, however, be sure that the recognition of the period of the moon's phases came before the creation of the septenary cycle. (The moon's phase cycle is 29.5 days and not simply 4 times 7, so the fit is not as precise as we might like.)

If the moon does not lie at the foundation of the week, then perhaps the planets do. There is more than a hint of a planetary origin in the mere listing of the names of the days. The following table shows the Anglo-Saxon and English equivalents for each of the Latin named divinities in the day sequence:

LATIN	*ANGLO-SAXON*	*ENGLISH*
Dies Solis	Sun's day	Sunday
Dies Lunae	Moon's day	Monday
Dies Martis	Tiw's day	Tuesday
Dies Mercurii	Woden's day	Wednesday
Dies Jovis	Thor's day	Thursday
Dies Veneris	Frigg's day	Friday
Dies Saturni	Seterne's day	Saturday

Obvious in this list are the sun and the moon; less so, the match-up between Jove, also known as Jupiter, and his Nordic counterpart, Thor. The planet Saturn appears in the list as well. In fact all celestial bodies that move regularly through the zodiac and were known before the invention of the telescope appear in the 7-day list, though arranged in an order that makes little sense to us: Sun, Moon, Mars, Mercury, Jupiter, Venus, and Saturn. Today we line up the planets in the order of their distance from the sun—Mercury, Venus, Earth, Mars, and so on—but that was not what mattered in Babylonian astronomy. And the Babylonians—indeed, everybody in the world before the Renaissance, as far as we know—did not conceive of the sun-centered system that gives rise to the modern way we in the West learn to list the planets. For them a more sensible order consisted of listing the celestial wanderers according to *how fast they moved* from one constellation of the zodiac to the next, from the slowest to the fastest: Saturn, Jupiter, Mars, Sun, Venus, Mercury, and Moon. In the more astrologically motivated astronomy of the past, each hour of the 24-hour day was thought to be presided over or ruled by a planet, the order of designation being given by consecutive runs through the 7-day list. A day received its name from the planet that presided over its first hour. Thus, the first hour of the first day was given over to Saturn, and that day was named Saturn's day. On that day Saturn also governed the 8th, the 15th, and the 22nd hours. Counting down the list, the 23rd hour of the first day would belong to Jupiter; the 24th and last to Mars. Therefore, the first hour of the next day would be enjoined to the sun, and the name of the second day of the week would be Sunday. Because 24 divided by 7 leaves a remainder of 3, to finish up the order of the day names in the Babylonian week cycle, all we need do is count off by 3s. Three positions forward from the sun lies the moon; thus we have "moon-day" or Monday as the third in the week cycle. A count of 3 more takes us to Mars, whose day is the equivalent of Tuesday (Mardi Gras means "fat Tuesday"). Next in the list come Mercury's day, Woden's day or Wednesday; then Jupiter (Thursday); and finally Friday, Venus being the equivalent of Frigg or Fria. The cycle is completed when we return to the first hour of the 8th day which, like the first day, turns out to be represented by Saturn. While Saturday was the first day of the week in the world of Exodus, upon their flight from Egypt the Jews made it the last day of the week—out of pure hatred, so it is said, of their oppressors.

While the weekday scheme seems to be of pre-biblical origin and was used extensively throughout the Middle East, it was not formally introduced into our calendar until late in Roman times, not until the reign of the Christian emperor Theodosius late in the fourth century, though it had been initiated a few generations earlier by Constantine. Earlier the pagan Romans had been using an intricate backward counting scheme with a threefold unequal division of time that was unmistakably tied to the month.

The calends, from which we derive our word *calendar*, were the first days of the month, traditionally the time when religious leaders called people together to outline the festal and sacred days to be kept during that month. The ides fell at midmonth, usually the 13th or 15th day; and the nones, on the 9th day before the ides. The 4 to 6 days between calends and nones were named the "days before the nones." The 8 days between the nones and the ides were the "days before the ides." Finally, all the rest were the "days before the calends" and could be as many as 9. This backward way of counting time is similar to our reckoning time before the hour ("a quarter to six") or to the countdown before the launching of a space vehicle.

The scheme for naming the 7 days of the week, as outlined, grew no doubt out of the ancient practice of scientific astrology. The term *scientific* is appropriate here, for astronomers were required to predict precisely where the planets would be in order to prognosticate the course of human history. The influence of the planets on society was thought to be determined by where they lay among the stars, and the predictive power of a planet was tied directly to the "magnitude of its sphere." In other words, a planet's distance from the earth determined the size of its orbit *around the earth*, and that in turn was reflected in its speed. The slowest (Saturn) was thought to be farthest, and the farthest was considered the most powerful—a notion diametrically opposed to present knowledge, the power of gravity weakening dramatically with distance. So strong was this ancient astrological influence that 7 became a sort of magic number. The number of the planets served as the core of an associative principle that had significance for designating other entities: the metals (mercury is quicksilver); trees, plants, and animals (onions and donkeys belong to Saturn!); and, getting back to time, the supposed seven ages of man. In the scheme of the Greek astronomer Ptolemy of Alexandria (c. A.D. 150) the human time order is heaven bound, going from the lowest to the highest orbits. The period of infancy up to four years old was ruled by the moon; childhood, or ages four to fourteen, by Mercury; adolescence (fourteen to twenty-two) by Venus; youth (twenty-two to forty-one) belonged to the sun; full manhood (forty-one to fifty-six) to Mars; early old age, which lasted to sixty-eight years, was dominated by Jupiter; and whatever time was left belonged to Saturn. (A millennium and a half after Ptolemy laid down these seven ages, Shakespeare celebrated them in the well-known passage that heads this chapter.)

This associative way of thinking is, as I have said, an easy way to recall perceived patterns in the universe, a way of fitting patterns and events into a scheme or system covering all the mutual influences that might occur among them. If I assign an entity in a particular position in a list to one of a series of rotating states or qualities, then that entity automatically acquires a relationship to the quality; there is no need to look for a causal connection. I may say, for example, that just as I name the parts of my body from my head to my foot, so too may I name the stages of my life from birth to old age by passing along a continuum from top to bottom and by identifying each stage in one list with a segment or joint in the other. I can say that my head represents childhood and my foot old age. By arranging—in a single super list, table, or diagram—all the things and events that make up my universe of existence—elements, seasons, even the constellations of the zodiac—I can fashion a hierarchically ordered system whose core is the associative principle.* Often the properties will be found to oscillate between extremes in like manner as I pass down the continuum; that they are extremes may be a motive for their fitting together with each other in the first place. Thus, the seasons and the winds can be said to alternate like one's temperament or disposition, just as the good and evil properties of the planets balance one another out as we pass downward through their shell-like orbits from heaven to earth, Saturn being evil, Jupiter good, Mars evil, and so on.

*This is the principle embodied in the old nursery rhyme:

This is the way we wash our clothes,
Wash our clothes, wash our clothes,
This is the way we wash our clothes,
So early Monday morning.

This is the way we iron our clothes, etc.
So early Tuesday morning.

And so on through Wednesday (mending), Thursday (scrubbing the floor), Friday (sweeping the house), Saturday (baking bread), and Sunday (going to church).

In some cultures of the Amazon, the tapping of a woodpecker's beak upon an infected tooth is said to alleviate the pain. Of this association the French anthropologist Claude Lévi-Strauss has remarked:

> The real question is not whether the touch of a woodpecker's beak does in fact cure toothache. It is rather whether there is a point of view from which a woodpecker's beak and a man's tooth can be seen as "going together" (the use of this congruity for therapeutic purposes being only one of its possible uses), and whether some initial order can be introduced into the universe by means of these groupings.[5]

Such order was achieved by most of our forebears, including the early Christians in their association of Christ with Sunday. They met on the sun's day because it was believed to be the first day in Genesis in which the creation of the world was concluded. It was also the day Christ, their savior, rose from the dead. Thus, Christ, like the sun, became the light of the world.[6]

The Month and Its Moon

While we are unsure of the origin of the weekly cycle, there is no doubt about where the month comes from. The moon intrudes itself upon us, displaying its variability in shape, light, and position as well as a reversibility in its cycle. The moon is the epitome of continuous time reckoning, for its behavior suggests both continuity and duration; yet its changing aspects make it nature's ideal event marker as it exhibits noticeable differences from night to night.

Not only does the moon seem to beg for our attention—especially if we live in the country and can see it unimpeded by tall buildings—the menstrual period tied the human body to its light early in the distant past. Our word *menstruation* signifies "moon change," the Latin *mens* meaning "moon." German peasants call the menstrual period simply *die mond*; in France, it is *le moment de la lune*. For every woman the position of the moon in her cycle is different; but for a given woman, it is generally the same. At some point early on, a mental connection was made between a woman's failure to menstruate at

the appropriate lunar phase and the birth of a child nine moons later. The Maya *tzolkin*, or 260-day cycle—the most important time unit in their calendar—was likely related to the nine-moon (265.7 day) interval between human conception and birth (see chapter 6).

At first, there was no attempt to count the full complement of days in a month, for people needed to know not *how long* one actually was, but only *when* an event would take place. Like the sunsets that move from day to day along the horizon, the moon is its own time indicator. To those early observers, when it came the month began, and when it was gone, the month ended. Meantime, the thickness of its crescent or the bulge of its gibbous phase was enough to mark the time between. When people first applied arithmetic to the creation of a time-reckoning system—which, as we have seen, may have happened over 20,000 years ago—it must not have been difficult to discern that the full cycle of lunar phases transpired in about 29 or 30 days. Our ancestors probably initiated the tally with the appearance of the thin crescent of the "new moon" in the west after sunset, which many tribal cultures greeted with great joy, and still inspires moon watchers in our own culture. At least, this seems the most logical and decisive point to begin the count cycle: either you see it or you don't. In respect to the full moon, it is not always easy to decide on which of two nights its disk most closely matches a perfect circle. Our modern versions of where the cycle commences makes even less sense: that is, the point of conjunction or the time when the moon in its orbit passes directly between sun and earth, which we call "new moon" though the moon is not actually visible then. The first thin crescent is the young moon. We know for sure that in the ancient Middle East the month began with the actual observation of the first crescent. Astronomers were delegated to stand on a high place and peer low into the west at dusk to spy the visible signal that would indicate that they did not need to add a 30th or a 31st day to the present month but instead could wipe the slate clean and begin the cycle over again with "day 1." Imagine the difficulties we would have today—paying rent, collecting debts, meeting deadlines—had such a system persisted!

For some the first crescent is a symbolic representation of the resurrected old moon—the one that returns after having become obscured in the light of dawn a day or two before. For our ancestors, the phases became celestial parallels in micro-time of the waxing and waning cycle of the hero's life in the old succession myth. In one ver-

sion, the visible young moon conquers the devil of darkness as he waxes to maturity: you can even see the face of this man-in-the-moon who blazes forth triumphantly at the peak of his career—the full moon. But then the devil begins to eat away at him, and he starts to wane, lose power and wither away in old age. His feeble remnant falls from the eastern pre-dawn sky, and he disappears. During the time of new moon, some tribes used to say, "The moon is dead." But soon his son returns anew to avenge the death of his father.

That we number the days of this cycle suggests we prefer to deal with time abstractly. In most tribal societies, the phases are broken down into units that, rather than being numbered, are listed and named after concrete descriptions of the phase and position of the moon or of the way other parts of the living world behave at that time of the cycle. The very name of the day of the month gave away information about where the moon was in its cycle. This kind of naming system is laden with natural qualities. In the East Indies, for example, "little pig moon" and "big pig moon" correspond approximately to the 11th and the 12th days of our cycle, when the moon is well into the gibbous phase: it is at this time that the pigs, excited by the lunar light, are likely to break out of their pens and scramble about the fields. The 14th day is "lying," an apt description of the way the full moon rests on the horizon when it rises in the east at sunset. The 16th is "burner" because the pre-dawn moonlight shines through the door of the house. They call the 26th and the 27th days of the phase cycle "long tree trunk" and "short stump," respectively—words that may simply represent the declining shape of the crescent. Perhaps woodcutting activity might once have been associated with that time of the month. The anthropologist who gathered the data before the turn of the twentieth century seems not to have asked. "Going inside" and "inside" refer to the last visible crescent (day 28) and the next night's vanished moon because, the natives say, "they are going back to their house to rest." In Polynesia, the 3rd day after full moon, when it rises well after dark but still remains luminous, has a beautiful and descriptively apt name: "the sea sparkles at the rising." Also in parts of Polynesia, the first crescent meant "to twist" because it looked like a thread; the second day of the month was "crescent"; the third and fourth, "the moon has cast a light," because you have seen your shadow by it for the first time; the eleventh, "conceal," because the sharp points of the crescent are lost; the thirteenth, "egg," which describes the roundness at this stage of the gibbous phase; and so on.

Our division of the month into roughly four weeks seems unimaginative, even casual, by comparison with these indigenous calendars that reveal a people who operate close to their natural world. Indeed, it seems to be a general rule that the more complex a bureaucracy, the more abstract and contrived the month calendar. Where the Romans preferred a non-uniform three-fold division into seemingly inconvenient calends, nones, and ides, the earlier Greeks were more exacting, dividing the month into 3 decades, or periods of 10 days*—perhaps a derivative of counting on the fingers. The names of these intervals, however, retained the old descriptive elements: the Greeks called them "waxing," "middle," and "waning"; and the middle period may have consisted of time borrowed from the halves of an even more natural 2-part lunar-phase cycle. Whatever the case, this uniform method of dividing lunar time possesses certain advantages for the conduct of state business: each decade becomes an exact measure of the 30-day month; also, the number of the day of a decade is connected to the number of the days of the month: for example, the 3rd of a decade is the 3rd, the 13th, or the 23rd of the month. Compare this scheme with ours in which the name of a day of the week has no obvious connection with the number of that day in the month. When we reckon by weeks and then try to switch over to the time of the month, we need to consult a calendar in order to determine on what day of the week the month begins.

The Months and Their Politics

The names given to the individual months that make up the cycle of the year can, in some societies, be as informative as those given to the days that comprise the month. The sequences of actual month names on page 110 say a lot about the people who created them and the environment they lived in:

*Had the French Revolution succeeded, this custom might well have been reintroduced into the European calendar in 1789.

A.	*Spawning month*	*Naked-tree month*
	Pine-sapwood month	*Pedestrian month (when man goes home on foot while ice still remains)*
	Birch-sapwood month	*Month in which men go on horseback*
	Salmon-weir month	*Great month*
	Month of hay harvest	*Little-winter-ridge month*
	Ducks-and-geese-go-away month	*Wind month; month of crows*
B.	*Deer month*	*Maize or great-corn month*
	Strawberries month	*Turkey month*
	Little-corn month	*Bison month*
	Watermelon month	*Bear month*
	Peach month	*Cold-meal month*
	Mulberry month	*Chestnut month*
	Nut month (when they are crushed and mixed with flour to make bread)	
C.	*Millet-is-cut month*	*Bulls-seek-shade-of-Sakoa-tree month*
	Winter month	*The-guinea-fowls-sleep month*
	Beans-flower month	*Rains-rot-the-ropes (with which the calves are tied) month*
	Month in which tamarinds of the north are ripe	*Gourds-flower month*
	Tamarinds-and-beans-are-ripe month	*Month in which the grains of Fano are ripe*
	Month in which cythere tree flowers	

Clearly, the people of group A must be sedentary and live in a cold climate. Some of the life forms in their month list are familiar to those who reside in the northwestern part of the United States and the southwestern Canadian provinces: the running of sap and the spawning of salmon are time markers as distinctive as any celestial event. Actually, the people responsible for that lunar calendar live in the tundra of northern Siberia (the Ugric Ostiak). On the other hand, those who devised calendar B must be from a much warmer climate and appear to be hunter-gatherers, at least during part of the year. The names of their warm months indicate the variety of vegetables and fruits they collect, while colder moons are assigned to the animals they hunt. We can sense the turn of the seasons around harvest time when their concerns pass from corn to turkeys, and the change from

the grinding of nuts in the dead of winter to the picking of strawberries in early spring. This is the lunar calendar of the Natchez tribes of the lower Mississippi River valley. Finally, group C surely must reside in a tropical zone that has flowering trees and a moist climate where monsoon rains "rot the ropes." These are the Malagasy, the people of the coast of the island of Madagascar, off the east coast of central Africa.

Our calendar has vestiges of a similar descriptive lunar-naming system in the harvest moon (the first full moon after the autumn equinox) and the hunter's moon (the next one following), which appear to be among the few temporal constructs passed down to us by the native Americans who lived in the continental United States before contact with Europeans. Otherwise, our months were named according to an abstract set of concerns. Rather than wanting to keep track of when to pick berries, we in the West have long tried to make the months fit exactly into the seasonal cycle of a year. This seems never to have been much of an issue for other people; indeed, while the Siberian Ostiak had 12 months, the Natchez had 13, and the Malagasy, 11.

The story of the attempts to make the months fit into the years constitutes a major chapter of our Western calendar. We are the beneficiaries of the old Roman calendar, which, though first written down about 300 B.C., probably dates back to before the founding of the republic in 510 B.C. This calendar, which began simply as a convenience for farmers, consisted of a listing of festivals and *fas*, or "right days," for conducting business. Not until society became urbanized did the calendar become formal, complicated, and subject to the many irrational vagaries still present in it today—vagaries that have led to much calendar reform over the centuries.

As we have seen, the Roman calendar utilized the two shortest and most obvious astronomical time units: the day, measured by the successive appearances of the sun; and the synodic month, starting with the successive appearances of the crescent following the new moon; these time units easily lent themselves to measurement via counting. In addition, an 8-day market week of uncertain origin was meshed with nature's two cycles to produce a 120-day year, or *annus*, that consisted of four months bearing the names of deities—Martius, Aprilis, Maius, and Junius; each consisted of 30 days, an approximation of the lunar-phase cycle. Later, six months were added—Quintilis, Sextilis, September, October, November, December. Their names, unlike those

of the months preceding, signified their numerical order—fifth, sixth, and so on. This form of the year, made up of ten lunations or 300 days, was probably devised to correspond roughly to the gestation period of both humans and cattle. Because it seemed more orderly to keep the weekday names in step with the month—that is, to begin each new year on the same day name—four additional days were added later (traditionally by Romulus, with his brother Remus, the mythical founder of Rome), one each to the months of March, May, July and October. That brought the number of days in the year to 304, a number divisible by 8 without remainder. The rest of the seasonal cycle simply was not tallied: it fell during that portion of the year when the fields lay fallow, and therefore was not significant. While this notion of unaccounted time might bother us, it made sense to the Romans, who also related time to activity and apparently found it logical to count more for the time when things happened and to count not at all when nothing happened. Though the early Romans had the concept of a span of time equivalent to our year and related to the seasonal or solar cycle, their calendar was primarily a lunar cycle.

Perhaps the desire to incorporate natural periods of longer duration into a date-reckoning scheme is universal among all societies, the lengthier sequences of events serving usefully as checks against one another which might be employed in planning the future. In the Roman world, the first attempt to coordinate the lunar month with the solar year can be traced to Numa Pompilius, the second king of Rome. He simply added 50 days to the 304-day calendar of Romulus. In the revised calendar, 8 days were subtracted from among the other months, the sum being added to 50 to make a 58-day period; this interval then was divided in half to form two new 29-day months—January and February. They were tacked on to the end of the month list to convert the 10-month year into one of 12 months, the closest approximation to a solar-seasonal year that would also accommodate a whole number of lunar synodic months. By 150 B.C., an additional day was added, to the month of January, perhaps to keep the total days in the year an odd number (which was considered lucky). The Roman year had thus grown from a humble agrarian time count to a cycle of 355 days, a number that would not accommodate a whole number of traditional market weeks without the occasional insertion of extra days into the calendar, a process known as *intercalation*. It had taken nearly six hundred years from the time of the inception of the calendar before

Roman chronologists took on a challenge that was to occupy them, if not with equal intensity at all times, through the zenith of their empire: how to devise a manageable, lasting method for inserting days into the calendar in such a way that it would keep in step precisely with both the moon's and the sun's cycles?

The goal of the calendrical game was to write the perfect canon, the heavenly musical score that most ideally captures the eternal beat of a pair of natural celestial rhythm makers. The closer one listens to the rhythm, the more nearly perfect the possibilities that can be devised.

To understand the problem of intercalation confronting Roman chronologists, let us look at the periodicities of the moon's and the sun's cycles, which today can be measured with extreme precision: (a) the year of the seasons, or the tropical year (365.2422 days), is defined as the interval between successive passages of the sun across the vernal equinox, an imaginary starting point on the zodiac; (b) the lunar synodic month (29.5306 days) is defined as the interval between two successive passages of the moon by the sun; this is the familiar month of whose phases I have been speaking. Now, if the tropical year is divided by the lunar month, the quotient is: A/B = 12.3683. Thus, while the closest approximation to a tropical year, the 12-month count falls short by 0.3683 of a month, about 11 days. Intercalation by, say, adding a 13th month into the list about every three years can make the lunar and solar event sequences more harmonious.

There are other ways to solve this problem, each of which was attempted at one time or another in the history of the Western calendar:

1. Insert 3 months over the course of 8 years, thus approximating the remainder of the quotient A/B by 3/8 or .3750.
2. Intercalate 4 months over the course of 11 years, which would approximate the remainder by 4/11 or .3636.
3. Intercalate 7 months over the course of 19 years, making the remainder 7/19 or .3684. This scheme is known as the Metonic cycle after the fourth-century B.C. Greek astronomer Meton, who first recognized it.
4. Intercalate 31 months over the course of 84 years, thus approximating the remainder by 31/84 or .3690.

The Romans had, however, a solution of their own. In 150 B.C., they created a 22- or 23-day month called Mercedonius, which was inserted after 23 February in every other year or as needed, thus advancing the average year count from 355 to about 366. In the Old Roman calendar, 23 February marked the Festival of Terminalia, a day of sacrifice to Terminus, the god of boundaries. His festal date had been the last day of the year in an older form of the calendar.

Now the politics of intercalation became an issue in the development of the calendar, for the pontiffs, those Romans responsible for the administration of the cults of the state, ordered the calendric observances. Periodically they allowed the full years to be those during which their friends were in office.

The intercalation problem was not confronted with any rigor until a century later, when Sosigenes, chief adviser on calendric matters to Julius Caesar, recognized the shift of the sun's position in the heavens relative to the dates being tallied in the seasonal year. By then, civil time was already out of joint with nature's astronomical time by three months. In 45 B.C., Sosigenes suggested the following set of remedial measures, which have since collectively come to be known as the Julian calendar reform:

1. Make in the year count an adjustment that results in the restoration of the date of the passage of the sun by the vernal equinox to the correct date, then 25 Martius. This necessitated the intercalation of three whole months in 46 B.C., a year that came to be known as the "Year of Confusion"—with 445 days!
2. Abandon totally the true lunar synodic month as a calendar base by introducing 12 alternating 30- and 31-day months that added up to a year of 365 days. This signal event in our history ended once and for all the habit of month intercalation; for the first time, the annual cycle of the sun became the only natural period to serve as the fundamental time unit in the calendar.
3. To plan for the future, in every fourth year let one day be added to the year, at the end of Februarius. Averaged over a 4-year period then, the length of the man-made year would become 365.25 days, a close fit to the natural one.

With this step the difference between the canonic and the seasonal years became:

Man-made year	365^{d}	6^{h}	0^{m}	0^{s}
Natural year	365^{d}	5^{h}	48^{m}	46^{s}
Difference per year			11^{m}	14^{s}

Thus, solar events, even with the intercalation program of the Julian reform in place, would fall behind the tally kept by the chronologists by just one day in a little over a century, hardly enough to concern the Romans given the temporal quagmire out of which they had just extricated themselves. The Julian reform would suffice for sixteen hundred years.

Anti-Semitism and the need to determine the date of Easter Sunday were jointly responsible for the next action in the reform of the Western calendar—an action decidedly ecclesiastical in nature. With the emphasis of unity in the Roman empire being placed upon the Christian church in the fourth century A.D., pagan cults and rituals along with the old Roman calendar were abolished and in their place was instituted a calendar based upon ecclesiastical reckonings and the commemoration of saints. One goal of the Council of Nicaea (Iznik in Asia Minor) held in A.D. 325 was to set a single date for the celebration of Easter by Christians in both the Eastern and the Western Holy Roman empires. Traditionally, the date had been fixed in the Hebrew calendar as the 14th day of the month of Nisan, which began with the appearance of the crescent of the spring moon, the one nearest the spring equinox. The Hebrew calendar, with its strictly lunar base, did not, however, observe the equinox with any precision. In fact, we have no details about how they actually determined the month of Nisan. The Christians were compelled to celebrate the anniversary of the Paschal date close to the time of year when the event was documented as having occurred, and to fix it on a Sunday. Above all, church law dictated that Easter must not fall on the Hebraic equivalent. The *computists*, specialists in charge of Christian calendric computations, believed a conflict would be avoided if they selected the first Sunday after the full moon that followed the vernal equinox. Now, since it already had been recognized that the equinox was falling earlier and earlier in the calendar year (it had shifted backward about three days in the four centuries since the Julian reform), the religious problem of determining Easter Sunday became tied to the astronomical problem of fixing the place of the vernal equinox in the zodiac.

Given the set of rules for determining the movable feast, the computists were called upon to reconcile three periods that do not readily mesh: the week, the lunar synodic month, and the solar year. It turned out that Easter could occur any time between 22 March and 25 April; and it would take over five million years before the dates of the Paschal observance would recur in the same order. Having discovered the impossibility of devising a mathematical formula to set dates in the future, the computists created complicated tables based on averaged full-moon intervals. These long-winded tables of *epacts* listed the age or phase of the moon on 1 January, from which the Easter date easily could be computed for that year. But these artificial tables gave only approximate information about the phase of the moon on New Year's Day (the error could amount to 2 or 3 days); the true motion of the moon was far too complex to be formulated precisely in tabular form. One of the calendrical debates that followed after the Middle Ages centered around the extent to which religious festivals really needed to be calculated with astronomical accuracy. After all, as the great German astronomer Johannes Kepler is reputed to have said, "Easter is a feast, not a planet."[7]

By the sixteenth century, the recession of the real year with respect to our artificial account of it had grown to 11 days (figure 3.3). Easter Sunday began on the average to fall later and later in the season and thus to appear warmer and warmer. In 1582, Pope Gregory XIII appointed a commission to deal anew with the reform issue. As was the case a millennium and a half before, two actions were needed to assure that the future festival date would arrive at the proper location in the year of the seasons: the equinox needed to be restored to its proper place in the year cycle; and the commission needed to devise a mechanism to hold it fixed.

After much debate about whether the lost time might be made up in small parcels over a long interval, the first problem was solved, as in Caesar's time, in a single bold stroke simply by dropping 10 days out of the calendar. Thus, the equinox was moved from the 11 March date on which it had occurred in 1582, to 21 March. Pope Gregory XIII wrote a decree declaring that the day after 4 October of that year would be 15 October.

The second step of the Gregorian reform consisted of changing the leap-year rule by decreeing that among century years, only those divisible by 400 shall be leap years. Thus, while A.D. 1600 and 2000 would be leap years according to the new system, A.D. 1700, 1800, and 1900 would not. This recipe had far-reaching consequences for it drastically reduced the shortfall inherent in the Julian leap-year system by setting the length of the calendar year, averaged over long periods of time, below 365.2500 days to 365.2425 days, or only .0003 longer than the true year of the seasons. So near perfect was the new rule that the man-made year cycle would now roll ahead of the seasons by just 1 day in 3,300 years!

FIGURE 3.3 The Gregorian calendar reform. A member of Pope Gregory's commission on the calendar alarmingly points out the backslide between the Julian calendar and the year of the seasons, each represented by a set of day marks framing a zodiac. After several years of bickering, the Pope's commission took decisive action and dropped ten days out of the calendar, thus putting artificial time and nature's time back in step. SOURCE: Archivio di Stato, Siena, Italy.

As might be expected, the Gregorian reform was immediately adopted by all Catholic countries, but was resisted rigidly by the Protestant-dominated nations like Germany and at first given little attention by non-Western cultures. Great Britain and its colonies did not adopt the new calendar until 1752, by which time they needed to drop 11 days from the count. Indeed, in early life, George Washington

celebrated his own birthday on 11 February. The calendar was not accepted by Russia until the Bolshevik Revolution of 1917; by then, even more days needed to be eliminated.

Minor reforms have been suggested since the time of Pope Gregory, such as agreeing to convert A.D. 4000, 8000, and 12,000 to common years, which would reduce the difference to 1 day in 20,000 years. Finally, at an Eastern Orthodox congress held in Constantinople in 1923, yet another rule was adopted in the parade of legislation engendered by the drive for accuracy. It stated that century years divisible by 900 will be leap years only if the remainder is 200 or 600. The resulting calendar is accurate to 1 day in 44,000 years.

All reforms seem to aim for pristine completion of the year cycle as well as precise arrival at a solar date. The more fingers in the bureaucratic pie, the greater the concern to build up and tightly interlock larger and larger cycles to gain control of the future. In the last analysis, any new rules we might devise in the future to improve accuracy would be futile because we know now that the length of the tropical year is itself changing because of the gravitational disturbances the earth encounters from other bodies in the solar system, and the rate of change is comparable to the difference between the true and the man-made years.

It has taken Western culture more than twenty-five centuries to devise an eternal and unchanging artificial framework that can assure the exact setting of a date far in the future with maximal certainty. Our goal, begun modestly, had always been to foretell the actions of nature's heaven as unerringly and precisely as possible. In pursuit of that goal, people traveled a sinuous, often irrational course, one involving accommodation among religious and political as well as among astronomical concerns. Along the way, Westerners modified that goal by electing to sidestep a part of the problem that could not be mastered—the synchronization of the natural, lunar, and solar cycles. The development of our calendar has also been accompanied by increased complexity and abstraction, as ever more detailed correction programs carry us farther away from nature. Yet it is ironic that our attempts to devise modes of time reckoning arose out of the eternal wish to keep our lives in tune with nature. With the development of technology—from sun watching at the horizon to weight-driven clocks to atomic timekeeping devices—we have removed our marking of time from nature's realm and in the process, become ever less in touch with the events that occur there.

4

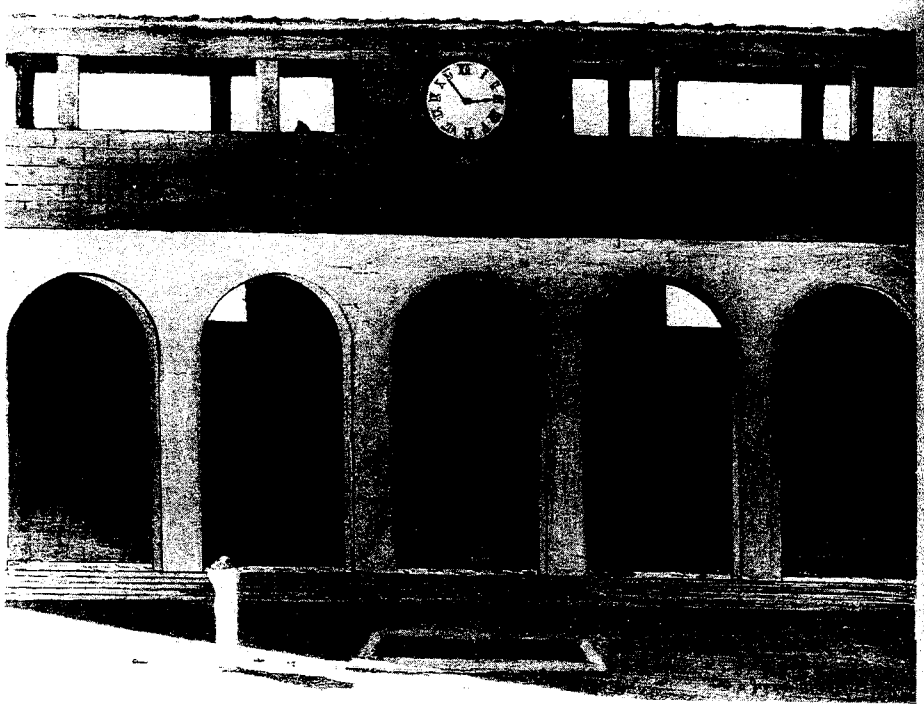
THE YEAR AND ITS ACCUMULATION IN HISTORY

> The more the universe seems comprehensible, the more it also seems pointless.
>
> —STEVEN WEINBERG,
> *The First Three Minutes*

THOUGH THE YEAR is the longest time-reckoning cycle in the formal calendar, the one on a wall or desk that you consult on a regular basis, we have nevertheless fashioned even bigger bundles of time, to tie events of the relatively remote past to those of more immediate recollection. Large time units like century, era, and epoch lead one to wonder how events separated by such physically insensible intervals can be thought to have any meaningful relation to one another.

As I shall discuss in part III, the Western tendency to reckon time in huge parcels is hardly unique. Some of the philosophical repercussions of the West's approach are, however, unusual. The idea that time comprises a linear succession of events that are related through cause and effect has replaced the earlier associative way of conceiving time, where rituals are acts performed or festivals celebrated in response to cyclic phenomena in nature, such as certain phases of the moon or the solstices.

In discussing the macroscopic makeup of time, I shall confront



Enigma of the Hour. Giorgio De Chirico. Milan, Private Collection, Marburg/ Art Resource, New York.

10

BUILDING ON THE BASIC RHYTHMS

I do not want to call an astronomical theory scientific until it gives us control over all the irregularities within each period and thus frees us from constant consultation of observational records.

—ASGER AABOE

AT LEAST the process of acquiring information about the nature of time starts out the same: it comes from human experience. The seventeenth-century British philosopher John Locke likened the human mind to an empty blackboard, a *tabula rasa* on which experience is written.[1] (Today we might substitute the more familiar computer screen.) Human sensation is the contact point between chalk and blackboard. Gradually our slate accumulates perceptions of sounds, tastes, and smells—stimuli that fly across space into our sharply tuned receivers: we're all ears.

How we decipher the writing on the blackboard—how we interpret what it means—is another matter. We think, we reflect, we form ideas. We are forever dipping back into our reservoir of acquired experience, recollecting the information we have chosen to make note of, as we try to cast it in some order that makes sense of our particular circumstances and for our particular aims. Time begins in human consciousness with the determination of a sense of order. As the philosopher-physicist Jacob Bronowski has remarked:

> For order does not display itself of itself; if it can be said to be there at all, it is not there for the mere looking. There is no way of pointing a finger or a camera at it; order must be discovered, and in a deep sense, it must be created. What we see, as we see it, is mere disorder.[2]

Even if this sounds simple, how can we come to know an idea about time's order that resides in somebody else's brain? Because we speak the same language and come from the same culture, if I am successful at expressing myself, by using words and pictures, by giving examples, by designing metaphors and models you can relate to, then I might be able to set off a ringing alarm of familiarity in your head. Consequently you might be able to get an inkling of what is rattling around in mine.

Concrete human expression is the raw material out of which we build up our impressions of what made our predecessors tick. Their material remains become a testament. They have left us mementos: books, carved bones, standing stones, buildings, sculpture, and paintings—which we eagerly photograph and measure, or collect and cram into boxes and museum cases. The stuff they once possessed gives legitimacy to our present thoughts about them; tangible expressions of human knowledge are all we have to go on.

The process of expressing our thoughts in concrete form may have begun when humans first started counting on their fingers to divvy up the kill after a day's hunting, to bundle together the sequence of days and nights—all the intricate components of the harmonic sequence of events that makes up the biorhythmic and astrorhythmic cycles I have discussed. Each beat in a given time sequence came to be identified with one of the human appendages. Native tribes of North America witnessed and identified each day of the month with a part of the body. Day 1, the first crescent, was the baby finger of the right hand; day 2, the next finger; and so on. After the thumb (the fifth day), the count passed to the wrist, to the bone between wrist and elbow, then to the elbow. The lunar count waxed upward, going from joint to bone over the shoulder to the head, which represented the fourteenth day or full moon; then it waned down the left side of the body, each named body part corresponding to its lunar likeness in reverse.

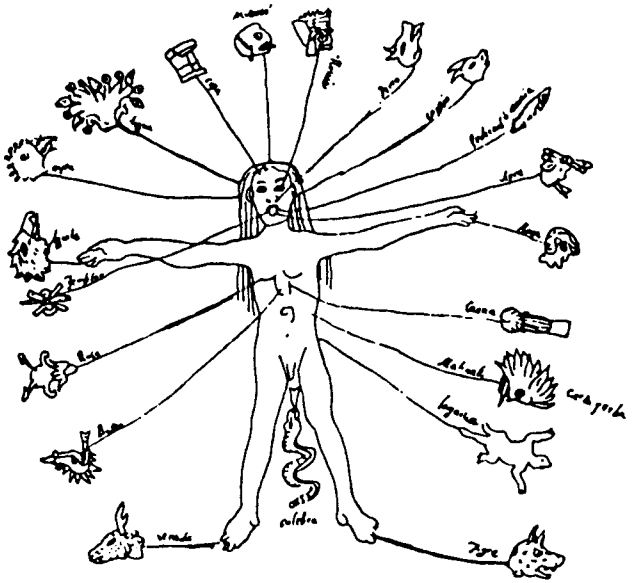
Time counting by the body is not just a practical convenience or a mnemonic, like tying a string around your finger to remember something. It is part of a process of creating meaning by the act of associating seemingly different objects with one another. When I move over the top of my body from fingertip to fingertip, I display and express a hidden likeness between the makeup of my body and the composition of time; for a moment the tips of the baby fingers of my extended arms are transformed into opposing crescent moons, and the flow of the count up one side of my body and down the other becomes a manifestation of the reversible phase cycle. My head, like the full moon, is the only singular essence in the chain. Similarly, the flow of blood among the organs becomes a body metaphor, one that can be likened to the passage of the moon around the zodiac, each of its component constellations being associated with one of the diverse bodily parts (figure 10.1).

Recurring Cycles

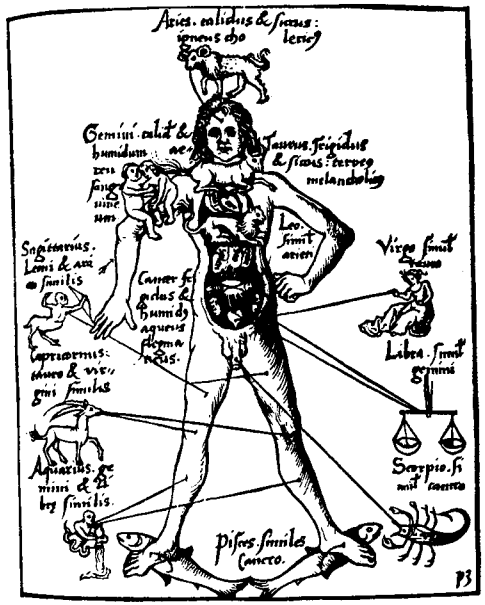
This way of expressing what it means to be human by linking the parts of the universe within to those that lie outside of ourselves seems fundamental. Yet as we have seen, time is not conceived in the same way by all human minds, nor is it reckoned by all peoples of the world in precisely the same manner, though at the most general level, there are certainly parallels. In many parts of the world both past and present, for example, there is an overwhelming tendency to think of time in the form of recurring cycles, a continuous sequence of events with neither beginning nor end, the past forever repeating itself.

All around us, as I discussed in chapter 1, nature broadcasts its rhythm—a decidedly cyclic rhythm. We do not know how the living world caught its rhythmic sense: whether the beat of life is driven by a ticking from without rather than a vibration from within. But we do know that all of us in the community of life, from oysters to emperors, mimic celestial and seasonal movements and changes. To me it does not really matter where to draw the line that divides who behaves pensively and reflectively as opposed to instinctually and innately, be it gorilla or lemur—maybe even my cat. (Since I have lived with her for fifteen years, I know the difference between instinct and calculated mischief!)

The domination of cyclic time in human thought and action is the result of a conditioning process we have all been through because we live in an environment filled with interminable repetitive alternations—day and night, the seasons, the phases of the moon.



A



B

FIGURE 10.1 Time's clock in the parts of the body. Reminiscent of the biorhythms of chapter 1, these diagrams, (*A*) from Central Mexico and (*B*) from Central Europe, depict the association between various body parts and time units. For other cross-cultural similarities in the graphic expression of the meaning of time, see figure 4.2. (*A*) Twenty day signs in the Mexican Calendar from the Codex Vaticano Latino, pl. LXXIII in A. Lopez Austin, *The Human Body and Ideology*, vol. I (Salt Lake City, Utah: University of Utah Press, 1988), p. 348. Copyright © 1988 by the University of Utah Press. (*B*) Organs, limbs, and joints controlled by the zodiac. SOURCE: G. Reisch, *Margarita Philosophica*, a late medieval encyclopedia (Freiburg, 1503). The Huntington Library, San Marino, Calif.

Every visceral flip-flop in the biological world marches in time with these metronomic beats: a plant raises and lowers its leaves, a groundhog mates and hibernates, corals and clams lay down growth ridges. If we all really believe our insides are part of the outside world, then isn't it normal for us to develop cyclic forms of expression of human action and interaction? And isn't it natural, by extension and extrapolation, to suppose other cycles exist that tie into the orderly framework of our world, cycles simply too long to be easily experienced—life and death, the royal succession of kings, the occurrence of floods, earthquakes and volcanic eruptions, destructions and re-creations of the entire universe? Common sense is the logic of cyclic time reckoning.

The cosmogonic creation myths in the *Popul Vuh* and the Bible are not mystical spinoffs of overimaginative, primitive fantasizers bent on anthropomorphizing the universe. The myths I have talked about can be understood as expressions of some of the basic ways our ancient ancestors thought about time. There is nothing illusory in their celebration of the harmony and rhythm we can all feel in our bones, nothing deceptive about back-pedaling cyclic time into the domain of the gods.

It takes many cycles to make a god—beyond a lifetime, several generations, centuries. People begin to draw the line between human and suprahuman worlds when they feel crushed by a time dimension they cannot really perceive—a stretch so vast that they are compelled to gear it to some form like themselves that resides outside of time as we live it. World ages, mega-units of time, become the boundary line where the multiplication of cycle upon cycle, *baktun* upon *katun*, *mahayuga* upon *yuga* become less natural and more abstract, less environmentally related and more purely numerical. In old Western European cultures, the 26,000-year cycle of the precession of the equinoxes emerges as one of nature's long-distance signposts on the cyclic road of time.

The wheels of time roll on level ground and uphill as well as down. They can be perceived as static, like those of ancient Hinduism; progressive, as revealed in the Maya and Inca origin cycles; or even degenerative, as the pre-Classical Greeks interpreted the world and—indeed, the way modern cosmologists still tend to view it today—as a system tending toward calculated disorder. Still, modern cosmology does have something in common with the Maya and Aztec views of creation and re-creation, for we retain vestiges of this cyclic view of time. Many cosmologists continue to believe that previous universes

may have existed before the Big Bang and that other universes may yet rise out of the ashes of our own.

Our modern scientific creation myth seems not so out of step with many of the others. Modern astrophysics places the beginning of time approximately fifteen billion years in the past—but a few days in the life of Buddha and only a thousand times the length of the longest time units in the Maya Dresden Codex. Like the creation stories of other cultures, ours began with a drastic transformation—a great separation of one form into many, followed by a number of rapid shuffles in the states of matter and energy—all of it happening in but a few seconds of time. The early action was played out in a relatively small sector of the domain of space and time—a domain of colossal temperature and near-infinite density—existence in its most abstract, mathematically extrapolated form. Creation's place and time is both forever impenetrable by our probing scientific instruments and incapable of revealing any empirical evidence about itself, at least within a time radius of 10^{-43} seconds after the creation event, at which time the laws of physics we know today first became applicable. Opponents of this view, some of them retreaded outcasts of the largely discredited steady-state theory of cosmology, see the Big Bang as a local effect, a tiny ripple in an infinite, eternal space-time manifold. Some visionaries have hypothesized a space-time manifold perforated by countless microcosmic creation points.

The numbers are staggering and the scales awesome, but the basic themes of our creation myth—cataclysmic transition, the separation of entities, and the rapid-fire alternation between states of turbulence and quiescence, between anxiety and relaxation—are not terribly different from the series of creation battles in *Enuma Elish*, from the sequence of violent changes that brought about the emergence of the Inca Viracocha's dominant state of being, even from the flashy, hierarchical creation by word of mouth in Genesis. The flow of the rhythm is the same.

Stripped of its detail and attendant mathematical jargon, however, there is one cardinal difference in the creation myth of the twenty-first century with respect to all those of the past: it is purposeless. We humans are totally left out of it (recall the epigraph to chapter 4). There is no body of Pwan Ku to decay and give birth to us, nor does Yahweh speak to us of human direction, action, and purpose. Whether the galaxies expand apart infinitely leaving us in our own dark little corner of space-time, or whether we are caught in the instantaneous crush of an impending collapse of the universal fireball, the cosmic

myth told by modern science offers humanity as indifferent an ending as beginning. We emerge as the great nonparticipants who have no influence on the outcome. There is no Tonatiuh or *huaca* for us to feed, no year and day bearers we must help to carry the burden of time. We have not the slightest cosmic duty to perform. We pay a dear price for the freedom we gained in our struggle for cosmic independence when we willfully separated consciousness from its god-bound fetters. And we are only just beginning to deal with the consequences of venturing outside a participatory universe.

Modern cosmology also has managed to iron out the segment of the time circle on which we run—to put off the future so far that it matters little to think about, much less to act upon it. Besides, we have enough short-period kinks in our time machine to contemplate, such as the depletion of the ozone layer, global climatic change, and colliding tectonic plates.

Cyclic time dominates, but it is not all the same. It comes in different flavors: dream time and agri-time, seasonal time and mythic time. Hesiod had both Works *and* Days. No one thinks past and future cycles are exactly the same, for none of our days is truly identical to another, and one winter can differ markedly from the next.

Small cycles imitate big cycles. Contemporary Maya say the day is like the year in each of its parts. The *Popol Vuh* follows cyclic creation, the sowing and the dawning, by paralleling the cycle of Venus. And in the ancient version of our calendar, the twelve days of Christmas signal what will come to pass in the forthcoming twelve lunar months. Pick up any farmer's almanac and discover next year's weather forecast. Micro-time structures macro-time.

Despite the danger of model building (once you make a model, you can be tempted to force-fit everything into it), we nevertheless have tried to fashion various mental loops and twists that incorporate all of these complex properties of cyclic time. We clipped our circular wire and made it into a coiled spring that always returns us to the same side of our circular course but places us slightly higher up as we travel around it.

The Linearization of Time

But how does such a model incorporate the Maya understanding of the past, not only as the prologue to the present but also the prophecy for

the future—time past and time future all rolled into one, as the historian Nancy Farriss has characterized it?[3] And how do we devise a cyclic model so that it emphasizes the importance of transition in every reckoning system I have discussed: the signal event of the dawning of Venus that follows the sowing in the Maya calendar, the drastic shifts in Nuer behavior occurring in that sharp borderland between wet and dry seasons in eco-time, or the Chinese and Balinese joints in time? Major changes are always accompanied by festivals, the rites of passage that break up the monotonous flow of ordinary time, the way our weekend calls an end to the duration of the workday week.

Perhaps the best model for time in the modern world is a series of interconnected hoops rolling up a great hill of progress. While we live cyclically from sleep to wakefulness, day to day and week to week, in the long run our existence seems to be a string of endless *nows*, a sequence of completed successive stages, each unique and nonrecurrent. Our language of time is filled with terms and ideas that denote linear succession. We use lines of evidence to find out who committed a crime. We follow a line of thought, bridge a gap, draw a conclusion, take a sequence of courses in school. Our means have ends; we set a career path, pursue our goals, look forward to a new millennium, some of us to a second coming. Effect follows cause, response follows stimulus, and reward comes from hard work. We glide forever upward on our endless time line. Our evolutionary tree sprouts skyward from ages past into the present; its branches grow upward and outward into the future. Our chain of events is said to progress and develop. TV newspeople continually update us, and we are forever trying to catch up with what's happening in the sequence.

Modern Westerners stand in stark contrast to those Trobriand gardeners whose language possesses no tenses, no way of distinguishing by the use of words between past and present. One ethnologist tells us that they despise directive behavior; that they perceive reality atemporally, in terms of fixed patterned wholes.[4] A tree is supported by its trunk, a house by posts, an incantation by its opening line, a hunting expedition by its leader. In each case, the latter term has the same meaning and is identified by the same word: *u'ula*. Pattern is the source of truth in this culture. Linear connections, causality, and sequentiality are no concerns of theirs. They place no value on the future as we do when we use the word *progress* to describe which way we shall go to get to it. For them, the present is not the road to the future, and the future is neither good nor bad, better nor worse than

the past. Even their means are not climactic. There is no "just dessert" to look forward to. Instead, the relish, the most savory part of the dinner, is consumed with the rest of the staple food. The persistent sameness that seems so irksome to us is perfectly normal to them.

The linearization of time that dominates Western thought is often regarded as a property unique to our culture. But I have shown that other highly organized, bureaucratic cultures, like the Chinese and the Maya, also linearize time to some degree. I do not mean, however, that linear time is a property of advanced civilized societies that have real history, while the cyclic perception of eternal returns is conceived exclusively in primitive or savage minds. Anthropologists also have learned that advancement is a value-laden term. While we might say that Spanish technology was more advanced than Aztec, we could also say the Nuer system of kinship is more advanced than ours. The anthropologist Johannes Fabian has suggested that we invent such dichotomies as a way of distancing the unfamiliar.[5] We magnify the differences between us and them and append human values to each side. Even after five hundred years of exploring new lands and strange people, our Western minds continue to resist the essential humanness in the Other that we see in ourselves. Yet, paradoxically, we leapfrog backward over the present-other and search the pages of prehistory for people like ourselves in the Stonehenges of the past, people upon whose shoulders we might stand. Are they so far away from our own space and time that they can pose us no threat?

Our obsession with linear progression conditions us to look downward to past time as well as outward, away from ourselves in space, at other contemporary cultures. We label them all "traditional" as if to imply that they are all the same—all static, unformed, undeveloped, not yet having a history of their own.

One historian has said of the early Greeks that their astronomical knowledge was primitive, "a farmer's or shepherd's astronomy [which one] should not be at all surprised at finding in any settled community, whether literate or not"; it lay below the advanced or scientific level.[6] And another characterizes most foreign calendars in general as laden with superstition and unemancipated from the fetters of the religious cult.[7]

Superstition is another value-laden term that gives us license to pass judgment upon a culture without ever examining or experiencing it. Literally, it means "to stand in awe and amazement"; but Webster's also describes it as a "system of beliefs by which religious veneration

or regard is shown toward objects which *deserve none*," or "the assignment of such a degree or such a kind of veneration or regard toward an object, as such *does not deserve*," and "a faith or article of faith based on insufficient evidence [italics mine]."[8] When we use the word *faith* to characterize a belief held by some other culture, we take it as an article of our *own* faith that the evidence for such a statement is insufficient, and therefore that the belief is not deserving. Yet we reach this conclusion not by examining any evidence but, instead, by invoking the principle that there can be no causal connection between two such entities. The connection, therefore, makes no sense under the only valid set of terms by which *we* understand the world.

Controlling the Rhythms

By comparing our time with theirs, we have also discovered that whether a civilization develops a long-term methodology for categorizing events depends more upon who is in charge of time and what purpose it will serve, than upon any measure of the native intelligence (whatever that is?) of time's user. And while simple basic categories like *cyclic* and *linear* are useful concepts, the way people invent and use time also has much to do with the control of activities in the society in which they live. Man-made year cycles are fastened to the agrarian economy at points of high tension. They begin and end when consumer goods are most readily available and in their greatest abundance. The farmer's crisis always occurs at planting time and is never exactly the same. Neither is the anxious tension when harvesters measure out the store of grain to feed the populace, nor the sigh of relief when they finally can assure themselves there will be enough for everyone. Festivals for invoking or paying debt to the gods are positioned strategically in relation to periods of work.

Business calendars, social calendars, and religious calendars—all are components of time in an organized society, each one serving different interests. In state and imperial societies like Rome and Cuzco, bureaucratic rulerships worked toward merging cycles and schedules into a single, all-encompassing calendar, one capable of addressing all interests.

In our case, the cultural taproot of calendrical organization grew out of economic determinism and materialism, though, as we have

seen, the Judeo-Christian religion played a major role. Babylonian counting and timekeeping began with an economic motive, and the idea that time is money grew out of medieval mercantilism. Today the rigid control of human time is still powered largely by the business of making money in a highly industrialized, technological world.

When speaking of control, we usually think of empire; but cultural control has both material and ideological aspects. Territorially, it can mean direct subjugation by tribute and taxation, the way the Aztecs dominated the basin of Lake Texcoco; but it also can imply stylistic and ideological influence without direct occupation or intervention, the way ancient Teotihuacan captivated the interest of parts of the Maya world. As cultures expand, they become more segmented socially, authority becomes more centralized, agriculture intensified. Political, military, and religious institutions proliferate.

The *etic* approach to cultural evolution explains these changes by applying the Darwinian principle of adaptive change to societies immersed in a complex gearbox of interacting systems. All cultural institutions respond to a combination of biological and social needs. Human technological and subsistence systems interact with environmental systems to generate all of society's institutions.

Only the ruling powers can introduce new festivals and rites or eliminate the old ones. To control society, they must cultivate roots with the past. The further back they trace their connections, the more safe and secure any act they perform or deed they commit. They are forced constantly to write and rewrite their own history; and to do it, they are compelled to devise and sanction explicit official ways of doling it out.

Since time must be controlled minute by minute, second by second, in our complicated world, we universalize it so all can march in lockstep. Just as, to survive, we develop systems of population control, crop control, and control in the distribution of wealth, so, too, we have perfected time control. Geoffrey Conrad and Arthur Demarest are among the modern anthropologists who have trouble with this functionalist approach to cultural evolution.[9] It leaves too little room for free will. Ideology only justifies; it does not promote. It becomes the device rulers invent or modify to legitimize their rulership. People's values and beliefs always seem to follow in the wake of developments within the sphere of economic subsistence. Perhaps we persist in placing an ancient person's stomach before the head because we have not emerged from the mental rinse cycle that followed the great

wash of deterministic ideas about time and evolution let loose in the middle of the last century.

How does pure function explain the temporal extremism of the Maya written calendar or account for anti-Semitism as a major controlling element in the Gregorian reform? As Conrad and Demarest suggest, we must not think of economics and ideology as cause and effect. Rather, we need to view them together in a more holistic way if we are to have any hope of understanding cultural change.

Time control began when somebody drove a stick into the ground and began to use the varying lengths of its shadow as a means of signifying the quiescent duration that separates one event from the next. Longer periods, like days and months of the year, could be marked out by timing the heliacal risings of bright stars or by notching the phases of the moon onto a piece of a bone—as our ancestors may have done twenty thousand years ago. The events they chose were not the comets and supernovae that suddenly emerge from the celestial scenery to dazzle our modern cataclysmically oriented minds. These people were looking instead for phenomena that repeat in a dependable way and occur in the right time at the right place—the passing of the sun overhead in Java or Yucatan, the emergence of the Pleiades from behind the sun at planting time in highland Peru, the first daggers of Venus's returning morning light at the onset of the rainy season in Yucatan.

But there also lay in every Javanese and Yucatecan, if not in us, a recognition of the parallels between natural and sacral periodicity. The spiritual side of humankind molded cosmogonic myth and its enactment through ritual to re-create the creation, to bring time-past into time-present, to regenerate the world. Why bother to debate whether sacred time preceded utilitarian time or whether the two are the same or different? What emerges as a constant in each calendar I have discussed is that time captivates not as a pure fact of nature but instead as a dimension of life that ultimately can be submitted to cultural control. The material embodiment of time evident in the book, the codex, the carved door lintel, the ceremonial stela, as well as the grandfather clock—all have the effect of making past and future concrete and official. Even the oral folk tale, the Andean *quipu*, the Inca sun pillars, and the skewed axis of Uxmal's House of the Governor: all ways of expressing time, without the use of writing in the traditional sense, give structure to the calendar.

Time systems became more complex and ornate as an economy and its attending bureaucracy grew and diversified. In China and

Europe, mechanical clocks replaced sundials. We slowly began to manipulate nature's direct input into the timekeeping process for our own benefit. Intercalation was one of the first steps toward human intervention, an insertion of society's time into celestial time. Thus, we make the year complete by improving upon nature where we believe it has failed.

In a sense, the Maya did to the Venus cycle what medieval Christendom did to the sun cycle. The Venus table in the Dresden Codex tampers with time and reduces it to a cultural creation based on minor variations in nature's harmonic heartbeat which can be detected only by careful listening and close observation. In bureaucratic societies, human actors take over both nature's script writing and directing.

The modern mass production of timepieces—with their artificial hours, minutes, and seconds—symbolizes the extent of our single-minded struggle to exercise control over that ghostly mechanical entity we imagine to be jogging alongside us, as close as a shadow but uninfluenced by the way we behave. When you say you are strapped for time, perhaps you are only expressing your frustration at the way you have become enslaved to that oscillating chip you carry about on your wrist.

Human culture emerges as the great processor of time. Like the rest of the biological world, our ancestors began by sensing the orderly biorhythms of natural time—the beat of the tides, the coming of the rains, the on-and-off stroboscopic flickering of the full moon's light, the comings and goings of swallows, locusts, and the red tide. Unlike the New Haven oysters that relocated in Evanston, somewhere back in the distant past we became impatient and dissatisfied. We grabbed hold of the controls; we changed the order. We manipulated time, developed and enhanced it, processed, compressed, and packaged it into a crazy-quilt patchwork to conform to our perceived needs: greater efficiency in dividing up the day means more earning power for both the corporate head and his workers; greater precision in Olympic timing makes for a better Reebok sneaker; and strategic positioning of daylight-saving time gives us more rest and recreation, and that leads to a longer personal time line.

The sociologist Michael Young uses the terms *habit* and *custom* as ways of giving humanness to the process of cyclic entrainment, that behavioral locking-in to nature's cycles in which every segment of the living world participates.[10] Driven to conform to the monotonous strains of linear, techno-time, we do great harm to both our health and

our psyche. We work both night and day, we keep our environment at constant time and temperature, and we think of the future only in terms of prolonging individual human life. Young's three-part agenda for reversing social evolution calls upon us to change our attitude toward death by emphasizing its role in a cyclic process rather than its finality, to reawaken human awareness to the seasonal cycle, and to break the metronomic gridlock of our daily round. His regimen seems to say, "let's all loosen up and raise a little real-time consciousness." While Young's consciousness-raising scheme may seem a bit naive, I applaud him for recognizing that our subjugation to the yoke of fatalism is indeed conscious and that it has the effect of removing us from any real participation in the rhythm of the universe. We desperately want to take up an instrument to play, but our ambition to conduct the whole orchestra forbids us from doing so. Evans-Pritchard envied the Nuer because they seemed content just to play along.

While the cultural filter, that great processor through which nature's rhythms pass, has produced many different versions of time, as a fifth millennium of recorded history completes its cycle all the ways of reckoning this elusive medium have slowly begun to merge toward one. Human diversity dissolves into unity as strange languages and customs become extinct. As we evolve slowly and inexorably into one world, we also move toward reckoning change and activity by a single clock. We are united by time zones, an international dateline, and a universal second. Modern secular time transcends both nation and religion, both environment and demography. Time becomes more objective, less spiritual and unemotional. The World Calendar may have failed on its last go-round; but like the metric system, it will ultimately triumph.

Why bother, then, to tell stories about circular, linear, and in-between time-reckoning systems long buried in the past? Because a spark of human desire still burns within us to reconnect ourselves to the rest of the universe, to renegotiate the dialogue about human limitations. We all seek contentment in what we do—felicity, as Aristotle called it.[11] And the common denominator underpinning all of our stories from the *Theogony* to daylight-savings time has been the deep-seated human desire to live in an orderly universe. Temporally speaking, we desire the capacity to anticipate where things are going, to relieve our anxiety by peeking around nature's corner as far as it will allow.

Paradoxically, our mechanical way of repatterning time has led to a way of knowing it that is totally divorced from the real world. We

have reduced time to pure number, Aristotle's measure of all things. With a push of the button and a quick glance at a series of registers, an array of blinking numerals triggers my anxiety or allays my fears about the future, and it does so instantaneously and with Olympic accuracy.

Or, perhaps technology only masks my fears about what the future may hold. Since there is great insecurity in direct observation, we always try, as the chapter epigraph suggests,[12] to reduce empirical data to the barest minimum possible. If we bureaucratize the cosmos, we need never interact with it. We can become insensitive to it.

Such a futuristic scenario seems an ironic capstone to a pyramid whose foundation is the ancient connection between human beings and the rest of nature. It was not so long ago that we were all behaving like tide-bound oysters and barometric potatoes. The human race began as a part of the harmony of nature: we were written into the score. We accepted our role and responded to nature's sheet music, sometimes being surprised by it but always going with its flow. What changed it all may have taken place in that dark cave in France over a thousand generations ago when an exhausted hunter, running calloused fingers over a piece of bone on which he had long been making deliberate notches, first began to recognize—a pattern.