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THE BEGINNINGS OF TIME-MEASUREMENT AND THE ORIGINS OF OUR CALENDAR[1]

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Introduction

The processes of matter seem to be the most tangible yardstick which we can apply to that mysterious flow which we call time. But the processes of matter are sublimely indifferent to the insignificant time frontiers erected by man's petty scientific terminology. As if in ridicule of such barriers raised by the children of time, the operations of the universe cross and recross the tiny areas which man has staked out. We are like some frontiersman in the night holding up a torch over a dark stream and imagining that the circle of its hurrying current revealed by the torchlight is all there is to the stream, while there may be Great Lakes above and a thundering Niagara below.

In this brief discussion of a vast subject let me make it clear that I am not dealing with any philosophical conceptions of time or its nature. I am merely endeavoring to present a sketch of some historical aspects of man's notions of time, by a study of the earliest sources of information available, with the purpose of disclosing especially the earliest known methods of time-measurement and the origins of our calendar.

[1] Lecture before New York University, given on May 16, 1935, The James Arthur Annual Lectureship on "Time and its Mysteries."

Discontinuous Time

Modern science has so long been dealing with time as something in *continuous* flow that we accept this conception as a matter of course. This notion of time, however, as uninterrupted duration, in ceaseless, ever-continuing flow, was the final result of ages of human effort to deal with it, and did not arise until an advanced stage of civilization. An American Indian, before he was touched by civilization, would have told you that he was "fifty winters" old, or a younger native would have said that his age was "twenty snows." He thus measured time in disconnected fragments, and throughout the globe that has been the only conception of time discernible by primitive men. Some of these time fragments are fixed seasons in the early man's folk-calendar. Among certain Swedish peasants even at the present day a birthday may fall at the "rye harvest" or at the "potato harvest." A Palestinian peasant may fix the date when a note falls due, not at the end of a continuous series of months, but at the next ripening of the fakûs, a kind of cucumber. Convenient fractions of time may be designated as so many *nights*. In English we still have in common use the period "fortnight," an abbreviation of "fourteen nights." Somewhat less common is the term, "sennight," for "seven nights." This use of nights as a series of disconnected time fragments, still current in English, is of course a survival from primitive usage, like our own North American Indian's measurement of a short journey to a mountain visible on the horizon as "so many sleeps." For a longer journey, however, to the sea far behind the mountain, the Indian would say, "so many moons."

For ages the primitive man had no conception of time, but merely of a series of disconnected units of time, what modern investigation calls "discontinuous time." The short period during which the moon disappears is so brief that a succession of moons was not broken up into disjointed links, and a series of moons therefore gave the early man his longest uninterrupted flow of time. The moon thus became the first continuous time-measurer for periods of time within the year. Almost everywhere the primitive woman knows that, ten moons (that is about nine months) after her periods have stopped, her child will be born. That measurement of the length of pregnancy is one of the oldest continuous time units on record; but it fell short of a year by almost three more moons. The process of linking together the disconnected time units to form a year and thus build up a calendar was an achievement belonging to an advanced stage of civilization.

The Luni-Solar Year

The cycle which we call a year was of course early observed by primitive man. The changing phases of the face of nature could not fail to attract his attention nor could he fail to notice that certain of these phases recurred with great regularity. On some of them he was dependent for sustenance and life itself. Every day there impinged upon him some aspect of the natural world, of sky and earth in a sweepingly wide range, from the far-off celestial bodies above to the changing life below, of trees and plants, cattle and birds and insects, and the sacred observances of man himself, based to no small extent upon occurrences in the natural world. While he had noted these recurrences for ages, the early man made no effort to determine the number of days in the cycle between any one of these events and its next recurrence, and thus to establish the length of the year. Simple as it seems to us, the conception of the year, the length of its duration and the mere arithmetic of counting the days which it occupied were far beyond human powers at first. What he did at first observe, however, was that the seasons recurred after an interval of about twelve moons. For ages his ideas of the length of year remained wholly vague as a group of roughly twelve moons. Gradually each moon month gained a name drawn from some event in the life of plants and animals, or some sacred observance of man himself connected with such an occurrence in nature.

The effort to fit the series of moon months into the cycle of the year was never successful. Throughout the ancient world, especially in western Asia and Greece, man struggled with the practical problem of the incommensurability of the length of the year and the moon month. We are accustomed to say that the Greeks were the first people to gain complete intellectual emancipation, but in the measurement of time their men of science suffered under such complete intellectual subjection to inherited tradition in the use of the moon month as a subdivision of the year that they continued to use a year divided into months, of which there were twelve and a fraction in each year. They resorted to elaborate devices for making a term of years equal to a given number of integral moon months. They devised a cycle of eight years with three intercalated moon months or, more accurately, of nineteen years with seven intercalated moon months. The engineer Meton, who adopted the nineteen-year cycle from acquaintance with Babylonian astronomy, knew well enough that his elaborate cyclic scheme did not match exactly with the observed new moons. In view of this fact it is most extraordinary that the Greeks never possessed the intellectual emancipation to reject the moon entirely from their calendar and adopt a conventional month dictated by social needs. They knew of the Egyptian calendar, and in the middle of the fifth century B.C. Herodotus praises it, evidently under the impression that its year of 365 days was correct. But the Greeks had inherited their lunar calendar from Babylonia, and it was so firmly entrenched in their life, beliefs and customs that they were never able to cast it off.

From the earliest times the lunar month dominated the calendar of western Asia, where it arose at least as early as the fourth thousand years B.C. under the leadership of Babylonian civilization. The Babylonian kings at first adopted an erratic method of intercalated months inserted at irregular intervals, by royal command whenever the king noticed, as Hammurabi says in one of his letters, that "the year hath a deficiency." He then ordered the insertion of an intercalary month. It was not until 528 B.C. under Persian sovereignty that Babylonia adopted a fixed lunar cycle for the insertion of intercalated months at regular intervals. It was this cyclic system which was introduced from Babylonia by the Greeks. At the very time when the Greeks were thus fastening upon themselves the intolerable inconvenience of a lunar calendar they might have observed that Darius the Great, the ablest administrator of the ancient world, had introduced into the Persian Empire the Egyptian calendar, which disregarded the moon month. The long-established habits of the Western Asiatic peoples, however, and especially the eventual triumph of Islam, resulted in the universal restoration of the lunar calendar. The disharmony between the lunar and the solar year was carried to the absurdest conceivable extreme by Mohammed, who was so densely ignorant of the nature of the calendrical problem that in the Koran he actually forbade the insertion of intercalary months. The so-called "lunar year" of 354 days, being eleven days shorter than the solar year, revolves entirely around the solar year in a little over thirty-three years, that is, about three times in every century. A monthly observance like Ramadhân, the month of fasting, if it is now in June, will be in April six years from now. It is now (1935) 1,313 years since the Hijra, or the Hegira, the beginning of the Moslem era, but each of our centuries contains over 103 of the shorter Moslem lunar years. In 1,313 of our Gregorian years there are about forty-one more Moslem years, so that the Moslem era of the Hijra is now in the year 1354 (that is, 1,313 plus forty-one).

The authorities of the Jewish church in the Orient avoided such absurdity, and employed intercalation to keep their lunar calendar at least roughly within the framework of the solar year. All western Asia therefore still continues to suffer under the inconvenience of the most primitive form of time-measurement, the lunar calendar.

The Stellar Year

The Egyptians were the only ancient people who clearly recognized the cause of that inconvenience and possessed the courage and intellectual freedom to remove it. The total incommensurability of the solar or stellar year and the so-called "lunar year" could be discovered only after determination of the length of the solar or stellar year, and recognition of the fact that there is no such thing as a "lunar year."

The determination of the length of the year, together with the discovery that it had a fixed length, was a long slow process lying far back in prehistoric ages. As we shall see, it is an extraordinary fact that it was not the sun which first furnished early man with the length of the year. Other natural phenomena much more intimately within his circle of observation must first have revealed to him the beginning of another annual cycle. The beginning of the annual run of salmon, the blossoming of certain plants or, after the introduction of agriculture, the successive tasks of cultivation might mark the years. The peasants of Palestine call the years so many "threshing floors"; the Arabs of Lower Iraq count the years by "date harvests"; in the East Indian Archipelago the years are counted by "rice harvests." The conception of a year thus arose gradually. On the East Indian Island of Bali the two monsoon seasons are each made up of a list of months which have the same names and are therefore identical for the two halves of the year. This fact shows us that the two seasons were separated from each other and the conception of the complete year cycle had not yet arisen. The process of uniting the seasons into a year was therefore a slow and gradual one. At first, as may still be observed among some surviving primitive peoples, there arose a list of moon months which did not fill the entire year. After those months were past, before the beginning of a new year, there followed a period of indifferent length, completing the old year. This intermediate period of varying and indifferent length served to adjust the inequality between the solar year and any number of integral lunar months and brought the months into rough correspondence with the solar year. Eventually there arose a list of lunar months, twelve to thirteen in number, which were thought to fill the entire year. There is, however, no equivalence between an arbitrary series of lunar months and a solar or stellar year. Hence there really is no such thing as a "lunar year," and Mohammed's year of 354 days is a creation which corresponds to nothing in nature. Historically, the lunar month has been useful as first suggesting a convenient series of twelve subdivisions of the year, but beyond that fact it has caused endless confusion and complication throughout human history.

The lunar month of course contributed nothing to the determination of the length of the year, and curiously enough the sun, the other great luminary, did not first enable man to discover the year and determine its length. While the sun's apparent revolutions shift their positions from season to season they nevertheless go on in an unbroken series with no beginning and no end. The sun's apparent motions therefore did not at first suggest the year cycle. It is quite evident that primitive men had very early begun to observe the stars and to notice the reappearance of a prominent star or group of stars after it had been invisible for a time. Such a reappearance was an event which cut sharply into the sequence of events in the stellar sky, and easily came to mark the beginning of the year. In several regions of South America the word for Pleiades is the same as the word for year. In the eighth century B.C. Hesiod places his agricultural program in the calendar by observing the return of the Pleiades in May. If the Greeks had only continued to build up their calendar on this stellar observation, they might have saved themselves centuries of difficulty and complication with their inherited Babylonian lunar calendar.

In prehistoric ages, many thousands of years ago, the dwellers along the Nile, the greatest river known to ancient man, very naturally began their year with the beginning of the annual rise of the vast river, as the most important terrestrial phenomenon of which they knew and also the source of fertility on which an agricultural people depended for their very life. The four-month season of the inundation, which fructified the fields, was followed by another four-month season of planting and cultivation, and a third and final four-month season of harvest. This year of three four-month seasons was obviously one which arose out of the life of an agricultural people. It was essentially an agricultural folk-calendar, and its months were obviously moon-months in the beginning and doubtless continued to be so for thousands of years.

But, like primitive man everywhere, these earliest known agricultural peasants along the Nile had begun at a very remote date to scan the heavens and observe the stars, probably some thousands of years before Hesiod was doing the same in the eighth century B.C. There is probably no other country in which Sirius, the Dog Star, the brightest of the so-called fixed stars, is such a brilliant and noticeable spectacle in the evening sky. In the latitude of Lower Egypt Sirius rises about four minutes earlier every day. Every fifteen days he rises about an hour earlier, so that eventually he rises in full daylight, when he is of course entirely invisible. After a period of some months of invisibility, this brilliant and beautiful star suddenly reappears on the eastern horizon at sunrise. This "heliacal" rising of Sirius, as it is called, is a noticeable and sharply defined event. By a remarkable coincidence this heliacal rising occurs very near the time of the beginning of the inundation. In antiquity this date was the nineteenth of July. By a lucky accident, the beginning of the year at the advent of the inundation in the enormously ancient peasant calendar was thus fixed at the moment of an important astronomical event. The basis of the calendar which was to become that of the civilized world was therefore a stellar, not a solar year.

The 360-Day Year

It is important to notice that the earliest observances of the heliacal rising of Sirius must have been very primitive in character, as we shall later illustrate. Persistent dust storms, such as we experience to-day, desert fogs and mists or sometimes storm clouds must have made the determination of the exact day when Sirius reappeared on the eastern horizon not a little uncertain. It is certain that the length of the stellar year as measured by successive sunrise reappearances of Sirius was at first roughly established by the Egyptians as 360 days. As early as the fourth thousand-years B.C., that is, well back of 3000 B.C. we find this 360-day year divided into thirty-six decads of ten days each, for grouping the constellations along the celestial equator. This appearance of a circle of thirty-six decads in the fourth millennium B.C. is highly significant. It is certainly the oldest appearance of a circle of 360 divisions. The Sumerian sexagesimal system, in which sixty appears as a numerical unit (called *šuššu*), is without doubt enormously old; and in all probability arose from the length of the year—360 days—by dividing it into six parts. It seems probable, as concluded by Zimmern, that *šuššu*, the Babylonian word for sixty, means "one sixth." In both Babylonia and Egypt the convenient and basic number (360), of fundamental importance in the division of the circle and therefore in geography, astronomy and time-measurement, had its origin in the number of days in the year in the earliest known form of the calendar. While its use seems to be older in Egypt than in Babylonia, there is no way to determine with certainty that we owe it exclusively to either of these two countries. A common origin older than either is possible.

The 365-Day Year

The Egyptians found their primitive 360-day year very convenient in business and social life, and it therefore survived far down into the historic age; but as their observations of the heliacal rising of Sirius accumulated, they finally discovered that the year, as they thought, contained 365 days. We are in a position to determine the date when they took administrative action to make this discovery of the approximate length of the year practically effective. In the year 4236 B.C., as determined by Borchardt, some now unknown ruler of prehistoric Egypt, without doubt residing in Heliopolis, introduced a calendar year of 365 days. It began with the heliacal rising of Sirius, that is, on the nineteenth of July. This calendar contained the three old agricultural peasant seasons: the inundation, the cultivation and the harvest, each season containing four months. The epoch-making importance of this calendar lies in the fact that these twelve months were entirely divorced from any connection with the moon, so that the deviser of the calendar could make each month thirty days long. By the addition of five feast days at the end of the year, this year of twelve thirty-day months or 360 days became the earliest known and practically convenient calendar of 365 days.

Earliest Fixed Date in History

The only celestial phenomenon to which any attention was paid in devising this calendar was the establishment of the beginning of the year at the first heliacal rising of Sirius. In other words, the mind that devised this calendar put social and economic needs first and divorced the calendar from celestial processes. It is of the greatest interest to observe that this calendar inevitably soon parted company with Sirius, for, owing to the fact that the stellar year is about a quarter of a day longer than 365 days, Sirius rose a day late, every four years; that is, at the end of the fourth year after the introduction of the calendar he rose on the second day of the New Year or one day late; at the end of eight years two days late; that is, on the third day of the year; at the end of twelve years three days late; that is, on the fourth day of the year; and so on to the end of the year. The calendar-makers did not at first observe this discrepancy, and when they finally did become aware of it, they held to the supremacy of social considerations, and made no attempt to shift the calendar back into harmony with Sirius. Eventually, therefore, in four times 365 years, that is in 1,460 years, the Egyptian calendar revolved entirely around the celestial year. A remark by Censorinus informs us that in the year A.D. 139, Sirius rose on New Year's day, that is, New Year's day in the civil calendar of Egypt once more coincided with the heliacal rising of Sirius. It is easy to compute that the next earlier coincidence of this kind must have occurred in 1318 B.C., the next earlier in 2776, and a still earlier one in 4236 B.C. Archeological considerations forbid us to suppose that we may push back still another such period of 1,460 years. We may therefore conclude that the civil calendar of Egypt was introduced in 4236 B.C.

This date, near the middle of the forty-third century B.C., is not only the earliest fixed date in history, but also the earliest date in the intellectual history of mankind. It has been well said that "the Egyptian calendar is the greatest intellectual fact in the history of time reckoning,"[2] but it is far more than that. For the introduction of this calendar was

[2] Nilsson, "Primitive Time Reckoning," p. 280.

an intellectual feat, marking the dawn of a recognition of the supremacy of social requirements. As we have already remarked above, in divorcing this new calendar from the processes of nature, the Egyptians were recognizing for the first time a world of social needs which they placed first. It is to-day the earliest known such recognition, and the earliest dated intellectual event in human history. It ushered in the great epoch, which was in full development after 4000 B.C., when the Egyptians discerned that their once purely nature-gods, who had originally been only personifications of natural forces and natural phenomena, like the Sun-god Re, or the Vegetation-god Osiris, were gradually shifted from a world of natural processes to be arbiters in a newly discerned social arena, where moral forces were emerging. The calendar was thus the beginning of a great movement in human life which carried over the thought of man from the world of nature to the world of human life.

EGYPTIAN SOURCE OF EUROPEAN CALENDAR

This remarkable calendar remained the exclusive possession of the Egyptians for over thirty-five hundred years after its introduction. The effort of Darius the Great to introduce it into Western Asia late in the sixth century B.C. proved unsuccessful. The Greeks, as we have seen, wasted their scientific gifts in adding one futile refinement after another to the hopelessly inconvenient and complicated Babylonian lunar calendar. Nearly four and a half centuries after the fruitless attempt of Darius, another great administrative genius gave Europe for the first time a sane calendar. In 46 B.C. Julius Caesar introduced into the Roman Empire the Egyptian calendar, with one important modification. He provided for the addition of one day to the year of 365 days once in every four years. The history of this important innovation is interesting.

The first knowledge of a year of 365 days was brought to Europe by Thales, the Ionian philosopher, who learned of it on a visit in Egypt. Curiously enough, Herodotus also learned of it there and praises it as a perfect solution of the complications due to the incommensurability of moon-month and year. Neither Thales nor Herodotus seems to have known that the year of 365 days was too short. It is obvious that the Egyptians early observed the rate at which the heliacal rise of Sirius diverged from the beginning of the calendar in their civil year, revealing to them that their 365-day year was a quarter of a day short. The extraordinary achievements of the Babylonian astronomers in the Chaldean and Persian periods included a computation of the length of the solar year by Nabu-rimannu, or Naburianos, as the Greeks called him. Not long before 500 B.C. this great astronomer calculated the length of the solar year as 365 days, six hours, fifteen minutes and forty-one seconds—a result which is only twenty-six minutes and fifty-five seconds too long. This is the earliest known close approximation to the length of the solar year.

For over a century and a half no one seems to have made any practical application of this new knowledge. It was not until the third century B.C. that the Egyptians made an effort to correct the error in the length of the year. We still possess the granite stela of Ptolemy Euergetes I, bearing his decree, dated in the year 238 B.C., which commanded that every fourth year should be one of 366 days. But the Egyptian people obstinately refused to conform to this decree, and the correction in the calendar never became effective.

In 380 B.C. the able Greek astronomer and mathematician Eudoxus visited Egypt and there learned the fact that the year was really about 365¼ days long. Then for the first time this fact became common knowledge in Europe. Some two centuries later, that is, early in the second century B.C., the great Greek astronomer Hipparchus announced that 365¼ days was in error, that is, it was too long by one three-hundredth of a day. This error was unknown to Caesar, and we all know that for this reason in March, 1582, the Julian calendar was superseded by that of Pope Gregory.

It is evident, however, that Julius Caesar brought to Europe for the first time a sane calendar system of twelve thirty-day months. If jealous Roman emperors and other scientifically ignorant meddlers had not utterly disfigured the Egyptian calendar, we would not be calling the ninth month September (with the numeral seven), the tenth month October (with the numeral eight), the eleventh month November (with the numeral nine) and the twelfth month December (with the numeral ten)! Nor would our young people be obliged to learn and repeat a verse of poetry in order to find out how many days there are in a month.

The Week

With the introduction of the Egyptian calendar time became something in which *human* processes were, so to say, systematically staked off into annual stages and substages. These subdivisions of a calendar, particularly the shorter ones, arise only at an advanced stage of social development. The origin of the month was of course due to a celestial phenomenon, but that of the week was in origin purely human and social. A market week of three, four, five, six, eight and ten days is a calendar division of purely secular origin. It is found over practically the entire globe, where civilization has advanced sufficiently to possess arts and crafts, with exchange and commerce of a primitive kind. It is quite commonly a *rest* day on which work is forbidden. There is a universal connection between market day and religion. Among some peoples, as among the Hebrews, the religious significance of the day predominates, and the feature of rest becomes a religious mandate. For our subject, the week, whatever its origin or significance, is of slight importance, for the week has played practically no part in time-measurement.

The Day

For many reasons, which are too obvious to need enumeration, the smaller subdivision, the day, has always been of fundamental importance in the measurement of time. It is extraordinary that among the various peoples there should be such wide diversity in the understanding of just what a day is. Modern astronomers consider a day as beginning at midday and therefore lasting from midday to midday. The peoples having a lunar calendar conceive the day as lasting from evening to evening; while in modern life the day begins at midnight and lasts from midnight to midnight, a point of practical convenience as marking the transition from one day to the next, and ignoring the night. This conception of a twenty-four-hour day is not even yet in our railroad time-tables. We really have two periods of twelve hours each, very inconveniently distinguished in our time-tables by leaded or black-faced type suggesting darkness at *midday,* which we sagaciously shift to light-faced type, suggesting daylight at *midnight!* The modern languages possess no word for the twenty-four-hour day. Only the ancient Greeks seem to have possessed such a word in their convenient *νυχθήμερον*. The Egyptians began the day at dawn, which seems the natural thing for an originally peasant people to do. The practise of beginning the day at dawn was adopted by Europe at an early date, and continued down into medieval times. It was the introduction of the striking clock, in the fourteenth century of our era, which shifted the beginning of the day to midnight.

There was as much diversity in the *length* of the day as in the time of its beginning. In view of the varying length of the *daylight*-day no one finds anything strange about a flexible or elastic day. It is in the subdivisions of the day that we have come to expect constant length. Division of the day into hours is unknown to primitive peoples. The Greeks and Romans in the West and the Chinese in the East had originally no hour divisions of the day, which they all received from the Near East. The Greeks were accustomed to identify times of day by such cumbrous devices as "the time of full market," which was the middle of the forenoon. Subdivision of the daylight-day into twelve parts was introduced into Egyptian life at a very early date. We find it in the Pyramid Texts, and this means that it was practised in the fourth millennium B.C., that is, before 3000 and possibly as early as 3500 B.C. The Egyptian was interested in a convenient division of his day into twelve parts, but he was not concerned that these twelve parts should be of constant length. The reason for this probably lay in his early timepieces, as we shall see. The Babylonians also possessed a subdivision of the day at an early date, but it divided the daylight-day into six parts, and the night into six more. The modern habit of translating the Babylonian term *bêru* (formerly read *kasbu*) for this part by "double hour" is of course very misleading, if not entirely incorrect.

The Earliest Timepieces

Sun-Clocks

What type of time-measuring devices the Egyptians at first employed we do not know. The earliest such devices that have survived in Egypt date from the fifteenth century B.C. They were of two kinds and measured time either by the observation of celestial processes or by the employment of physical processes under artificially arranged terrestrial conditions. The celestial processes employed for time-measurement were the movements of the sun and the stars. In a country as nearly cloudless as Egypt the observation of the sun was a valuable means of determining time. The Egyptians therefore devised the earliest known sun-clock. In its oldest form it was an instrument shaped like a T-square laid down horizontally. The cross-head of the T-square was laid toward the east in the forenoon, and was sufficiently thick to form a barrier casting a shadow along the much longer stem, which was graduated with marks for six hours. At dawn the shadow of the cross-head cast westward by the sun just clearing the eastern horizon covered the whole length of the graduated scale out to the mark of the first hour at the end. As the sun climbed the eastern sky the shadow shortened until at noon it disappeared at the mark of the sixth hour. The instrument was then turned around with the cross-head of the T-square toward the west, so that the lengthening shadow cast by the afternoon sun marched back along the hour marks to the twelfth, identical with the first hour at the end of the scale.

Such a system of determining time by measuring the length of the shadow cast by the sun was of course continually subject to alteration caused by the seasonal changes in the position of the sun. At first these Egyptian sun-clocks were fitted to the length of the day at the equinoxes and were not correct at any other season. It would have required some generations of experience in instrument making to have enabled even the supreme skill of the Egyptian craftsmen to produce a shadow clock of this type, which would have indicated correct time.

The sun-clock makers tried to adapt their instruments to seasonal changes by using a *series* of hour scales, eventually *seven* in number. This showed progress and improvement; but such a sun-clock was not an accurate timepiece.

Moreover, the Egyptian did not yet know enough of the motions of the earth and sun nor of the mathematics involved to discern the underlying principles which should have governed the construction of his sun-clock, and especially the arrangement of the hour scale for the different times of day and for the changing seasons of the year. He further improved his clock by employing only a narrow beam of sunlight and shortening the graduated scale by raising it to an oblique angle of some forty-five degrees above horizontal. While improving the accuracy of the device, these changes also made it small enough to be portable. It was indeed the earliest known portable timepiece. It was equipped with a plummet so that it might be kept in the plane of the horizon; but little could be claimed for its accuracy. The great Egyptian conqueror Thutmose III refers to the hour indicated by the sun's shadow at a critical moment while on his first campaign in Asia. It must have been, therefore, that he carried with him into Asia some form of sun-clock. It is probably only a coincidence that the oldest sun-clock we possess bears the name of this king (fifteenth century B.C.).

Another form of sun-clock employed the *direction* of the sun's shadow, rather than its length. Lines diverging from a center were marked on a plane surface, which might be either vertical or horizontal, and these enabled the observer to determine the different hours, which were marked next to the lines. This form of instrument was simply a sundial, and evidently the ancestor of our own sundials. Again the Egyptian makers did not understand the rather complicated problems involved in making such a device indicate time accurately. It is interesting to note that one of these Egyptian sundials bearing the name of the Pharaoh Merneptah of the thirteenth century B.C. has been discovered in Palestine.

Stellar Clocks

We have seen that the Egyptians began their year by stellar observation. They must have begun very early the determination of the hour also by observation of the stars. The word "hour" was written in hieroglyphic in the earlier period of Egyptian writing, with a *star* after it as the so-called "determinative." In order to use the night-sky as a stellar clock it was necessary that the observer should build up a list of important stars together with the times at which they crossed his meridian at different seasons of the year. If complete for all the seasons such a list would enable the Egyptian at any time of year to observe the night-sky and determine the hour. He seems to have devised a primitive type of "transit instrument" intended to enable an observer to determine the instant when a given star crossed his meridian. Naively simple and undeveloped, this instrument was employed as the observer sat cross-legged on the flat roof of a building, supposably often a temple. Opposite him at the other end of the building squatted his assistant facing him, and both of them exactly on the same meridian which was probably marked on the roof. We know that the Egyptian engineers and surveyors of five thousand years ago could lay down a meridian with a good deal of accuracy. The oldest pyramid, that of King Snefru at Medum, was oriented in the thirtieth century B.C. with surprising accuracy. Our astronomical observer, seated on a meridian line which we may regard as fairly accurate, peeped through the forked top of a palm branch which he held in his hand as a kind of sighting staff, and sighted through the slot in the top of the palm branch at the stars in the opposite northern sky over the head of the squatting assistant. A star rising to culmination over the assistant's "crown," that is, the exact center of his head, might be over his "left eye," over his "left ear" or over his "left shoulder." These positions were determined with some precision by the use of a plummet. As the observer looked through the slot in his sighting staff, he held his plummet well out in front of the staff, so that the plumb-line at a point near its top cut through the star he was observing, and at a lower point just above the weight the plumb-line also cut through some part of the head or figure of the observer's assistant squatting at the other end of the building. The plumb-line then cut through one shoulder, one eye or one ear of the assistant. Thereupon the observer could wait until, as he followed the star with his plumb-line past the ear and the eye, the plumb-line finally cut through the top or crown of the head. The star was then in culmination and was crossing the observer's meridian. This was the most important function of the device. It was chiefly a transit instrument and as such is the oldest known astronomical instrument. It was called in Egyptian a *mrḫ · t* or *merkhet,* meaning "instrument for knowing," to which we should add the word "hour." As an "instrument for knowing the hour" is of course a timepiece, we may regard *merkhet* as the earliest known word for "clock."

It is obvious, as Borchardt has observed, that these meridian observations themselves would necessarily have had to be accompanied by some kind of time record such as is furnished to-day by the astronomer's clock. He has supposed that the Egyptian observer originally compiled a time-table of hours when important stars crossed his meridian or occupied definable positions near it, which could be stated in terms of the head and shoulders of the observer's squatting vis-à-vis. Two such star-tables have been preserved, pictured in the tombs of Ramses VI and Ramses IX at Luxor, that is, about 1150 and 1120 B.C. The positions of the stars are given at twenty-four different times of the year, that is, twice a month, on the first and the fifteenth. These tables very much need detailed study by an experienced astronomer. Thus far the only star identifiable is Sirius, and his only determinable position is his culmination. These position-tables must have been accompanied by time-tables, probably on papyrus, which now seem to have perished.

Water-Clocks

Evidently some kind of timepiece was employed in the compilation of these time-tables, otherwise the culminations observed would not have furnished any indications of time. Borchardt has demonstrated that the Egyptian water-clock, the famous clepsydra, or "water-stealer," as the Greeks called it, was used for measurement of the hours of the *night* and has therefore concluded, with much probability, that it was a clepsydra which was used to furnish the time data which transformed the night-sky for the Egyptian into a vast stellar clock.

There were two types of the clepsydra, one which we may call an *outflow* clock, and the other an *inflow* clock, according as the water flowed out of, or into the graduated vessel serving as the clock. In both these forms of clock the principle was essentially the same. Of the inflow type, which seems to have been the more accurate system only two specimens are known to me. Thirteen examples of the outflow type have been preserved in whole or in part. The oldest of them bears the name of Amenhotep III, and therefore dates from around 1400 B.C. We know, however, of a maker of such clocks, who lived 150 years earlier, about 1550 B.C. This man, whose name was Amenemhet, is the earliest known astronomer, physicist and clock-maker in the history of science. He left a brief autobiography engraved on the wall of his tomb-chapel in the great cemetery of Egyptian Thebes, which lies opposite modern Luxor. Amenemhet proudly tells us that he lived and served at the court of the first three pharaohs of the eighteenth dynasty. He takes evident satisfaction in relating that he made a clock for Amenhotep I, that is, some time in the middle of the sixteenth century B.C. He avers that he had read all the existent literature on the subject, as a modern scientist might do. Whether in the course of this reading, or as a result of his own researches, does not appear, but our clock-maker tells us of his observation that the winter night was fourteen hours long, while the night of the harvest season (summer) was twelve hours long. He mentions that he constructed his clock in accordance with the fact that he had noted an increase in the length of the nights from month to month and also a decrease from month to month. He then goes on to say: "I made a clock (*mrḫy·t*) computed for the year . . . [it was correct (?)] at the going in of the harvest season (summer) in the cultivation season (winter), at the union (?) of the moon with its seasons. Every hour was at its time."

Externally this clock, built by Amenemhet for the king of Egypt, was of unique interest, for it was the earliest timepiece of which we have any record, fitted with tiny statuette figures so devised that they appeared at the proper intervals and indicated the hours. Unfortunately, the text of Amenemhet's autobiography is much damaged and very fragmentary. His description of these mechanical arrangements informs us that "Nekhbet (the Moon-goddess) walked at the same time with Re (the Sun-god) [while she extended the symbols of life and prosperity] which were in her hand, to the nostrils of his majesty. Then she went down (meaning she dropped out of sight) . . . ," and unfortunately at this point there is a bad gap in the text, after which we find the words: "[and Re] rejoiced when he saw these goddesses ascending and descending before him." As Sethe has noticed, "these goddesses" are obviously the well-known hour-goddesses, each personifying an hour. Amenemhet had evidently arranged small figures of these goddesses, each of whom came into view at the proper point of time, thus by her appearance announcing the hour. It must be borne in mind that these figures belonged to a water-clock and not to a mechanical clock of cog-wheels and gears, for such mechanical developments were devices entirely unknown in the sixteenth century B.C. They did not come in until the Hellenistic Age, after Alexander the Great. We may suppose, with some probability, judging from the verbs of motion employed in the description, that the moving figures were attached to floats on the surface of the water in the clock, and that they therefore moved up and down with the changing level of the water. It must have been a pleasing and picturesque timepiece which Amenemhet devised, and he tells us with evident satisfaction that it pleased the king. It was the earliest of these ingenious artistic mechanical clocks of which we see the first reaching Europe when Saladin sent such an elaborate timepiece to the Emperor Frederick II in A.D. 1232.

Amenemhet's fragmentary description of his elaborate clock, combined with all the data now observable from an examination of the surviving Egyptian water-clocks, especially the oldest of the outflow clocks, does not reassure us regarding our ancient astronomer's ability to construct an accurate timepiece. In the simplest terms this device consisted of a water vessel, with a hole in or near the bottom for the escape of the water and a graduated scale of hours engraved on the inside from the top to a point near the bottom. To a modern scientist it would be axiomatic that the sides of the water vessel should be vertical and parallel; or, stated more simply, the vessel should be a cylinder. To our surprise, however, we find that all the Egyptian water-clocks are inverted truncated cones. The only reason I can suggest for this unsuitable form is that its flare made the scale of hours on the sloping inside walls of the vessel more accessible and more legible. Of the complications which this form added, the Egyptian's limited knowledge of hydraulics left him wholly unaware. If the column of water had been cylindrical, its rate of escape would have been greatest when the column was highest, that is, when the greatest pressure was being exerted on the water escaping at the vent. This variation in the rate was obviously increased by giving the vessel a flare, so that the upper half contained a much greater volume of water than the lower half.

The Hour

Now the function of such a clock was to divide the night into twelve equal parts. There was, however, no sufficient method for securing a uniform flow of water during each one of these twelve parts. The hours decrease too rapidly in length from the beginning to the end of the scale of hour marks on the inside of the vessel. Only in the middle is one hour that is approximately correct. Amenemhet indicates that his clock was adjusted to show the hours for all seasons of the year. His narrative, as well as the surviving water-clocks, show that whether the night was short or long, it continued to be divided into twelve periods, that is to say, in winter each of the twelve periods of the night was longer, and during the nights of summer each of the twelve periods was shorter. In other words, the hours were not of constant length. We are accustomed to a flexible *day* of varying length, but an *hour* of elastic length is surprising to us. The scheme of marks was intended to indicate the lengths of the nights in all the different seasons. Indeed the later water-clocks provide for indicating a change in the length of every night, from night to night, and in the period around 300 B.C. these indications were essentially correct.

The Hour and the Twenty-four-Hour Day

The twenty-four-hour day, with hours of variable length, longer in the winter nights and shorter in the summer nights, or longer in the summer days, and shorter in the winter days, reached Greece with the Egyptian clocks in the time of Alexander the Great. We know that an Egyptian clock was shown to the cynic Diogenes as something unusual and curious. It passed thence to Rome, where the first sun-clock appeared in 293 B.C., having come into Italy by way of the Greek cities of Sicily. The first water-clock did not arrive in Rome until 159 B.C. It is important to notice that the Greeks and Romans both had small divisions of the day long before this. Homer knew of divisions of the night determined by observation of the constellations, and Herodotus tells of Babylonian devices for determining divisions of the day. The oldest evidence of the twelve-hour day in Greece is in the Homeric studies of Aristotle, where he refers to "the twelve parts of the night" (τῆς νυκτὸς αἱ δώδεκα μοῖραι).

The Egyptian hour of varying length, which thus came into Europe with the twenty-four-hour day, remained in use nearly down to the end of the Middle Ages. The Babylonian *bêru* (formerly *kasbu*), a period of one sixth of day or night, was of fixed length, and may eventually have had some influence on the European hour; but the hour of fixed length did not come into general use in Europe until the fourteenth century of our era, when it was introduced by the striking clock, which inevitably gave it wide currency.

Subdivision of the Hour

We have already seen that primitive life did not possess the subdivision of the day into hours. Much less did it have any shorter divisions of time. There are of course inexact terms of no fixed significance, as we say, "the twinkling of an eye" or the German "*Augenblick.*" For a vague period of about half an hour, the natives of Madagascar say, "a rice-cooking," while for a moment they say, "the frying of a locust." The Cross River natives say, "a complete maize-roasting," for something less than a quarter of an hour. In Illinois when I was a lad, a farm-hand would facetiously indicate a moment by the phrase, "two jerks of a lamb's tail." The shortest interval of time indicated by the Egyptian was written in hieroglyphic simply by the upraised head of a hippopotamus, with a horizontal line cutting it off. This line was intended to represent the surface of the water, and the idea suggested was that of the instant of time during which the hippo cautiously thrust his head out of the water for a quick glance around and its almost instantaneous disappearance. That was the Egyptian scribe's ingenious writing of the word "instant"; but this word did not indicate a subdivision of the hour. In so far as we can discern, the hour was divided in early Christian times in Egypt, into the half, the quarter, the eighth, etc. The sexagesimal subdivisions of the hour into minutes and seconds, now customary with us, are not earlier in the Orient than about A.D. 1000, and they did not appear in the western world until the end of the Middle Ages. The source of these divisions is unknown, but it has been suspected with some probability that the Arabic astronomers applied them to the hour from the use of them in dividing the circle, in which connection they are likewise not of early oriental origin. Even Ptolemy did not divide the circle into sexagesimal degrees, although he did apply the sexigesimal divisions to the radius of his circle.

There are indications of a small division of time employed by the Egyptian surgeons at an early date (nearly five thousand years ago) for the counting of the human pulse, and it is known that Hippocrates some twenty-five centuries later was already counting the pulse. Obviously some subdivision of the hour, and some timepiece for measuring it, must have been used for this purpose. The surprisingly accurate determinations of the length of the planetary revolutions by the Chaldean astronomers must have required timepieces adapted for use in measuring fractions of time smaller than the hour. No examples of Babylonian timepieces have survived, however, and the whole matter awaits further investigation.

Eras and Periods Longer than a Year

Of periods longer than a year the primitive mind had but the vaguest conceptions. Indeed primitive men may entirely lack the *conception* of even a year. In the Philippines the Bontoc Igorots have no notion of a year. It is of course possible to count a series of years without any notion of the year itself. The Bataks of Sumatra use smallpox epidemics as marking-off periods, usually nine to twelve years in length, and a native will say that his house is "two smallpox epidemics old." The Hottentots keep records of the ages of their live stock by the number of calvings or lambings. But among people of lower intelligence there is no conception of a long period of time. A Dahomey Negro rarely knows how old he is, and we are all familiar with the old darky who has no idea of his age.

With the advance of civilization man's increasing knowledge has had a profound influence upon his conceptions of time, and especially his discernment of ever-lengthening periods of time. The astonishingly long reigns claimed for their early rulers by the scribes of Egypt and Babylonia must have been compiled in a primitive age of naive and childish fancies, whose fantastically impossible periods could not have grown out of any just impressions of time as measured by human history. The flow of time was not at first revealed to man by the processes of nature. The erosion of a river valley and its changing contours would not be discernible, because the early observer had no knowledge of how those contours looked one thousand years earlier. But when he saw a huge pyramid with gaping holes gnawed into its flanks by the biting sand-blast which the powerful Egyptian north wind drove against it, he knew just how that pyramid slope had looked when it left the hands of the architect a thousand years earlier. Thus the slow decay of the works of man taught him what the processes of nature could not at first have revealed. Such unwritten human records in Babylonia and Egypt began to reveal to men after 3000 B.C. the slow march of time, which became more and more evident as those records gradually took written form. The earliest known annals of a nation compiled in the twenty-eighth century B.C. covered some fifteen hundred years of human history, that is, they extended from the forty-third to the twenty-eighth century B.C. The men of the Pharaoh's court, therefore, in the twenty-eighth century B.C., that is, some 4,700 years ago, could look back upon a lapse of time a little longer than that which we survey as we contemplate the period that lies between us and the so-called fall of Rome in A.D. 476. For those men time had long since ceased to be a discontinuous duration. The earliest mention of an era appears on a monument of Ramses II in the thirteenth century B.C., a monument which is dated in the year 400 of an era which had begun about 1720 B.C.

In Babylonia the cycle of nineteen years for the intercalation of the lunar months evidently discloses a conception of time as a continuous flow of duration. It was introduced in 528 B.C.

Science and the Continuous Flow of Time

It is evident that historical impressions of the long and continuous flow of time, especially for some centuries before the beginning of the Christian era, had led the men of the Hellenistic Age and the early Roman Empire to their dreams of a thousand years, which have left us the rather misleading significance of the word "millennium" as a Golden Age.

It is rather natural science than human history which has so enormously expanded our modern conception of the flow of time. About 400 B.C. the Chaldean astronomer Kidinnu, whom the Greeks called Kidenas, discovered the precession of the equinoxes, involving a cycle of twenty-six thousand years. That was the longest period revealed by the vast celestial clock for many centuries, indeed, perhaps even into modern times. It was followed by the geologists' estimates of the length of the periods required for the formation of the earth. Much more precise are their computations of the length of the much later process which has produced the present surface of the globe. In our prehistoric survey of Northeastern Africa, it has been possible to date the desiccation of North Africa in the middle of the Old Stone Age and to show that the sand dunes of Nubia, as they marched southward, left the North African coast of the Mediterranean about thirty-five thousand years ago. The computations of De Geers have shown that it is about nine thousand years since the retreating ice of the Glacial Age reached its present latitude, while the investigations of the American geologists would indicate that the Ice Age began probably a million years ago. Such researches, especially the field investigations of our own Prehistoric Survey in Northeastern Africa, have revealed to us this imposing panorama of terrestrial processes as the vast stage where we discern earliest man emerging as the only implement-making creature, whose prehistoric life is thus disclosed interlocking with the processes of nature, which formed our globe. It is a tremendous spectacle: the geological process, marching hand in hand with the cultural advance of man.

Such disclosures of the position of man in the universe form for us the culmination of man's sense of time as an historical process no longer discontinuous. We begin to feel a range of time measured by the emergence of the life of man in the universe, until we are aware that there is no time apart from man. Those celestial processes with which our knowledge of duration now begins, as they are disclosed to us in incomprehensible gulfs of millions of light years, are for us essentially timeless. We now recognize that modern investigation of early man has revealed him to us filling the gap between the incalculable duration of the celestial processes on the one hand and on the other the more comprehensible periods of the terrestrial processes that formed our globe as the home of man and led over to the historic age. Thus in vastly remote prehistoric ages, when the present surface of our globe was being fashioned by geological forces, we begin to see man, all unconscious of those forces about him, but suddenly revealed to us rising out of them and entering a realm of time, because he was, and still is, the first and only creature to be aware of time. He was its creator, the first being possessed of the ability to look back along his own trail and to recognize the point in the timeless process of the universe where the creature man entered a new and mysterious realm, which by that very fact made him the creator of a domain of time.