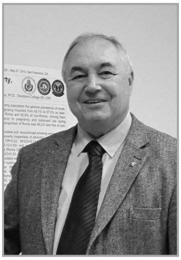
V. TÁRSADALOMTUDOMÁNY ÉS RITMUS



AZ IDŐ MÉRÉSE AZ ÓKORBAN

DR. HERCZEG TAMÁS ret. biologist.
Sundial Section of the Hungarian Astronomical Association
E-mail: tamasherczeg29@gmail.com

DOI 10.23716/TT0.23.2020.19

Absztrakt:
A földi természet ritmusát az égitestek, főleg a Nap „járása" határozza meg. A természet ritmusából akkor lett az ember számára idő, amikor az ókori emberek közösségbe szerveződtek, letelepedtek, és kialakult a munkamegosztás. E folyamat kezdete az i. e. 5. évezredet követő évszázadokra tehető. Ezt követően a szervezett társadalmak megfigyelőhelyeket építettek (pl. Mezopotámiában, Egyiptomban, a Földközi- és Fekete-tenger partvidékén, a brit-szigeteken, Közép-Amerikában), az ókori bölcsek e referencia pontokról figyelték a Nap, a Hold és a csillagok járását. Felismerték az ismétlődő periódusokat, és megjósolták azok bekövetkezését a jövőben. Meghatározták a sziderikus év és a holdhónap hosszát, felismerték a napforduló és a napéjegyenlőség napjait, a Vénusz szinódikus periódusát, a csillagképek mozgását. Az időszámítást naptárakba foglalták, és az év, a hónap és a hét fogalma megjelent a mindennapi életben is (pl. Hammurabi törvényei, holttengeri tekercsek). A napot kisebb egységekre, órákra és percekre osztották, ezek mérésére vízórát és napórát konstruáltak. Az ókori meghatározások olyannyira alapvetőek és pontosak voltak, hogy a középkorban megjelenő mechanikus csillagászati órák is megjelenítették őket (lásd pl. Hanza-óracsalád), sőt még korunk időszámításának alapjait is képezik.
Kulcsszavak: időszámítás, napóra, naptár, ókor, csillagászat.

Introduction

The existence of the nature and the rhythm of the Earth and their changes are basically determined by the periodic movement, circulation and rotation of the celestial bodies surrounding us and the Earth itself. It is no mere coincidence that intelligent mankind living in close contact with nature has been watching the celestial bodies and their movements since ancient times. The first proof of this is the representation of the Sun, the Moon and the stars on some rocks and cave paintings in the Stone Age[1]. The depictions can be found on each of the populated continents of that time, and they extend through several millennia. (For example, the paintings of Altamira and Lascaux caves are dated to 10–20,000 BCE.) The symbols of the celestial bodies do not usually appear on their own, but in the context of the time and the creators' representation of fauna; given the absence of a system of writing, the images lack written explanations or legends.

Today's interpretation of prehistoric figures is supported by two principles: 1. The ancestor sought a realistic representation of nature. 2. The creators did not do unnecessary work, meaningless graffiti or engraving, and minimized the use of equipment (eg, hard-to-prepare dyestuff) and labor. (It could not have been simple to cling to a rock or to engrave a stone at a height of several meters, in the darkness of the cave.) For this reason, the smallest detail of the figures should be considered very carefully. Consideration of such details led, for example, to the realization that the ceiling of the Bull's Hall in the Lascaux cave was in fact a prehistoric planetarium, where the depiction of the *Pleiades* and *Hyades* could be recognized as part of the image of a bull, proving that the prehistoric man was watching the movement of stars.[2]

Annual rhythm

The term 'year' may cover different periods, depending on the periodic movement we observe[3]. In our age, 1 year means the time in which the Earth once goes once around the Sun. The exact definition of this period is not simple even nowadays[4], and in the absence of mechanical timers, our ancestors could only rely on natural observations. Stars, whose visibility showed the periodicity associated with the Earth's circulation, were well suited for estimating the year. The *Pleiades* and the accompanying *Hyades* in

[1] WILDGEN 2004. 117–154; SZALAY 2012.

[2] RAPPENGLÜCK 1997. 217–225.

[3] This article cannot discuss the concept of time and year in detail. A very good review is given by Lippincott et al. 2002.

[4] The following factors hamper the determination of the Earth's circulatory time: 1. The Earth moves around the Sun on an eccentric circular path, so its circulatory speed is not constant. (when it is closer to the Sun its speed is faster; farther away from the Sun, its speed is slower. See Kepler's second law.) 2. In addition to circling the Sun, the Earth rotates on its own axis, an addiional motion that must also be taken into account. 3. The Earth's axis of rotation is not perpendicular to the circular plane, but has an angle of about 23.5^{o}. 4. The angle of rotation axis is not constant, as it changes slightly in an approximately 26,000-year cycle. The axis moves along a conical surface, so the Earth is rotating in a swag, resulting the so-called *precession*.

the Bull constellation were such configurations: they disappeared from the sky at a particular time of the year, but they reappeared on the horizon later. The time between the first appearances marked the *sidereal* (star-related) year. Over Lascaux, this first appearance was on the 283rd day of the year. (The last visibility was on the 237th day of the following year.)[5] Since the *Pleiades* were visible from every inhabited area of the Earth at some given time of the year (with different dates of appearance depending on the observation site), it is not surprising that they played roles in different myths connected with nature. Obviously, the astronomical observations were not just for observation's sake, and on the basis of previous experiences ancient observers could predict some recurring changes in nature, and be prepared for them. An example is the observations of ancient Egyptians about *Sirius*. *Sirius* is a typical (double) star whose movement can be easily followed by the naked eye. There are indications from the 5th millennium that the Egyptians had linked *Sirius*' incursion of the Sun with the flooding of the Nile.[6] And, as we have noted, the time between the two first appearances – similar to that of the *Pleiades* – is a *sidereal* year.[7]

Even nomadic communities could observe the characteristic movement of the Sun: its appearance on the horizon changes day by day between the two extremes of the two solstices. The place of the Sun's appearance is related to the length of the daylight: the more north-east the sun rises, the longer the daytimes and shorter the nights, the south-east *vice versa*. The north-eastern extremity is the summer solstice, the south-east is the winter solstice. The time to reach the same solstice point is the so-called *solar* (Sun-related) year, the length of which (currently) is 365 days 5 hours 48 minutes 46.7 seconds.

[5] RAPPENGLÜCK 2004. 93–119. The author has proven by computer modeling that the Stone Age depictions of stars and constellations reflect the temporal position of the celestial bodies in the past. The scientific analysis also indicates that the ancient pictures of constellations show seasonality and are related to certain celestial phenomena, as well.

[6] Above Egypt, the star Sirius rose together with the Sun during two months in the summer, so no appearance could be observed with naked eye. However, around 19th of July, Sirius rose ahead of the Sun, and the star was already visible before the first light of the Sun. The annual flood of the Nile also started in the middle of July, so the appereance of Sirius was an indicator of forthcoming flood.

[7] For the Egyptians, the appearance of Sirius was used not only to measure time, but also for orientation. Their temples were directed toward Sirius so accurately that the approximate date of church construction can be concluded from the deviation of the orientation of a temple. VÖRÖS 2007. 91–92. and 163–169

.

Monthly rhythm

In the daily life of people, the annual cycle was often too long, so a shorter, more practical time range was needed and defined by the periodic movement of the Moon. Depending on the particular comparison we make, we can talk about the following lunar cycles:

1. *Sideric*: from the same star to the same star. (27 days 7 hours 43 minutes 11 seconds.)
2. *Tropical*: from vernal equinox to vernal equinox, (27 days 7 hours 43 minutes 4.7 seconds.)
3. *Anomalous*: from perigee to perigee. (*Perigee* means the point in the orbit of the Moon at which it is nearest to the Earth.) (27 days 13 hours 18 minutes 33.1 seconds.)
4. *Draconic*: between two ascending nodes, that is when the Moon crosses from the south to the north of the ecliptic of the Sun. (27 days 5 hours 5 minutes 35.9 seconds.)
5. *Synodic* (lunation): from the same phase to the same phase of the Moon. (29 days 12 hours 44 minutes 2.9 seconds.)

As can be seen, though the lengths of different lunar cycles are not exactly the same, all of them are around 28 days.

The basics of chronology: counting of annual and monthly cycles, creating calendars

Note that, according to the above mentioned definitions, neither the determination of *sidereal* or *solar* year nor monthly rhythm needed the concept of number; it was enough to observe the characteristic points of the cycle of celestial bodies. However, around 5,500 BCE the first civilizations (the Sumerians in Mesopotamia, the Mayans in Peru, the indigenous peoples in Egypt, China and India) emerged from the nomadic lifestyle to the settled one, moving from harvesting to crop production.

The need for work organization, division of labor, and knowledge transfer led to the development of writing and counting. Wise men specialized in observing nature, finding sites for celestial observation, or building such sites to observe the celestial phenomena. They not only watched the astronomical events, but also tried to anticipate the future (*Fig. 1.*).

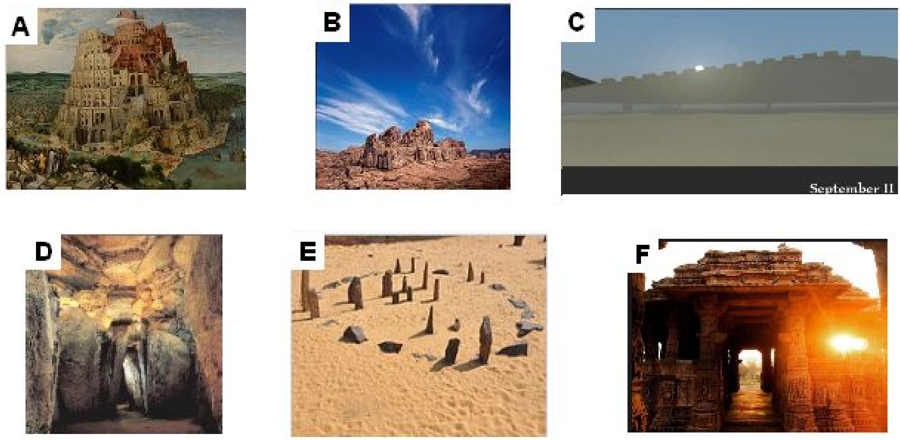


Figure 1: *Some ancient astronomical observatories. (A) The tower of Babel painted by Pieter Bruegel the Elder (ca. 1583). The original tower related in Genesis 11 is thought to have served as an observatory, as well. (B) Megalithic observatory in Kokino, Republic of Macedonia. (C) The Thirteen Towers, solar observatory built in the 4th century BCE at Chankillo, Peru. (D) Passage-grave in Newgrange, Ireland. The rising Sun enlightens the inner side of the cave solely at the winter solstice. (E) Reconstruction of a ca. 7,000 year old calendar circle of Nabta Playa, Egypt. (F) The ca. 3,000-year-old Sun Temple in Modhera, India. The rays of the rising Sun light the sanctum sanctorum inside solely during the days of the equinox. (Pictures from Wikipedia, the free encyclopedia.)*

The ancients were able to count the days (the alternation of daytimes and nights) in the solar and lunar cycles, and this knowledge was organized in calendars. We can say that as many civilizations have emerged, many calendars existed, and the presence of religious celebrations occupied an important place in the calendars. Calendars were usually based on a 28-day lunar cycle divided into 4 weeks. The days of the week were named (*Table 1*).

Table 1: **The calendar from the 1st century CE reconstructed from the Dead Sea Scrolls.** The first month of the year began at the Spring equinox (now called March.) The first day of the year was always Wednesday. The high days were on the same days every year. The first day of the quarters was also on the same days. One year consisted of 364 days (no information about compensation).

Days of week	MONTHS														
	I. IV. VII. X.					II. V. VIII. XI.					III. VI. IX. XII.				
Wednesday	1	8	15	22	29		6	13	20	27		4	11	18	25
Thursday	2	9	16	23	30		7	14	21	28		5	12	19	26
Friday	3	10	17	24		1	8	15	22	29		6	13	20	27
Saturday	4	11	18	25		2	9	16	23	30		7	14	21	28
Sunday	5	12	19	26		3	10	17	24		1	8	15	22	29
Monday	6	13	20	27		4	11	18	25		2	9	16	23	30
Tuesday	7	14	21	28		5	12	19	26		3	10	17	24	31

The lengths of artificial calendars did not coincide with natural time periods, in which case the difference was either ignored (e.g. Qumran calendar[8]) or the principle of 'unequal split + remnant' was applied. The *Julian* calendar, the ancestor of today's calendar, was introduced by *Julius Caesar* in 1st January 45 BCE. One 'normal' year had 365 days, and every three normal years were followed by a leap year with 366 days. However, as the solar year was somewhat shorter than 365.25 days (see above), the *Julian* calendar was always late compared with the solar one[9]. It was corrected during the time of *Pope Gregory XIII*, in October 1582 CE: 10 days were added to the date of the *Julian* calendar, and it was decided that the years that are exactly divisible by 100 are not leap years, except if they are exactly divisible by 400 at the same time.

In ancient times, cycles of more than one year were often developed, many of which were used in the Middle Ages, as well.

15-year *Indiction* cycle: this artificial cycle for collecting taxes and census was widespread in the Roman Empire and later in Europe.

19-year *Metonic* cycle: Moon phases recur on the same days of the *solar* year

28-year *solar* cycle: The leap day falls on the same day of the *solar* year (4 years x 7 days).

76-year *Callippic* cycle: after 4 consecutive *Metonic* cycles, with the days of *solar* year and *synodic* months coinciding.

304-year *Hipparchic* cycle: 4 times *Callippic* cycle. The proposal of the ancient Greek astronomer and mathematician *Hipparchus of Nicea* (190 BCE–120 BCE) has never been widely used.

532-year *Dionysius* or Easter period: 28 times *Metonic* cycles. The moon phases fall on the same day of the month and of the week, consequently the days of Easter are on the same days of the year.

The Mayan calendars are a good example how complicated calendars were able the ancient civilizations construct. The ancient Mayans used two kinds of calendars:

They had 365.242 days in a year in their civil calendar. (The bias increased 1 day only in every 5,000 year!) They had 1 year with the names of 18 months in it, 1 month with 20 days with both names and serial numbers (0–19), 1 week with 13 days with both names and serial numbers (1–13). This calendar had a 52-year repetition cycle.

[8] AMUSZIN 1986. 170–175.

[9] Some astronomical almanachs still give the days of the year according to the *Julian* calendar, too, as it may help with astronomical calculations.

The calendar for religion had 360 days in a year. (The first year of the calendar was the 3,114 BCE.)

1 K'in = 1 day
1 Winal = 20 K'in (20 days)
1 Tun = 18 Winal (360 days, 1 Mayan year, approx. 1 *solar* year)
1 K'atun = 20 Tun (7,200 days, or 20 Mayan years, approx. 20 *solar* years)
1 B'ak'tun = 20 K'atun (144,000 days, or 400 Mayan years, approx. 394 *solar* years)
1 Piktun = 20 B'ak'tun (2,880,000 days, or 8,000 Mayan years, approx. 7,885 *solar* years)
1 Kalabtun = 20 Piktun (160,000 Mayan years, approx. 157,704 *solar* years)
1 K'inchiltun = 20 Kalabtun (3,200,000 Mayan years, approx. 3,154,071 *solar* years)
1 Alautun = 20 K'inchiltun (64,000,000 Mayan years, approx. 63,081,429 *solar* years)[10].

Artificial division of days: the hours

The nomadic communities obviously noticed the different lengths of daytimes and nights, but there was no need for further subdivisions of time. Later agricultural communities, however, required shorter units of time to harmonize the communal work and the life of society. The uneven movement of the Earth resulting from its circulation and rotation around the Sun causes different lengths of daytimes and nights, and consequently different subdivisions of time (hours) of them during a year[11]. The civilizations divided the days into either 2x12 or 1x24 hours, the only question being: what should be the starting point of time measurement? In the Roman Empire the starting point of the daily time measurement was the disappearance of the Sun ("... *And the evening and the morning were the first day.*" *Genesis* 1:5). The Babylonians chose the sunrise, the Egyptians the *zenith* of the Sun (i.e. the shortest shadow of a stick on the Earth), the Greeks (*Hipparchus*) midnight[12] as the starting point.

[10] SCHALK 1993. It is interesting to observe that the Mayas used the powers of 20 in these cycles, which is very similar to the powers of two. However, the great numbers of the years were more like a game of numbers than a reflection of their excessive optimism.

[11] Today's modern solution: an average day equals 24 hours of equal numbers of minutes and seconds.

[12] In the Middle Ages, *Copernicus* (1473–1543 CE) also chose midnight as a zero point, which is especially interesting because it is the hardest to determine it exactly, as a midnight does not give so obvious signs like e.g. sunrise, sundown or the shortest shadow of a stick.

Ancient time measuring instruments

Two types of clocks were used to measure the hours: the sundial and the water clock. The oldest sundials engraved on stone come from the Valley of the Kings of Egypt and the Black Sea Culture in 14th–13th BCE. In Greek and then Roman times, the use of sundials became common for the timing of events and gatherings affecting the population. Even nowadays an octagonal building called the *Tower of the Winds*, made in the 2nd century BCE, can be seen in Athens, Greece, with traces of a sundial on each side along with the wall of the water cistern (*Fig. 2*.).

Figure 2: *Tower of the Winds clocktower in Athens, Greece. The tower had 9 sundials on the walls and a water clock inside driven by water flow from the Acropolis. (Photo: Herczeg, T.)*

Inside the tower a water clock was installed, fed by a stream. The stream gradually filled up a reservoir, converting the rise of water level to a time by using a pointer. The tank was emptied once a day at the same time by a responsible person and the measurement could start again. The water clock was used to refine the sundials and determine the time when the Sun was not visible.

The use of sundials and water clocks were so widespread in the Ancient Times that *Marcus Vitruvius Pollio*[13] wrote about their creation and function in his book published in the 1st century BCE (*Fig. 3.*).

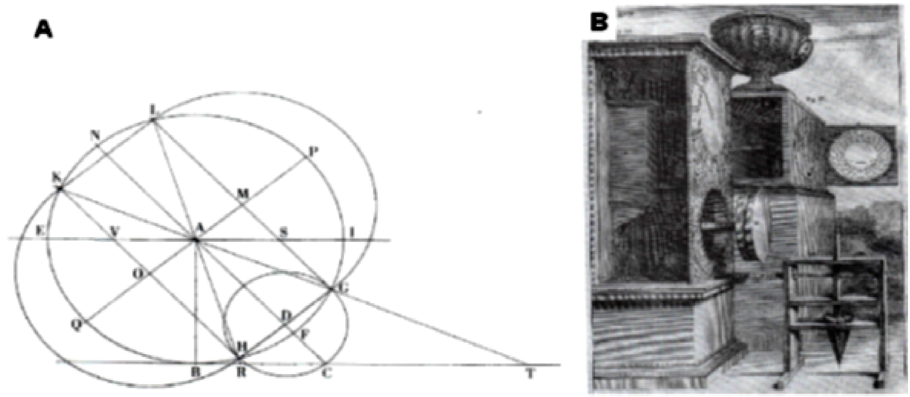


Figure 3*: (A) Geometrical scheme of the Meridian line and Gnomon-point of a sundial. A graphical procedure is given to determine the position of the shadow-casting stick (i.e. the gnomon in point* "*A*"*) and the projection of the North-South line (i.e. Meridian "AB" line). The 9:8 ratio of the length of the gnomon and its shadow in the original text corresponds to the place of Rome. (B) Drawing of a water clock from the 1st century BCE.*

Today, sundials are considered only as decorative elements of spaces and buildings, but they play a very important role in space research, as well. They help to identify and orient the objects viewed by the camera of a Mars rover or a Moon rover. Each rover has a built-in sundial that is always in the field of view of the camera, so it can be seen in every shot; using the time and direction of the shade of the *gnomon* of the sundial, viewers can accurately determine the exact direction of the vehicle's vision.[14]

[13] VITRUVIUS 2009. 192–199.

[14] See in details: http://www.scientificamerican.com/article.cfm?id=quottwo-worlds-one-sunquo and http://www.nasa.gov/jpl/msl/pia18390 [30.11.2018.].

A curiosity: "*The dials carry the word 'Mars' in seventeen languages, including Mayan and Sumerian, just in case the rovers were, through some strange accident, to return to earth via a wormhole and end up in 3000 BC.*" LENNOX-BOYD 2005. 126–127.

Conclusions

1. Since ancient times, people have been watching the periodic changes of nature.
2. The rhythm of nature is the basis of the time measurements of humanity.
3. The length of the days and the longer periods were determined by the movement of celestial bodies.
4. For periods shorter than a day, arbitrary units (hours, minutes) were created to harmonize the communal work and the life of society. To measure the artificial divisions of days sundials and water clocks were created.
5. It is complicated to harmonize the different traditional timelines, so even today, regular adjustments and corrections are needed.

References

AMUSZIN, I. D.: *The Dead Sea Scrolls and the Qumran Community*, [A Holt tengeri tekercsek és a qumrani közösség, *in Hungarian*] Gondolat, Budapest, 1986. 170–175.

LENNOX-BOYD, M.: *Sundials*. Frances Lincoln, 2005. 126–127.

LIPPINCOTT, K. (with ECO, U. – GOMBRICH, E. H. *et al.*): *The Story of Time*, [Az idő története, *in Hungarian*], Perfekt Gazdasági Tanácsadó, Oktató és Kiadó Részvénytársaság, Budapest, 2002.

RAPPENGLÜCK, M. A.: The Pleiades in the „Salle des Taureaux", Grotte de Lascaux. Does a Rock Picture in the Cave of Lascaux Show the Open Star Cluster of the Pleiades at the Magdalenian era (ca 5,300 BC)? *IVth SEAC Meeting* "*Astronomy and Culture*", 1997. 217–225.

RAPPENGLÜCK, M. A.: A Paleolithic Planetarium Underground – The Cave of Lascaux (Part 1), *Migration & Diffusion*, Vol. 5. No. 18. 2004. 93–119.

SCHALK, G.: *Times-Ages-Calendars*, [Idők-Korok-Naptárak, *in Hungarian*], TIT Uránia, Budapest, 1993.

SZALAY, K.: *Written rocks, painted caves. Art of Prehistory*, [Írott sziklák, festett barlangok. Őskorok művészete, *in Hungarian*], Kairosz Kiadó, 2012.

VÖRÖS, G.: *Egyptian Temple Architecture*, Kairosz Press, Budapest, 2007. 91–92. and 163–169.

VITRUVIUS: *The Ten Books on Architecture*, [Tíz könyv az építészetről, *in Hungarian*], Quintus Kiadó, Szeged. 2009. 192–199.

WILDGEN, W.: The Paleolithic origins of art, its dynamic and topological aspects, and the transition to writing. In: Eds. BAX, M. – VAN HEUSDEN, B. – WILDGEN, W.: *Semiotic Evolution and the Dynamics of Culture*, Peter Lang AG, European Academic Publishers, Bern, 2004. Ch. 7. 117–154.

Time Measurement in Ancient Times

The rhythm of nature on Earth is determined by celestial bodies, especially the orbit of the Sun. The rhythm of nature determined time for mankind, as ancient people were organized into communities, settled, and the division of labor emerged. The beginning of this process dates back to centuries after the 5th millennium BC, and can be followed for centuries afterwards. Subsequently, organized societies built celestial observation sites (e.g. in Mesopotamia, Egypt, the Mediterranean and Black Sea coasts, the British Isles, Central America), and the ancient wise men observed the move of the Sun, Moon and stars in these reference points. They recognized the recurring patterns and predicted their occurrence in the future. They determined the length of the Sidereal Year and the Lunar month, identified the days of solstice and equinox, the synodic period of Venus and the movements of constellations. Time-counting was included in calendars, and the concept of the year, the month and the week appeared in everyday life (see e.g. Code of Hammurabi, Dead Sea scrolls). The day was divided into smaller units, hours and minutes, and water clocks and sundials were constructed for their measurement. The ancient definitions were so basic and accurate that they were also applied in the Middle Ages by the mechanical astronomical clocks (see, for example, the Hanseatic Clock Family), and they are even the basis of recent time measurements and calendars.
Keywords: time-counting, sundial, calendar, ancient times, astronomy