Calendars from around the World

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- Introduction -

All human societies have developed ways to determine the length of the year, when the year should begin, and how to divide the year into manageable units of time, such as months, weeks and days. Many systems for doing this – calendars – have been adopted throughout history. About 40 remain in use today.

We cannot know when our ancestors first noted the cyclical events in the heavens that govern our sense of passing time. We have proof that Palaeolithic people thought about and recorded the astronomical cycles that give us our modern calendars. For example, a 30,000 year-old animal bone with gouged symbols resembling the phases of the Moon was discovered in France.

It is difficult for many of us to imagine how much more important the cycles of the days, months and seasons must have been for people in the past than today. Most of us never experience the true darkness of night, notice the phases of the Moon or feel the full impact of the seasons.

Ancient humans would have had good reasons for estimating the passage of time. The night brought risk and danger – for example, enemies and predators could approach unseen in the dark. Our ancestors were able to predict when sunset would occur by following the height of the Sun in the sky and the length of shadows. During bad or overcast weather, they also would have relied on the in-built biological clocks that provide an intuitive 'sense' of time.

Not every night is the same. For a few days each month, the Moon is near full and up for most of the night. The full Moon would have been ideal for nomads in hot climates that would only travel at night – providing enough light to allow them to navigate treacherous terrain. Farmers could work their fields long into the night under a bright Moon.

Growing, gathering and hunting food was a matter of survival for ancient civilisations. Their understanding of how the length of the day, the temperature and the rainfall changed with the seasons was crucial. Mistiming the migration of the caribou or losing a crop to frost would mean starvation. Keeping pace with the seasons became easier when people began making a tally of the number of days or the number of months that passed before the seasons began to repeat.

A rough idea of the length of the year is sufficient for a society to be able to feed itself. Remarkably, cultures as far apart as the megalith culture in Britain and pre-dynastic Egyptians (5500–3100 BCE) went to great trouble to determine the length of the year accurately.

By 4500 BCE (before the Common Era) the Egyptians had measured the length of the year as 365 days – a level of precision far beyond what is necessary for survival. This accuracy was driven by early religious beliefs where accurate calendars were developed to time-important events and festivals – a role they retain to this day.

Calendars are **social** constructs even though they have their roots in astronomy.

- The astronomical basis of calendars -

All calendars are based on astronomical cycles. The cycles are not constant in length and we cannot know about them to a high-enough level of accuracy to keep a calendar in synchrony with natural events over very long periods of time.

This makes calendars unreliable. Even direct observations made to maintain calendrical accuracy are themselves subject to error. For this reason calendars are usually based on rules designed to provide a good approximation to astronomical cycles over a period of time.

Day

From our vantage point on the surface of the Earth, the Sun rises along the eastern horizon and sinks below the western horizon.

Day and night occur because the Earth rotates on its axis in a westerly to easterly direction as viewed from above the North Pole. The time it takes for this to occur, i.e. the length of the day, depends on the reference point used to measure a single rotation.

The day length according to the Sun

From the perspective of an observer standing on the surface of the Earth, the sky appears to be an overarching hemisphere, one half of a celestial sphere across which all the heavenly bodies (Sun, Moon, planets and stars) move.

During the day, the observer will see the Sun climb in the sky during the morning and sink during the afternoon. The Sun is highest in the sky at local noon. For an observer in the northern hemisphere at local noon, the shadows cast by the Sun are at their shortest and point exactly due geographical north.

Measuring the length of the day using the movement of the Sun is called an apparent solar day. If our observer times exactly how long it takes for the shadows cast by the Sun to be at their shortest on two successive occasions, it will almost never be precisely 24 hours.

The difference in length between the shortest and longest apparent solar day can be as much as 16 minutes.

Apparent solar time records the rotation of the Earth with **respect to the Sun**. In the modern world, it would be difficult to organise our lives around a day length that is constantly changing. Instead, our clocks and watches measure a mean time that is based on the length of the apparent solar day averaged over the whole year. This is called the mean solar day and is 24 hours long.

Find out more about mean solar day in appendix 1.

Why does the **apparent solar day** differ in length from day to day? One reason is that the orbit of the Earth around the Sun is an **ellipse** and not a perfect circle but. Hence the distance of the Earth from the Sun changes over the year. (In January the Earth is closest to the Sun and in July it is furthest away.) The second reason is that the axis about which the Earth rotates is tilted so that the height of the Sun in the sky at local noon changes over the year – high in the summer and low in winter. These two factors conspire to alter the apparent speed with which the Sun moves across the sky at different times of the year, altering the day length.

The day length according to the stars

On a cloudless night we can see that the stars behave just as the Sun does during the day. They rise above the eastern horizon and move across the sky to sink somewhere in the west. At some time each star will reach its highest point in the sky as it crosses the local meridian. Astronomers can record the precise instant that a star transits the local meridian with a transit instrument. This is a telescope that is fixed so it only points along a narrow band of sky that coincides with the local meridian. The telescope can move in altitude and point at any star that becomes briefly visible in the narrow field of view.

The interval between two successive transits of a star is the length of the day measured by the stars. It is the time it takes the Earth to rotate to bring a star back to the same position in the sky it was on the previous night and is known as the sidereal day. The sidereal day lasts just over $23^h\ 56^m$. Because the sidereal day is shorter than 24 hours the stars rise four minutes earlier each night according to our watches. This is why we see different constellations in the night sky at different times of the year.

Months

The Moon orbits the Earth in a month. As it moves in its orbit we see it gradually change its position relative to the Sun and this alters the proportion of the Moons face that is illuminated as seen by an observer on the Earth's surface. This gives the phases of the Moon.

When the Moon is closest to the Sun in the sky, no part of it facing us is illuminated. This is a **new Moon**. We cannot see it except in the unlikely event that part or all of the Moon's disc moves in front of the Sun and creates a solar eclipse.

As the Moon moves away from the Sun a tiny sliver of its lit face becomes visible from Earth. This **waxing** (growing) crescent Moon is seen low in the western horizon just after sunset and itself sets not long after.

As the Moon continues in its orbit it moves further from the Sun in the sky. A larger fraction of the Earth-facing side is illuminated and it sets later. By day 7 the Moon is at **first quarter**, so called because it is one quarter of the way around its orbit, though it looks like a 'half Moon'. When the Moon has completed half of its orbit it is opposite the Sun in the sky so its entire lit side is facing us. This is a **full Moon**. It rises at sunset and sets at sunrise so it is up for the entire night.

The **waning** (shrinking) Moon looks the way it does because it is getting closer to the Sun. A embolden **quarter Moon** rises around midnight and is still high in the sky the next morning. The Moon is not just a creature of the night.

The length of the month reckoned according to the phases of the Moon, i.e. the time between one new Moon and the next, is called the **synodic month** and is very close to 29.5 days.

Years

All people living at mid- and high-latitudes experience the regular cycle of 4 seasons – spring, summer, autumn, and winter. At low latitudes, the tropics, the temperature does not change very much and there are wet and dry seasons. For ancient people, the progression of the seasons was critical for finding or growing food and would have motivated them to work out the lengths of the year and the seasons. Observing the position of the Sun and how its position changes in the sky with the seasons was one of the ways this problem was tackled. There is considerable archaeological evidence that this was undertaken independently by several cultures across the world in pre-historic times.

The seasons

To see how this works we need to explore what causes the seasons. The rotation axis of the Earth is tilted at an angle of 23.5° from the vertical. This angle is called the **obliquity**. As the Earth orbits the Sun over the year, first one pole then the other are tipped towards the Sun. This gives us the seasons, as shown in the animation below.

Summer solstice occurs on June 21 when the North Pole of the Earth is tilted at its maximum *towards* the Sun. This means the Sun will be directly overhead at latitude 23.5° north (the Tropic of Cancer) at local noon. On this day the Sun reaches its highest point in the sky for all observers in the northern hemisphere. Although astronomers regard this as the start of summer, the summer solstice is often called midsummer's day, reflecting the fact that this is the longest day of the year. It is hotter in summer than winter because when the pole is tilted towards the Sun its rays are more concentrated as they strike the Earth, and because the Sun is above the horizon for longer. For people in the southern hemisphere it is mid-winter at this time because the South Pole is tilted to its greatest extent *away* from the Sun.

The Earth orbits anti-clockwise as seen from above the North Pole and by about 22 September it arrives at the **autumn equinox**. This marks the start of autumn. At this time neither pole is tipped towards the Sun, which is overhead at the equator (latitude 0°) at local noon as seen from Earth. All places on the Earth experience 12 hours of daylight and 12 hours of night; indeed the term equinox means 'equal nights'. The autumn and spring equinoxes are the only two times when the Sun rises exactly due east and sets due west.

By **winter solstice** on 21 December, the North Pole is tilted furthest from the Sun, which is now overhead at local noon at latitude 23½ degrees south (the Tropic of Capricorn). The Sun rises to its lowest altitude above the horizon for northern hemisphere observers and this is the shortest day. For astronomers, winter solstice is the start of winter but it is often described as midwinter's day. The Sun's rays are spread out and the Sun is above the horizon for a shorter time in winter, which is why it is colder. Of course, people in the southern hemisphere experience summer when it is winter in the northern hemisphere.

Spring starts on the **spring,** or **vernal equinox**, which occurs around 21 March. As with the autumn equinox, days and nights are everywhere of equal length and the Sun is directly overhead at the equator at local noon.

It is common experience that the number of daylight hours changes during the year. In the UK we get many more hours of daylight in summer than in winter. However exactly how the number of hours of daylight and darkness we get each day alters during the year depends on latitude. Actually, for those at the equator there is no difference: days and nights are equal length throughout the year. For anyone living at the North Pole the Sun is above the horizon for exactly half the year when it is northern hemisphere summer, but never rises in northern hemisphere winter. This is reversed at the South Pole. At the poles day and night last essentially 6 months each. For latitudes between the equator and the poles, the difference between daylight hours and darkness at midsummer and midwinter increases towards higher latitudes.

The Sun's journey through the sky

The Sun follows a curved path through the sky over the course of the year. This is because of the tilt of the Earth. This path is termed the **ecliptic**. The position of the equinoxes are marked on the celestial sphere by where the ecliptic crosses the celestial equator — the equivalent of the Earth's equator on the celestial sphere.

At the spring equinox, the Sun crosses the celestial equator moving northward along the ecliptic as summer approaches for northern observers. At the winter equinox, the Sun moves south across the celestial equator and gets lower in the sky for northern observers and higher in the sky for southern observers who can look forward to their summer.

The year of the seasons

How long does it take to complete one cycle of the seasons? Defining the length of the year according to the seasons — has been central for the development of most calendars. Modern astronomy defines the year of the seasons or **tropical year** as the interval between two successive vernal equinoxes. The word 'tropical' comes from the Greek *tropos* meaning 'to turn' and refers to the fact that the Sun moves south to north and back during the course of the year of the seasons. There are a number of ways in which this can be calculated, and it varies over time due to gravitational pulls from other bodies in the solar system, but all methods of calculation agree that (to three decimal places) it is currently 365.242 civil days.

The sidereal year

The sidereal year is the time taken for the Earth to complete one orbit with respect to the fixed stars, and was equal to 365.2564 mean solar days in 2000. This means that over the course of a year an observer will be able to see every constellation of stars visible from his or her latitude.

The figure below shows how this comes about. Here the Earth is depicted in northern hemisphere summer; note how the North Pole is lit by the Sun. At this time an observer on the Earth could only see stars in direction 3 (e.g. the zodiacal constellation Scorpius) because these are on the night side. Stars in direction 1 are on the day side and hence invisible. Six months later when the Earth is on the opposite side of its orbit it will be northern hemisphere winter. Now stars in direction 1 (e.g. the zodiacal constellation Taurus) will be visible in the night sky but stars in direction 3 are only up during daylight hours. Stars in direction 2 (e.g. Leo) are seen in Spring, those in direction 4 (e.g. Pisces) in autumn.

We can think about this in another way. Because the sidereal day — the day length measured according to how the Earth rotates in relation to the stars — is shorter than 24 hours the stars rise four minutes earlier each night according to our watches. So:

- over 30 days the stars rise 4 x 30 = 120 minutes, or 2 hours, earlier
- over 12 x 30 days the stars rise 2 x 12 = 24 hours earlier.

Over the course of a sidereal year we see the entire panorama of the night sky visible from our latitude.

Several ancient civilisations, notably the Egyptians, Babylonians and the Greeks, have had calendars based on the stately amble of the constellations across the sky over the year. These are called sidereal (star) calendars.

Find out why the sidereal year is not the same length as the tropical year in appendix 2.

- Types of calendar -

There are three major types of calendar that have been used through history – solar, lunar and luni-solar. Sidereal (star) calendars have also been used, notably by the ancient Egyptians. Often more than one type of calendar is in use by a given society at the same time.

Solar calendars

Solar calendars are designed to keep in step with the tropical year so that the seasons occur at the same time each year over thousands of years. To construct a solar calendar the length of the tropical year must be known fairly accurately. This was first achieved by the Egyptians who, sometime just before 2050 BCE measured it as 365.25 days. Of course the extra quarter of a day raises a problem because it is not practical. The problem was solved by the **Julian calendar**, established in the Roman empire under Julius Caesar, by having three years of 365 days followed by one of 366 days, referred to as a **leap year**. However, even with the introduction of the leap year an error remains.

Adopting a calendar year of 365.25 days means that there is still a discrepancy between the length of the calendar year and the mean tropical year, which is only 365.24219 days long. The calendar year is 365.25 - 365.24219 = 0.00781 days – just under 11.25 minutes longer than the tropical year. This error does not sound very much but over time it builds up and after 1000 years, the seasons would be almost eight days earlier in the calendar year.

A solution was put in place through the calendrical reform undertaken by Pope Gregory XIII (1502–85) that lead to the **Gregorian calendar**, the major solar calendar in use today. In this calendar, the discrepancies are corrected by having century leap years *only* if they are exactly divisible by 400. This is called the **century rule**. Adopting the century rule means that the Gregorian calendar year is not 365.25 but 365.2425 civil days long. In the Common Era the century leap years are therefore in 400, 800, 1200, 1600, 2000, 2400 etc; i.e., over each 400 year period there is just one century leap year. An error of 0.00781 days in each Gregorian calendar year accumulates to 0.00781 x 400 = 3.124 days over 400 calendar years. During this time 3 century leap years have been omitted so the final error is 3.124 - 3 = 0.124 days in 400 calendar years. This amounts to just 0.124 x 86400/400 = 26.78 seconds per year. Hence the Gregorian calendar year is 26.78 seconds *longer* than the tropical year.

Lunar calendars

Lunar calendars are based on the idea that 12 synodic months of 29.5 day makes a year of 354 days. In the past, the first sighting of the young waxing crescent Moon just after sunset marked the start of each month. Today, tables predicting the first appearance of the crescent Moon are often used instead. Lunar calendars were developed by the ancient Hebrews, Romans, Celts and Germans. The Islamic calendar is the major lunar calendar in use today.

Since calendars cannot have half days, the 29.5-day length of the synodic month is accommodated by having 6 months with 30 days and 6 months with 29 mean solar days. Of course such a calendar runs fast against a solar calendar such as the Gregorian one by about 365.25 - 354 = 11.25 days. Hence lunar calendars are decoupled from the cycle of the seasons. Any particular day in a lunar calendar will appear 11.25 days earlier with respect to each successive Gregorian year, marching backwards through the seasons, making a complete cycle of the seasons in about 32.5 years in the Gregorian calendar.

Find out about the factors that affect the visibility of the new crescent Moon in appendix 3.

Luni-solar calendars

The fact that lunar calendars do not keep pace with the passage of the seasons has been regarded as a disadvantage. To overcome this many societies have a adopted a hybrid **luni-solar calendar**. These are lunar calendars which use various devices to bridge the missing 11.25 days so that the calendar year ends up close in length to the tropical year; the year of the seasons.

For example, the ancient Greeks used a lunar calendar of 354 days adding an extra 90 days every 8 years. This was calculated on the basis that 11¼ x 8 = 90 days.

An alternative method is to insert occasional **intercalary** synodic months in selected years. One method of choosing the number of intercalary months is the **Metonic cycle**. **It was calculated that** seven years, each consisting of thirteen synodic months, followed by twelve years of twelve synodic months (235 synodic months in all) lasts almost exactly 19 tropical years.

(7 x 13 x 29.5) + (12 x 12 x 29.5) = 2684.5 + 4248 = 6932.5 days;

6932.5 / 365.25 = 18.98 tropical years.

Hence it is necessary to insert 7 intercalary months over a period of 19 years.

The **Metonic cycle** is attributed to the Greek astronomer Meton of Athens, though it may have been invented by the Babylonians at around the same time, about 432 BCE.

Sidereal calendars

Probably all societies have devised constellations, patterns that help people make sense of the starry sky, often reflecting their mythologies. Modern-day astronomy recognises 88 official constellations that together tile the entire celestial sphere. Many of those in the northern part of the sky are inherited from Babylonian, Greek and Arabic civilisations.

As the Earth orbits the Sun, different constellations of stars come to dominate the night sky at different times of the year. This must have been noted by ancient people and indeed the ancient Egyptians, Greeks and Babylonians constructed **sidereal calendars** based on the movement of the stars.

- Calendars in history -

Egypt

The earliest timekeeping for which we have good evidence was Egyptian and the motivation for its development was religious.

The Sun god Ra was the pre-eminent deity early on. Egyptians noted the annual motion of the Sun *along* the horizon at sunrise (i.e. changes in azimuth, roughly speaking the compass bearing), including its most northerly and southerly excursions at the summer and winter solstices respectively. The south-easterly point on the horizon, where the Sun rose at winter solstice, was regarded as the birthplace of Ra. The Egyptians timed how long it took Ra to return to his birthplace, i.e., the interval between two successive winter solstices, as 365 days, sometime around 4500 BCE.

Egyptians predicted the time of sunrise (to determine the time at which offerings should be made to Ra) by watching for the rising of one of a series of 24 star patterns, each of which would herald the dawn for 15 days before being succeeded by the next. Stars move one degree westwards across the sky each apparent solar day *on average*, so 15 apparent solar days = 15O°; note that 24 x 15 = 360°, a full circle. The star pattern then served as a marker of the previous 1/24th increment of the day for 15 apparent solar days, and so on. Note that the decision to choose 24 star patterns established the **hour** as a unit of time.

A luni-solar calendar was developed in Lower (northern) Egypt to keep tally of when the all-important festival of the birth of Ra, at winter solstice, would occur. It had 12 months of 29 or 30 apparent solar days, the first beginning after the festival. It lasted 354 days. An intercalary month was inserted at the beginning every 2–3 years so that the year would be 365 days on average and the festival of the birth of Ra would always occur in the last month. Unusually, the Egyptians began their day with sunrise instead of sunset, and they began their month with the disappearance of the waning crescent Moon just before dawn.

Initially, in Upper (southern) Egypt the year was estimated by the time interval between two successive high water maxima on a nilometer. Later the Egyptians recognised that the annual inundation by the Nile always occurred just after the first appearance of Sirius (the brightest star in the sky situated in the constellation of Canis Major, the Great dog) just prior to sunrise, after an absence of about 70 days. This phenomenon is referred to as the **helical rising of Sirius** and the Egyptians realised that 365 (apparent solar) days elapsed between one heliacal rising of Sirius and the next. This seems to have allowed the Upper Egyptians to establish a sidereal calendar as early as 4241 BCE or 4236 BCE (depending on historical source).

Unification of Lower and Upper Egypt (around 3000 BCE) resulted in an easy merging of the calendars because the azimuth of sunrise at winter solstice was almost the same as the azimuth of the heliacal rising of Sirius about six months later around summer solstice. The heliacal rising of Sirius, rather than sunrise at winter solstice became the dominant marker for the passage of a year. The luni-solar calendar was calibrated by the heliacal rising of Sirius.

Eventually, probably before 2050 BCE, the Egyptians refined the measurement of the length of the year to 365.25 days, an estimate that would not be improved for another 3000 years!

Interestingly, the Egyptians divided their year into just three seasons of four months each, corresponding to: inundation (late June-late October), growth (late October-February) and harvest (February-late June).

Despite knowing that the year was actually 365.25 days the Egyptian priests, thinking that their calendar was too sacred to alter, refused to make the correction for the extra quarter of a day with the result that the luni-solar calendar was to drift with respect to the seasons, taking 1460 years to make a full cycle. This continued until Ptolemy III (238 BCE) instituted the introduction of a leap year every four years. Even so this edict was not properly complied with until 30 BCE when Rome conquered Egypt.

The complexities of the observationally determined luni-solar calendar meant that for everyday life the Egyptians developed a civil calendar with 12 months of 30 days preceded by 5 extra days giving a year of 5 + (12 x 30) = 365 days.

Megalith culture

The megalith culture of the beaker people which migrated from southern Spain, through France (Brittany) and into the British Isles around 3400 BCE saw farming overtaking hunter-gathering and the construction of a large number of stone structures, generally either circles or rows of standing stones or barrows. One of the earliest, Newgrange, a passage grave in the Boyne Valley in Ireland, built around 3300 BCE, has a 19 metre-long passage aligned with the rising Sun around the time of the winter solstice. However the alignment is not sufficiently tight to identify winter solstice precisely. Light enters through a hole in the roof (not the entrance, which was blocked off after the burials), so the alignment could not have been witnessed during the structures' working life. This strongly implies that it had a ritual not a calendrical purpose. (Winter solstice represents the birth of the new Sun in a number of civilisations, such as Egyptian and Roman.) Other Neolithic (New stone age) structures are also clearly aligned with the Sun (see Table 1)

Table 1 - solar alignments of Neolithic structures.

<table>
<tr><th>Structure</th><th>Alignment</th></tr>
<tr><td>Arminghall</td><td rowspan="2">sunset at winter solstice</td></tr>
<tr><td>Maes Howe</td></tr>
<tr><td>Newgrange</td><td>sunrise at winter solstice</td></tr>
<tr><td>Coneybury</td><td rowspan="2">sunrise at summer solstice</td></tr>
<tr><td>Phase 3 Stonehenge</td></tr>
<tr><td>Stonehenge cursus</td><td>equinox sunrise</td></tr>
<tr><td>Dorchester-on Thames cursus</td><td>sunset at summer solstice</td></tr>
</table>

However, early Bronze Age (about 3000 BCE) recumbent stone circles in north-east Scotland and standing stones in the west of Scotland have alignments which span the southerly limit of azimuth (90^{O} centred on SSW, as viewed from latitudes in northern Scotland) and corresponding declination for the setting Moon over the Metonic cycle. The limits to the range are the major standstills. Equivalently they correspond to the range of possible setting positions for the full Moon around the time of summer solstice, so the alignments do not prove that these Britons were aware of the Metonic cycle. The declination alignments are not accurate since the modes are -30^{O} and -19^{O}, but (ignoring the secular change in obliquity which can only amount to 0.3^{O}) they should be -28.5^{O} and -18.5^{O}, and the precision is also not remarkable at $\pm 1^{O}$.

The most spectacular megalith monument is Stonehenge on Salisbury plain in England. Phase 1 (constructed about 2950 BCE) was the earliest structure in the neighbourhood. It consisted of a circular ditch, inside which was a bank, and inside this is an array of 56 postholes (Aubrey holes). There were two entrances, one south, and one north-east which is aligned approximately with midsummer sunrise.

Phase 2 (in use between 2900–2550 BCE) was undoubtedly a timber structure although its exact form is not known. However the most ordered postholes are located at the north-east entrance and seem to define a series of walls that might have formed a corridor through which the midsummer Sun shone.

Phase 3 is the stone structure, erected in six stages, over a long time (2550–1600 BCE). It refines the alignment with sunrise at summer solstice, partly by the addition of the heel stone. Four other outer stones, the station stones, define a rectangle which specify the most northerly moonset and most southerly moonrise at major standstills. When the outer stones were incorporated into Stonehenge is not known.

Find out more about standstills in appendix 4.

Mesopotamia

Ancient Mesopotamia, located around the valleys of the Tigris and Euphrates rivers in modern Iraq, was divided into Sumer and Akkad. These were eventually unified into the Babylonian empire.

The ancient Sumerians (~3000 BCE) had a year of 12 months each of 30 days giving a year of 12 x 30 = 360 days. They divided each day into 12 periods (each equivalent to 2 hours), each further subdivided into 30 parts (equivalent to 4 minutes).

Ancient Babylonians adopted a lunar calendar in which the month began on the evening in which the crescent Moon was first sighted, or after 30 apparent solar days if bad weather prevented this.
By 2100 BCE this had been formalised into a fixed calendar based on 12 months alternating between 29 and 30 days. This gives a year of (6 x 30) + (6 x 29) = 354 days. A scheme for intercalating an extra month in three years of every 8 to synchronize the lunar calendar to the seasons was devised, but intercalary months were inserted irregularly or not at all, and in practise time keeping in Mesopotamia was a mess until the 5th century BCE.

During the reign of the King Nabonasser (traditionally dated between 747 and 734 BCE) Babylonian priest/astronomers discontinued their practice of first sighting of the crescent Moon to determine the beginning of a month. Instead, they returned to a fixed-length calendar that had 12 months of 30 days each, but with five days added at the end to make it a 365-day year. The same calendar was in operation in other cultures (e.g. the Egyptians) at around the same time. The Babylonian months were: Nisanu, Ayaru, Simanu, Du'uzu, Abu, Ululu, Tashritu, Arakhsamna, Kislimu, Tebetu, Shabatu, Adaru. New Year's Day was Nisanu 1.

The Babylonians divided the day into 24 equal divisions (presumably influenced by the Egyptians) because it fitted into their hexadecimal system (24 is exactly divisible by 6, and divides exactly into 360). Around 432–380 BCE the Babylonians adopted the Metonic cycle, which had 7 intercalary months every 19 years. The extra months were inserted into a year if its number divided by 19 gave the remainders 0, 3, 6, 8, 11, 14 or 17. The Babylonian calendar was the forerunner of the current Hebrew calendar.

Ancient China

Analysis of surviving astronomical records inscribed on oracle bones from the Shang Dynasty (around 1800–1200 BCE) shows that at least by the 14th century BCE the Chinese had a luni-solar calendar and had established that the solar year is 365.25 days and the synodic month is 29.5 days. From earliest times the beginning of the year was dated from the new Moon near the winter solstice. Various intercalation schemes were developed for the early calendars.

The insertion of intercalary months of 29 or 30 days at the end of a 12 month year was being done in accordance with the Metonic cycle (19 years with a total of 235 months during which 7 intercalary months were added) no later than 770–476 BCE, a century ahead of Meton.

By the 3rd century BCE, the above method of intercalation was gradually falling into disfavour, while the establishment of the **meteorological cycle** which divided the ecliptic into 24 **points** 15° apart (calculated on the basis of the mean longitude of the Sun until as late as 1644 CE) provided the basis for the intercalation method that would supersede it. It takes 15.218 days for the Sun to travel from one point to another, because the ecliptic is a complete circle of 360°, and the Sun needs 365.242 mean solar days (a tropical year) to finish this journey. Hence the Sun takes 2 x 15.218 = 30.44 days to go through two points. But since a synodic month is only 29.53 days there is a chance that a lunar month will contain no points. In this case an intercalary month of 29 or 30 days is inserted.

Initially calculations used *average* motions resulting from the cyclic relationships, but by the 7th century CE errors in the predicted and actual motion of the Moon resulting from this approximation were recognised and being corrected for.

Republican Rome

Early on (753 BCE) the Romans used a bizarre calendar with a year of 304 days split into 10 months; Martis, Aprilis, Maius, Junius, Quintilis, Sextilis, September, October, November, December. There were no weeks. The first, 7th and 15th days of each month were called kalends (origin of the word calendar), nones, and ides respectively. These corresponded roughly to first crescent waxing Moon, first quarter Moon and full Moon. Days of the month were named for how many days it fell before kalends, nones or ides.
In about 700 BCE two extra months, Januarius and Februarius, were added to the *end* of the year to make a year with 12 months in which the number of days in a month in which no intercalary adjustments were made were probably as follows: Martis (31), Aprilis (29), Maius (31) Junius (29), Quintilis (31), Sextilis (29), September (29), October (31), November (29), December (29) Januarius (29), Februarius (28), giving a year of 355 days. Intercalary corrections were attempted to maintain synchrony with the tropical year.
In theory this consisted of the insertion of an intercalary month (Intercalans or Mercedonius) lasting 27 or 28 days, alternately every two years, after February 23 (since February was the last month of the year) and dropping the last five days of February. This give a year length averaged over 4 years of [355 + (350 + 27) + 355 + (350 + 28)]/4 = 366.25 days. However intercalary adjustments were often manipulated for political advantage rather than for proper time keeping, i.e. the authorities responsible for organizing the calendar (Pontifex Maximus and College of Pontiffs) would make intercalary adjustments to keep favoured officials (magistrates) in power for longer, or to reduce the term served by an official who was out of favour with the authorities.

Julian calendar

The Julian calendar was instituted by Julius Caesar in 46 BCE to prevent corrupt manipulation of the calendar. It used the Egyptian calendar adopted by Ptolemy III in 238 BCE. This was a solar calendar with a year of 365.25 days, the extra quarter day being taken care of by having a leap year every 4 years. In fact, this calendar was not strictly adhered to by the Egyptians who tended to approximate the year to 365 days.

The Julian calendar was brought into synchrony with the seasons by having 46 BCE last 445 days, with 25 March as the vernal equinox, and the beginning of the year moved from 1 March to 1 January. The months of Quintilius and Sextilius were renamed Julius and Augustus respectively and the number of days in each month became what they are today. In 128 years, the Julian calendar accumulates an error of almost one extra day compared to the tropical year.

Medieval Christian calendar

The medieval church used a Julian year of 365.25 days despite astronomy showing that this produced an annual error of 11 minutes with respect to the tropical year. This meant that every 128 years, Easter (tethered to the vernal equinox, since — roughly speaking — it is defined as the Sunday after the full Moon that follows the vernal equinox) slipped one day with respect to the seasons. In addition, cultural differences in dating Easter arose because the Egyptian luni-solar calendar had 21 March as the vernal equinox, while the Julian luni-solar calendar had 25 March.

Constantine instituted the seven-day week (with Sunday as the first day) that had been introduced by the Babylonians around 700 BCE. Days of the week were named after objects in the solar system and the order comes from Mesopotamian *astrology*.

Table 2 - how the days of the week were derived.

Body	**Roman**	**Italian**	**Anglo-Saxon**	**English**
Sun	Sol	Domenica	Sun	Sunday
Moon	Luna	Lunedi	Moon	Monday
Mars	Martus	Martedi	Tiw	Tuesday
Mercury	Mercurius	Mercoledi	Woden	Wednesday
Jupiter	Jove	Giovedi	Thor	Thursday
Venus	Venere	Venerdi	Freya	Friday
Saturn	Saturnius	Sabato	Saturn	Saturday

Gregorian calendar

Pope Gregory XIII (1502–85) finally supported calendar reform that had been sought for centuries by astronomers. The reform was devised by the physician Aloysius Lilius.

Reform of the calendar took the best estimate for the length of the tropical year as $365^d\ 5^h\ 48^m\ 20^s$, kept the Julian calendar solution of leap years but, recognising that this amounted to a difference of 3 days every 402 years with respect to the Julian year of $365^d\ 6^h$ it adopted the century rule: drop the leap year in 3 out of 4 century years; i.e. only insert a leap year if the century year is exactly divisible by 400.

The lunar and solar components of the medieval Christian calendar had drifted because 19 tropical years is $1^h\ 27^m\ 30^s$ longer than 235 synodic months. Hence the Moon's phases had slipped backwards with respect to the tropical year at a rate of 1 day every 312.7 years. This produced difficulties in dating Easter, which depends on when the first full Moon occurs after the spring equinox. The reform was based on the fact that 8 x 312.7 is very close to 2500 which itself is seven lots of 300 plus 400, i.e., (7 x 300) + (1 x 400). This mathematical sleight of hand means that the drift of the Moon's phases against the seasons can be all but eliminated by dropping eight days, one every 300 years seven times, then another after a further 400 years.

Finally, ten days were removed from the calendar to return the vernal equinox to March 21, its supposed date at the council of Nicea in 325 CE.

The reforms were initiated in 1582 but were implemented slowly, facing resistance by Protestant countries. Britain was one of the last to adopt the Gregorian calendar, finally doing so in 1752. Eleven days in total (3–13 September) were expunged (the extra day because 1700 had not been a leap year according to the century rule).

- Calendars today -

Gregorian calendar

The Gregorian calendar/Calendars in history is the calendar used throughout the Christian world. It is also adopted as the calendar for commercial and administrative purposes in many other parts of the world where it runs alongside other calendars used for religious purposes. It is a solar calendar.

In the Gregorian calendar, years are counted from the birth of Christ which was determined to be in 1 AD (*Anno Domini*; in the year of our Lord) by the 6th-century scholar Dionysius Exiguus. Unfortunately the English historian Bede introduced a system of counting years backwards from 1 AD in which the preceding year was 1 BC (Before Christ) rather than zero. This is awkward when trying to compare dates across the divide. In the 18th century astronomers introduced the year zero so that 1 AD is +1, 1 BC is 0, 2 BC is -1 and so on. Because the Gregorian calendar is often used in non-Christian countries it is now commonplace to replace AD with CE (Common Era) and BC with BCE (Before the Common Era). Ironically, Jesus of Nazareth was actually probably born about 4 BCE.

There are two types of year in the Gregorian calendar, common years of 365 civil days and leap years of 366 days. Every year that is exactly divisible by 4 is a leap year except if it is exactly divisible by 100. These century years are leap years only if they are exactly divisible by 400.

Hence the Gregorian calendar is based on a cycle of 400 years, or 146097 days. Since 146097 is exactly divisible by 7 – the number of days in a week – the Gregorian calendar repeats every 400 years. Dividing 146097 by 400 gives an average of 365.2425 days per calendar year. This is very close to the length of the mean tropical year of 365.24219 civil days.

Find out more about the mean tropical year in appendix 5.

The order of the months and number of days in each month are inherited from the Julian calendar (Table 03) and the days of the week were originally derived from the Babylonians

Table 3 - months of the Gregorian calendar

Month	**Days**	**Month**	**Days**
January	31	July	31
February	28*	August	31
March	31	September	30
April	30	October	31
May	31	November	30
June	30	December	31
*In a common year; February has 29 days in a leap year.			

Cultural notes

(i) Easter day, the most important day in the Christian religious calendar which celebrates the resurrection of Christ, is a moveable feast which, to a first approximation, falls on the Sunday after the first full Moon on or after the vernal equinox. Thus the calendar year has to be synchronized with the tropical year as measured by the interval between vernal equinoxes.

Actually, dating Easter is rather more complex than implied above. Firstly, the church assumes that the vernal equinox occurs on March 21, which is not always the case. Secondly, the church uses tables based on the Metonic cycle to determine the time of the full Moon and this *ecclesiastical* full Moon need not correspond to astronomical full Moon. Moreover the Metonic cycle is not a perfect match between synodic months and Gregorian calendar years; 235 synodic months is 6939.688 days rather than 6939.6075 days (19 Gregorian calendar years). Hence 19 calendar years slip 0.08 days with respect to lunar phases. Ecclesiastical tables incorporate adjustments to prevent this error accumulating in the long term.

(ii) All the other moveable feasts in the Christian calendar (except Advent and Epiphany) are determined with respect to Easter.

(iii) Christmas celebrates the birth of Christ. It is fixed on December 25, a date borrowed by the early Christian church from the Roman festival '*Natali Invictus Solis*' (Birth of the New Sun) in the Julian calendar. It commemorated the winter solstice but was four day late because of the incorrect timing of the vernal equinox in the Julian calendar.

Hebrew calendar

The Hebrew calendar is a luni-solar calendar that is both the calendar of the Jewish religion and the official calendar of Israel. Derived from the Babylonian calendar, its present form was established by Sanhedrin president Hillel II in 359 CE.

In the past each month was heralded by the sighting of the first crescent moon in the western sky at sunset. However in modern times the beginning of the month is calculated by extrapolating from the new moon that started the calendar, which occurred $5^h\ 11^m\ 20^s$ after sunset on Julian day 6 October 3761 BCE, by adding the required number of synodic months reckoned at 29.530583 days (i.e., $29^d\ 12^h\ 44^m\ 2.4^s$). The approximately 11.25 day drift against the tropical year is corrected by adding an intercalary month of 30 days (Adar II) in accordance with the Metonic cycle so that intercalations are made if the year number divided by 19 gives the remainders 0, 3, 6, 8, 11, 14 or 17. The current 19-year cycle began in the Jewish year 5758 AM (*Anno Mundi*; year of the world), which began on 2 October 1997 in the Gregorian calendar. The Jewish day starts at sunset. Traditionally, days of the week have numbers rather than names, except for the seventh day, Sabbath, which starts at sunset on Friday and ends at sunset on Saturday.

Calculating the length of the year is complicated in the Jewish calendar. The first day of the solar year occurs on 1 Tishri (Rosh Hashanah). However the interval between two successive 1 Tishri can take any one of six values.

Table 4 - year lengths in the Jewish calendar

Year type	**Year length/days**		
	Deficient year	Regular year	Complete year
non-leap year	353	354	355
leap year	383	384	385

A regular year has alternating months of 29 and 30 days. A deficient year is made by removing one day from the third month (Kislev), and a complete year is made by adding one day to the second month (Heshvan).

The year length is determined by a set of four rules:

1. If the new moon occurs after noon, delay the new year by one day.
2. If the new year starts on a Sunday, Wednesday or Friday, delay the new year by one day (this avoids

Yom Kippur (10 Tishri) falling on a Friday or Saturday, and Hoshanah Rabba (21 Tishri) falling on Saturday (the Jewish Sabbath).
3. If two consecutive 1 Tishri are 356 days apart (an illegal year length), delay the start of the first year by two days.
4. If two consecutive 1 Tishri are 382 days apart (an illegal year length), and the first year starts on a Tuesday, delay the start of the second year by one day.

The Jewish calendar has a second new year, on 1 Nissan, which the start of the lunar calendar. This is why in leap years the intercalary month, Adar II, is inserted immediately before Nissan.

Table 5 - the structure of the Jewish calendar

Month	Deficient year	Regular year	Complete year	Festivals	Gregorian equivalent
Tishri	30	30	30	Rosh Hashanah (1), Yom Kippur (10)[1], Sukkot (15–21) Hoshanah Rabba (21), Shemini Atzeret (22–23), Simchat Torah (23)[2]	Sep/Oct
Heshvan	29	29	30		Oct/Nov
Kislev	29	30	30	Hanukkah (25 Kislev–2 Tevet)[3]	Nov/Dec
Tevet	29	29	29		Dec/Jan
Shevat	30	30	30		Jan/Feb
Adar/Adar I*	29/30	29/30	29/30	Purim (14/15)[4]	Feb/Mar
Adar II*	30	30	30		Mar/Apr
Nissan	30	30	30	Pesach (15–21in Israel, 15–22 elsewhere)[5]	Mar/Apr
Iyar	29	29	29		Apr/May
Sivan	30	30	30	Shavuot (6)[6]	May/Jun
Tammuz	29	29	29		Jun/Jul
Av	30	30	30		Jul/Aug
Elul	29	29	29		Aug/Sep
Total (non-leap)	353	354	355		365
Total (leap)	383	384	385		366

*The month Adar II is only present in leap years which consequently have 13 months. In leap years Adar I is 30 days long. In non-leap years (which have 12 months) Adar I is simply called Adar and has 29 days.

Cultural notes

(i) To ensure that no work is done on the Sabbath, Havdallah, the ceremony to mark the end of Sabbath is not done at sunset but when three medium magnitude stars should be visible.
(ii) Julian day 6 October, 3761 BCE is the date of the creation of the world according to Judaic mythology.
(iii) Numerous important events in Jewish history are commemorated in the Jewish calendar:

1. Yom Kippur, the Day of Atonement, is the most important day in the Jewish calendar.
2. Simchat Torah celebrates completion of the annual cycle of readings from the Torah.
3. Hanukkah celebrates the rededication of the Temple after the victory of the Maccabees over the Greeks.
4. Purim celebrates salvation from the genocide instigated under Persian rule. In leap years Purim is celebrated in Adar II.
5. Pesach is the Passover that celebrates the Exodus from Egypt and the start of the harvest season.
6. Shavuot celebrates receiving the Torah.

Islamic calendar

The Islamic calendar is the archetypal lunar calendar consisting of 12 synodic months, each of 29.5 days, giving a year of 354 days. It is 11.25 days shorter than the tropical year. Each month starts with the first naked eye sighting of the crescent Moon (*Hilal*). Since this depends on a variety of factors printed calendars are based on estimates of the sighting. Calculations which estimate when the crescent Moon will be visible by taking into account the astronomic factors which determine its visibility ensure the precision of these calendars.

Since it is not possible to have half days, a year of 354 days is achieved by having odd months of 30 days and even ones of 29 days, which gives each month an average length of 29.5 days. Because the synodic month is actually a little bit longer than 29.5 days, an extra day is added to the 12th month in leap years. Leap years are those in which dividing the year number by 30 gives remainder 2, 5, 7, 10, 13, 16, 18, 21, 24, 26 or 29. This gives a calendar with average month length 29.53056 days, quite close to the synodic month. The years are numbered with Islamic Year 1 corresponding to 622 CE. Islamic New Year 1425 started on 22 February 2004 in the Gregorian calendar.

Not all Islamic countries use the first sighting of the crescent Moon to signal the start of the month. In Saudi Arabia and Egypt the beginning of the month is fixed by the relative timing of sunset and moonset on the 29th day of each month. If the Moon sets before the Sun the next day is the 30th of the month. If the Sun sets before the Moon (by at least 10 minutes in Egypt) the next day is the first of the next month.

Table 6 - months of the Islamic calendar

Month	Days	Month	Days
1. Muharram	30	Rajab	30
2. Safar	29	Sha'ban	29
3. Rabi Al-Awwal	30	Ramadan	30
4. Rabi Al-Thani	29	Shawwal	29
5. Jumada Al-Ula	30	Zul Qida	30
6. Jumada Al-Thani	29	Zul Hijja*	29
* Zul Hijja has 30 days in a leap year.			

Cultural notes

(i).The Islamic Year 1 or 1 AH (*Anno Higerae*) is the year of Mohammed's migration from Mecca to Medina.
(ii). During Ramadan Muslims (with some exceptions; e.g. the seriously ill, travellers) are required to refrain from eating, drinking, smoking and sexual relations between sunrise and sunset.

(iii). Eid al-Fitr, the feast which breaks the Ramadan fast is on the first day of Shawwal.

Indian calendars

Three major types of calendar operate in parallel in India (aside from the Islamic calendar used by Indian Muslims); the Gregorian calendar which is the default calendar for non-religious purposes, an Indian National calendar meant for civil purposes but mainly used in government, and a variety of Hindu religious calendars.

The Indian national calendar was established by the Indian Calendar Reform Committee in 1957 CE. It is essentially Gregorian in structure although:

- months are named after the traditional Indian months and are offset from the beginning of Gregorian months
- years are counted from the Saka Era; 1 Saka is considered to begin with the vernal equinox of 79 CE, so the year 2000 in the Gregorian calendar was 1921 in the Indian National calendar.
- the reformed Indian calendar began with Caitra 1 in the Saka year 1879, which corresponds to 22 March 1957 CE.

As in the Gregorian calendar, normal years have 365 days and leap years have 366. In a leap year, an intercalary day is added to the end of Caitra. To determine leap years, first add 78 to the Saka year. If this sum is evenly divisible by four, the year is a leap year, unless the sum is a multiple of 100. In the latter case, the year is not a leap year unless the sum is also a multiple of 400.

Table 7 - Indian National civil calendar

Civil month	Length / days	Gregorian date of the first day in the Indian month
1. Caitra*	30	22 March
2. Vaisakha	31	21 April
3. Jyaistha	31	22 May
4. Asadha	31	22 June
5. Sravana	31	23 July
6. Bhadra	31	23 August
7. Asvina	30	23 September
8. Kartika	30	23 October
9. Agrahayana	30	22 November
10. Pausa	30	22 December
11. Magha	30	21 January
12. Phalguna	30	20 February
* In a leap year, Caitra has 31 days and Caitra 1 coincides with March 21.		

Hindu religious calendars have deep roots. Evidence for a luni-solar system with intercalary months operating in India can be found in the Rig Veda (one of the four Hindu sacred texts, a collection of 1082 hymns) dating from the 2nd millennium BCE. This was standardised in the *Surya Siddhanta* in the 3rd century CE and subsequently underwent several reforms and evolved into a number of regional variants.

The Calendar Reform Committee took one of the regional Hindu calendars (the Vikram calendar) and attempted to harmonise it with modern astronomical methods of timekeeping to produce the *Rashtriya Panchang*, which was intended to be a standard Hindu calendar. Astronomical calculations of solar and lunar position are made not with respect to Greenwich but to Longitude 82°30' E, Latitude 23°11' N, located in Madhya Pradesh. The Hindu calendar is complicated because it consists of a solar and a lunar calendar running side by side. The solar calendar is used for birth dates, for determining children's names and other astrological purposes, while the lunar calendar is used to date the numerous religious festivals.

The solar calendar has 12 **solar months**, based on the sun's position with respect to the fixed stars at sunrise. (Solar days are reckoned from sunrise to sunrise.) A solar month is defined as the interval required for the Sun's apparent longitude to increase by 30°, corresponding to the passage of the Sun through a zodiacal sign. Vedic zodiac signs (sun signs or *Rashi*) correspond to astrological zodiac constellations in the west and both are thought to have been derived from the Sumerians. The first month of the year, Vaisakha, begins when the true longitude of the Sun is 23°15'. Because the Earth's orbit is elliptical, the lengths of the months vary from 29.2 to 31.2 days, with the short months in the second half of the year around perihelion when the Earth is closest to the sun.

Table 8 - Indian solar calendar

Solar month	Sun's longitude / °	Duration / days	Gregorian date of day one in the Indian month
1. Vaisakha	23 15	30.9	13 April
2. Jyestha	53 15	31.3	14 May 14
3. Asadha	83 15	31.5	14 June 14
4. Sravana	113 15	31.4	16 July 16
5. Bhadrapada	143 15	31.0	16 August
6. Asvina	173 15	30.5	16 September
7. Kartika	203 15	30.0	17 October
8. Margasirsa	233 15	29.6	16 November
9. Pausa	263 15	29.4	15 December
10. Magha	293 15	29.5	14 January
11. Phalguna	323 15	29.9	12 February
12. Caitra	353 15	30.3	14 March

The ancient Vedic calendar once started with the spring equinox in Margasirsa. Since it now occurs in Caitra this suggests that the calendar was established in the seventh millennium BCE, because a four-month shift corresponds to one third of the cycle of the precession of the equinoxes; 25,800 / 3 = 8600 years.

Lunar months are usually measured from one new moon to the next, although in some northern states each month begins with the full moon. The first day of the lunar calendar is on the new moon in Kartika and is the start of Divali. Because most lunations are shorter than a solar month, occasionally two new moons occur in a solar month. A year containing such a solar month has 13 lunar months, one of which is intercalary. Intercalary months occur every two or three years following Metonic or more complex lunar phase cycles. More rarely a year will occur in which a short solar month will not include a new moon. These are termed decayed months and can occur only near perihelion. However a month around the preceding aphelion will have had two new moons, so the year will still have 12 lunar months.

Each lunation is divided into two *pakshas*, each of 15 lunar days (*tithis*). The *paksha* in which the moon is waxing is called the light half of the moon and the *paksha* of the waning moon is the dark half of the month. Each lunar day (*tithi*) is defined by the time required for the longitude of the Moon to increase by 12^{O} over the longitude of the Sun. This means that the length of a lunar day may vary from about 20 hours to nearly 27 hours. Lunar days are numbered 1 to 15 when the moon is waxing and 1 to 15 again when the moon is waning. Each civil day is assigned the number of the lunar day in effect at sunrise. Occasionally a short lunar day will begin after sunrise and be completed before the next sunrise, in which case a number is omitted from the lunar day count. Alternatively a long lunar day may span two sunrises, in this case the lunar day number is carried over to the next civil day.

Cultural notes

(i) The first day of Caitra is the beginning of the year in the National calendar and corresponds roughly to the spring equinox.
(ii) Divali (Festival of Lights) is a five-day festival that starts at the beginning of the lunar year in Kartika (October/November in the Gregorian calendar). Diyas (clay lamps) are lit to celebrate the victory of righteousness over spiritual darkness.
(iii) Holi (Festival of Colours) is a festival to celebrate the arrival of spring which falls on the day after the full moon in Phalguna (March in the Gregorian calendar). It is a joyful celebration. Bonfires are lit on the eve of Holi to commemorate a Hindu myth.

Chinese calendar

The Gregorian calendar is used in the Peoples' Republic of China for administrative and commercial purposes but the traditional Chinese calendar, which is a luni-solar calendar, is used for religious purposes and for agriculture. Astronomical calculations for the Chinese calendar are based on Latitude 120^{O} E.

The traditional Chinese calendar resembles the Hebrew calendar in having ordinary years with 12 months and 353, 354, or 355 days, and leap years with 13 months and 383, 384, or 385 days. Days are measured from midnight to midnight. The first day of the month is the date of the new Moon (not the first visible crescent used in the Islamic and Hebrew calendars). The tropical year is divided into 24 solar terms, each of which spans 15^{O} of solar longitude, which are given names that refer to the seasons or weather.

The solar terms are arranged in pairs each consisting of a Sectional solar term (Jeiqi) and a Principal solar term (*Zhongqi*). Each pair covers 30° of solar longitude. In other words, principal terms divide the ecliptic into 12 30° increments. The months of the Chinese calendar are numbered by the principal term that falls within it. The calendar is adjusted to ensure that the principal term for winter solstice always falls in month 11.

Rarely a month has two principal terms, in which case the numbering of the months may have to be adjusted to ensure that principal term 11 (winter solstice) falls in the 11th month.

Leap years have 13 months. To determine if a year is a leap year the number of new Moons between the 11th month in one year and the 11th month in the following year are calculated. If there are 13 new Moons from the start of the 11th month in the first year to the start of the 11th month in the second year, a leap month must be inserted. In leap years, at least one month does not contain a principal term. The first such month is the leap month.

Table 9 - principal terms in the Chinese calendar

Principal term	Sun's longitude / °
1	330
2	0 (vernal equinox)
3	30
4	60
5	90 (summer solstice
6	120
7	150
8	180 (autumn equinox)
9	210
10	240
11	270 (winter solstice)
12	300

One of the problems of the traditional Chinese calendar is that it was developed on the assumption that the motion of the Sun along the ecliptic is uniform. Although the rules for keeping the calendar in synchrony with the seasons work most of the time, discrepancies can arise.

Unlike most other calendars, the Chinese calendar does not count years in an infinite sequence. Instead years have names that are repeated every 60 years, corresponding to five repeats of the Chinese zodiac cycle of 12 animals (in sequence they are: rat, ox, tiger, hare, dragon, snake, horse, sheep, monkey, rooster, dog, pig). This system for naming years has been in use for about the last 2000 years, but is traditionally extrapolated back to 2637 BCE when the calendar was supposed to have been invented. The current 60-year cycle started on 2 February 1984. However a counting system is also now in use which has year 1 as the first year of the Yellow Emperor in 2698 BCE. In this system 2005 is 2698 + 2005 = Chinese year 4703. 9 February 2005 was the start of the year of the Rooster.

- Appendices -

Appendix 1

Mean solar day

The length of the mean solar day is actually about 86400.002 seconds or 2 milliseconds longer than 24 hours. The mean solar day was exactly 24 hours in 1820 but the gradual slowing of the Earth's rotation rate due to the braking action of the tides now means it is slightly longer. Time measured by precise astronomical observations in this way is called Universal Time (UT) and clearly suffers from irregularities in the Earth's motion.

To overcome this, our watches keep a 24 hour civil (calendar, ephemeris) day and since 1964 CE this civil time has been based on Coordinated Universal Time (UTC), kept by atomic clocks which can be accurate to one second in six million years! Leap seconds are occasionally added to UTC so that it is always within 0.9 seconds of UT. This ensures that our civil time keeps pace with time given by the motion of the Earth upon which our calendars ultimately depend. It might seem bizarre to do this by adjusting the uniform, precise time given by atomic clocks, but we have no way to alter the Earth's rotational speed to match the atomic clocks!

Appendix 2

Why the sidereal year is not the same length as the tropical year

It turns out that the rotation axis of the Earth does not point in the same direction for all time but slowly describes a cone — just as a child's spinning top wobbles as it slows down — over a period of 25 800 years. This is called precession and it causes the vernal equinox to move westwards along the ecliptic by 50 arcsec every year. (One arcsecond is a very small angle amounting to 1/3600th part of a degree.) This accounts for the tropical year being about 20 minutes shorter than the sidereal year. It has taken the vernal equinox from the constellation of Aries in ancient times (hence the vernal equinox is sometimes referred to as the First Point of Aries) into Pisces (at about year 1 of the Common Era; i.e. 1 CE) and it is now close to Aquarius.

Appendix 3

Factors affecting the visibility of the new crescent Moon

In lunar calendars the precise time for the start of the month is variable if it is based on direct first sighting of the crescent Moon because this is influenced by a number of factors, of which the weather is the most obvious. The contrast between the young crescent Moon and the dusk sky in which it sits is very low and, of course, the Moon is just the merest sliver so is hard to see. Even modest levels of haze are enough to obscure it.

Elongation

The most important astronomical factor in determining how easy it is to see the young Moon is how far away it is from the Sun in the sky. This is expressed as an angular distance called the elongation by astronomers. Immediately after the new Moon, its elongation can be anything between 0° (following a solar eclipse) to 5°, because the orbit of the Moon is inclined at 5° to the orbit of the Earth.

How rapidly elongation increases depends on the angular speed of the Moon across the sky. The angular speed can vary by as much as 22%. It is determined by the position of the Moon in its elliptical orbit (it is fastest at perigee and slowest at apogee) and the Earth-Moon distance (the greater the distance the lower the angular speed). These factors ensure that when the Moon is 24 hours old its elongation is between 10° and 15°.

Elongation is a major factor in determining the visibility of the crescent Moon because its width is proportional to the square of the elongation. Hence, as its angular distance from the Sun increases we see more of the Sunlit face of the Moon, so it gets brighter. The contrast between the brightness of the twilight sky and the lunar crescent increases with elongation. The outcome is that the earliest reliable sighting is around elongation of 10°; i.e., a one day old Moon.

Atmospheric refraction

Light from any celestial object is bent by the Earth's atmosphere before entering our eyes. The bending of light in this way is called refraction. It is most dramatic near the horizon where the thickness of atmosphere is greatest. Atmospheric refraction can advance the sighting of the crescent Moon but it is variable, since it depends on atmospheric temperature and pressure, and these produce the greatest variations near the horizon. Hence refraction decreases the precision with which we can predict the rising or setting of celestial bodies such as the crescent Moon.

Location

Longitude determines the time at which the crescent Moon can be seen. Observers to the east of the Prime Meridian at Greenwich experience dusk earlier than those to the west. On some occasions this may give easterly observers the opportunity to catch the young Moon earlier, but on others it will be too young for them to see it and it will be left to westerly observers, for whom dusk is later and the Moon several hours older, to make the first sighting.

Latitude alters the visibility by changing the altitude of the Moon above the horizon for a given elongation. The reason for this is that the path of the Moon across the sky is always quite close to the ecliptic and the angle between the ecliptic and the horizon gets steeper at lower latitudes. In addition, for a given latitude, the angle alters during the year, being at its shallowest in June and steepest in December. The steeper the inclination of the ecliptic to the horizon the greater the altitude of the Moon above the horizon for any value of elongation. The young crescent Moon is easiest to see around December and/or from low latitudes.

Appendix 4

Standstills

Standstills are the times when the Moon is at its greatest northerly and southerly declination in a given month and so its azimuth changes most slowly on succeeding days; i.e., the day-to-day retardation is at a minimum. There are about 27 standstills each year.

Major standstills occur every 18.6 years when the ascending node of the lunar orbit is at the vernal equinox. The declination of the Moon is then at its greatest (plus/minus 28.5°) and its azimuth at Moonrise or Moonset is at its most northerly or southerly. For Lat. 51.5°N the azimuth range for Moonrise at major standstills is 40–140°, and the equivalent Moonsets will be 220–320° respectively.

Minor standstills occur every 18.6 years but with exactly one half phase difference from major standstills.

Minor standstills happen when the ascending node is at the autumn equinox and the Moon has the lowest declination.

Appendix 5

Mean tropical year

Although the tropical year is defined as the interval between two successive vernal equinoxes, strictly speaking this is really an equinoctial year. It is currently close to 365.2424 civil days (365d 5h 49m 5.45s), and is given by an algorithm (Meeus, 1991) that calculates the interval between two successive vernal equinoxes using data for the Earth's orbit in 2000 CE. There are two points about using equinoctial years for calendar purposes.

(i) The vernal equinoctial year is just one type of equinoctial year. This is because the time it takes to do one lap of an orbit depends on which point is chosen for the measurement. The reason is that the Earth's orbit is elliptical and the angular speed of the planet varies along its orbit, being faster when the earth is closer to the Sun and slower when it is furthest away (see Kepler's laws). The effect of this is shown in the table below.

Table A1. Lengths of the year calculated for different points on Earth's orbit using data for 2000 CE.

Year. Mean time interval between:	Geocentric longitude* of Sun	Year length (ephemeris days)	Change in length (sec/century)
Spring equinoxes	0	365.24237	+0.893
June solstices	90	365.24162	+0.056
Autumn equinoxes	180	365.24201	-2.000
December solstices	270	365.24274	-1.075

*Geocentric longitude is the position of the Sun on the celestial sphere described by projecting lines of longitude from the Earth onto the celestial sphere. At the vernal equinox the Sun lies on the celestial sphere immediately above the Prime Meridian at Greenwich, 0° longitude. During each season the Sun moves 90° of geocentric longitude.

In fact there are an infinite number of equinoctial year lengths since it is possible to pick any point along the orbit and measure the time needed to make the round trip.

(ii) Although strictly speaking, the value for any equinoctial year only applies to the year in question because the orbital parameters change from year to year, modern calculations show that the vernal equinoctial year has remained between 365.2423 and 365.2424 civil days for the last four millennia years and will remain at its current value for the next 2000–4000 years. This stability is not typical but comes about because at the moment, just by chance, all the factors that disturb the Earth's orbit in such a way as to affect this measure of the year mutually cancel each other out.

Astronomers define a mean tropical year of 365.242190 civil days (365d 5h 48m 46s), based on formula by Newcomb (1897) or Laskar (1986) which describe the movement of a fictitious mean Sun and which are derived to be accurate approximations for about 8000 years. This is the value adopted by astronomers for time keeping purposes. Note that the average of the four equinoctial years in Table 00 is very close to the mean tropical year

Using it gives a difference between the Gregorian calendar year and mean tropical year (in 2000 CE) of

365.2425 - 365.24219 = 0.00031 days, which is about 26 seconds. A crude calculation shows this has amounted since 1582 to an accumulated error by 2005 of 26 x (2005 - 1582) seconds ~ 11330 seconds, or about 3h 9m. Unfortunately calculating how this error accumulates over the centuries is complicated by the fact that the length of the tropical year is not constant. Currently it is decreasing by about 0.53 seconds per century. Taking this into account the Gregorian calendar has drifted 2h 59m since 1582 and will be one day ahead of the seasons by about 4000 CE. At this time the vernal equinox will occur on March 19 instead of March 20. This could be corrected by having one leap year turned into a common year (i.e. losing a day), perhaps around 3000 CE, when the error will be 0.5 days.

At present the vernal equinoctial year happens to be a better approximation to the average year length of the Gregorian calendar, 365 + 97/400 = 365.2425 days, than is the mean tropical year used by astronomers. The difference between the calendar year and the vernal equinoctial year is currently 365.2425 - 365.24237 = 0.00013 days; just under 11.25 seconds each year. This means that the drift of the calendar against the vernal equinoctial year is much slower than against the mean tropical year. Moreover the stability of the vernal equinoctial year will hold the drift rate relatively constant for a couple of thousand years, other things being equal.

However, instituting reforms to correct the Gregorian calendar over longer time periods is not useful because of uncertainty about how the length of the mean solar day will change over time. It is currently increasing by 0.0017 seconds per century as the rotation of the Earth is slowed by tides exerted by the Moon. (The same effect is causing the Moon to get steadily further from the Earth so the length of the synodic month is increasing by 0.038 seconds per century.) In fact the combination of increasing mean solar day length and decreasing mean tropical year length means that the number of days in the mean tropical year are slowly decreasing.

Actually the Gregorian calendar is not the best match that has been achieved to the vernal equinoctial year. The prize for this goes to the Iranian calendar, which uses a complex sequence of leap year intercalations to give a year length of 365 + 143/590 = 365.24237 civil days.