CALENDARS
by David Le Conte

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Part 1

What date is it?

That depends on the calendar used:-

Gregorian calendar:	1997 May 20
Julian calendar:	1997 May 7
Jewish calendar:	5757 Iyyar 13
Islamic Calendar:	1418 Muharaim 13
Persian Calendar:	1376 Ordibehesht 30
Chinese Calendar:	Shengxiao (Ox) Xin-You 14
French Rev Calendar:	205, Décade I
Mayan Calendar:	Long count 12.19.4.3.4 tzolkin = 2 Kan; haab = 2 Zip
Ethiopic Calendar:	1990 Genbot 13
Coptic Calendar:	1713 Bashans 12
Julian Day:	2450589
Modified Julian Date:	50589
Day number:	140
Julian Day at 8.00 pm BST:	2450589.292

First, let us note the difference between *calendars* and *time-keeping*. The *calendar* deals with intervals of at least one day, while *time-keeping* deals with intervals less than a day. Calendars are based on astronomical movements, but they are primarily for social rather than scientific purposes. They are intended to satisfy the needs of society, for example in matters such as: agriculture, hunting. migration, religious and civil events. However, it has also been said that they do provide a link between man and the cosmos.

There are about 40 calendars now in use. and there are many historical ones. In this article we will consider six principal calendars still in use, relating them to their historical background and astronomical foundation. These six calendars are:-

Gregorian calendar
Hebrew Calendar
Islamic Calendar
Indian Calendar
Chinese Calendar
Julian Day Numbers

We shall also consider two ancient calendars: Egyptian and Mayan.

The astronomical basis of calendars

The principal astronomical cycles are:

Day Based on the rotation of the Earth on its axis
Year Based on the revolution of the Earth around the Sun
Month Based on the revolution of the Moon around the Earth

The complexity arises because the revolution cycles (year and month) are not integral numbers of days, and because none of the cycles is constant. We have first to note the definitions of: *Solar Day*, *Synodic Month*, and *Tropical Year*.

The *Solar Day* is the interval between successive returns of the *Mean Sun* (an artificial Sun which moves with uniform motion) to the same meridian. It is slightly (about 4 minutes) longer than the time taken for the Earth to rotate 360° on its axis with respect to the stars (the *sidereal day*).

The *Tropical Year* is the mean interval between the Vernal Equinoxes. It relates to the seasons, and is therefore the most important type of year for calendar purposes. It varies slightly, but is currently 365.24219 days (365 days, 5 hours, 48 minutes, 45.2 seconds).

The *Synodic Month* is the mean interval between conjunctions of the Moon and the Sun, and relates to the phases of the Moon. It is 29d 12h 44m 03s (29.5305879 days). Again, it is longer than the simple orbital period of the Moon on its axis, which is about 27.32 days.

Therefore, it can be seen that the year is not an integral number of days; nor is it an integral number of months, in astronomical terms.

Attempts to arrive at a solution to these problems have resulted in three distinct types of calendar (see box).

Solar calendar	Based on the tropical year. (Eg Gregorian Calendar.)
Lunar calendar	Based on lunar phase cycle. (Eg Islamic Calendar.)
Luni-solar calendar	Based on lunar phase cycle, but uses intercalary months every few years to bring it back into phase with the tropical year. (Eg Hebrew and Chinese Calendars.)

In a purely lunar calendar. 12 lunar months are about 11 days shorter than the tropical year. Therefore, in the luni-solar calendar an extra month is inserted periodically (an intercalary month). For example, if an extra month is added in seven years out of every 19, then the average calendar year is only about six minutes longer than the tropical year. This was the basis of several Babylonian calendars and of their Greek derivatives. The Jewish calendar is a close relative.

The Old Roman Calendar

Romulus was responsible for the introduction of the old Roman calendar. Its epoch (starting point) was the Foundation of Rome in 753 BC. Years were denoted "AUC" (*anno urbis conditiæ* or *ab* *urbe condita*). Therefore 753 BC was equivalent to 1 AUC. The year had 304 days divided into 10 months, starting in March. (Hence we have: September, October, November, and December as the 7th, 8th, 9th and 10th months.) The months were divided into three parts: *Kalends*, *Nones*, and *Ides*.

Nuna Pompilius, who reigned from 39 to 82 AUC (ie 715-672 BC) added two months, February and January to the start of year. The year then had 355 days. In 302 AUC (452 BC) February and January were reversed to take up their present positions.

The months alternated 30 and 29 days, with one extra day added at the end of the year. Every second year an extra month (called *Mercedinus* from the Latin word for wages) was added. This had alternately 22 and 23 days. But now the year was one day too long, on average. Therefore, further slight adjustments were made.

The Julian Calendar

By the reign of Julius Caesar (102-44 BC) the Roman calendar had reached a state of confusion, and the Greek astronomer Sosigenes advised Caesar in the redesign of the calendar.

The result was a major readjustment which took place in 708 AUC (46 BC). This year had two additional months of 33 and 34 days, inserted between November and December, and an intercalary month of 23 days. So the Year of Confusion lasted 455 days!

The new Julian calendar had 12 months, alternating 31 and 30 days, an exception being February, which had only 29 days in non-leap years. There was a leap year every four years, and the calendar year therefore averaged 365¼ days.

However, just two years after it came into effect Caesar died, and, unfortunately, the priests who were responsible for administering the calendar, apparently misunderstood the system. Instead of a leap year every four years, they had one every three years, and this went on for 36 years. Therefore by 9 BC three days had accumulated, and the Vernal Equinox had moved from 25 March to 22 March.

Changes to Julian Calendar by Augustus

Julius Caesar was succeeded by his grand nephew, Caesar Augustus (63 BC - 14 AD). He restored the Julian Calendar by having 12 years with no leap years, and by 4 AD everything was all right again.

Well, it would have been all right except for Augustus's meddling. Julius Caesar had been born in the fifth month, *Quintilis*, and Augustus therefore renamed this month *July* in his honour.

The sixth month, *Sextilis*, was of special importance to Augustus, and he renamed it August. However, August had only 30 days, and to give it the same number as July, which had 31 days, he transferred one day from February. February thus had only 28 days in non-leap years.

But then July, August and September all had 31 days, so to restore some semblance of the alternating sequence, Augustus moved one day from September to October, and another from November to December.

The Gregorian Calendar

The date of Easter is the Sunday after the first ecclesiastical Full Moon that falls on or next after 21 March. The ecclesiastical Full Moon is not the same as the astronomical Full Moon, as it is based on tables that do not take into account the complexity of the lunar motion.

By the 16th century the Vernal Equinox had shifted by ten days, and the astronomical Full Moons were occurring four days before ecclesiastical Full Moons, on which the date of Easter was based.

This is the reason why Pope Gregory XIII (AD 1502-1585) decided to reform the calendar.

The Pope was advised by Ghiraldi and Clavius. The objective was to restore the days which had been lost since the Council of Nicea, in AD 325. That Council had met to resolve, *inter alia*, the date of Easter. By that year 4 days had been lost from the original Julian Calendar, and the Vernal Equinox had moved from 25 March to 21 March.

The question has been raised as to whether the calendar should not have reflected the position of the Equinoxes at the time of the birth of Christ, rather than the date of the Council of Nicea. The difference would have been one day.

Because the calendar year was 365.25 days, rather than the tropical year of 365.24219 days, the annual mean error of the Julian Calendar was 11m 14s. Therefore, the accumulated error from AD 325 to AD 1582 (1257 years) was 9d 19h 20m 18s. It was, therefore, necessary to correct the calendar by 10 days.

Thus, by a Papal Bull issued by Pope Gregory XIII, 5 October 1582 became 15 October 1582.

The calendar was also redefined so that a leap year was skipped every 100 years, except for every 400 years.

The rule for the Gregorian Calendar is:

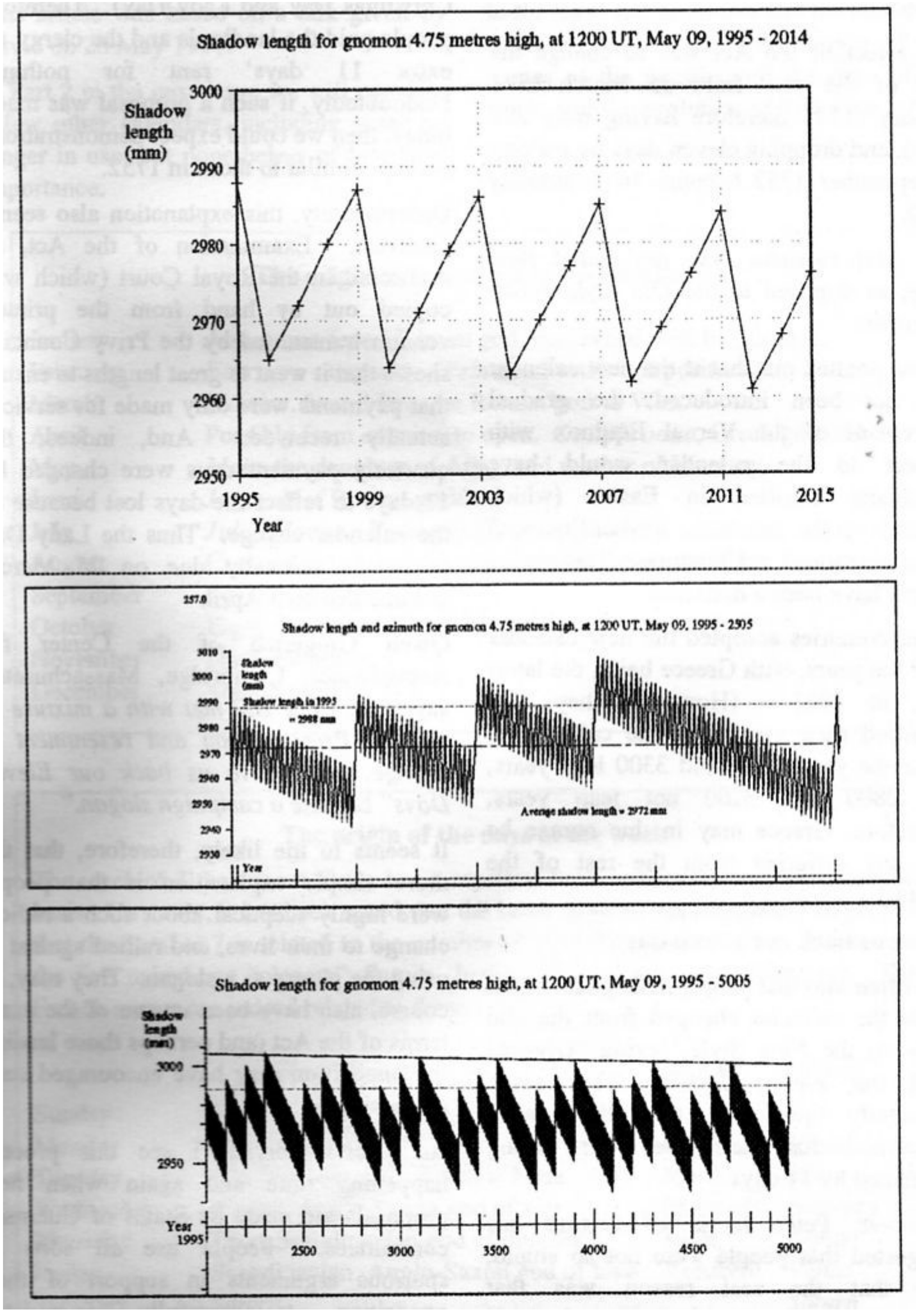
> *Every year that is exactly divisible by 4 is a leap year, except for years that are exactly divisible by 100; these centurial years are leap years only if they are exactly divisible by 400.*

Therefore, 1800 and 1900 were not leap years, and neither will 2100, but 2000 was a leap year.

The Gregorian calendar cycle is 400 years. (400 years equal 146,097 days. This is exactly divisible by 7, and therefore the calendar exactly repeats after 400 years.)

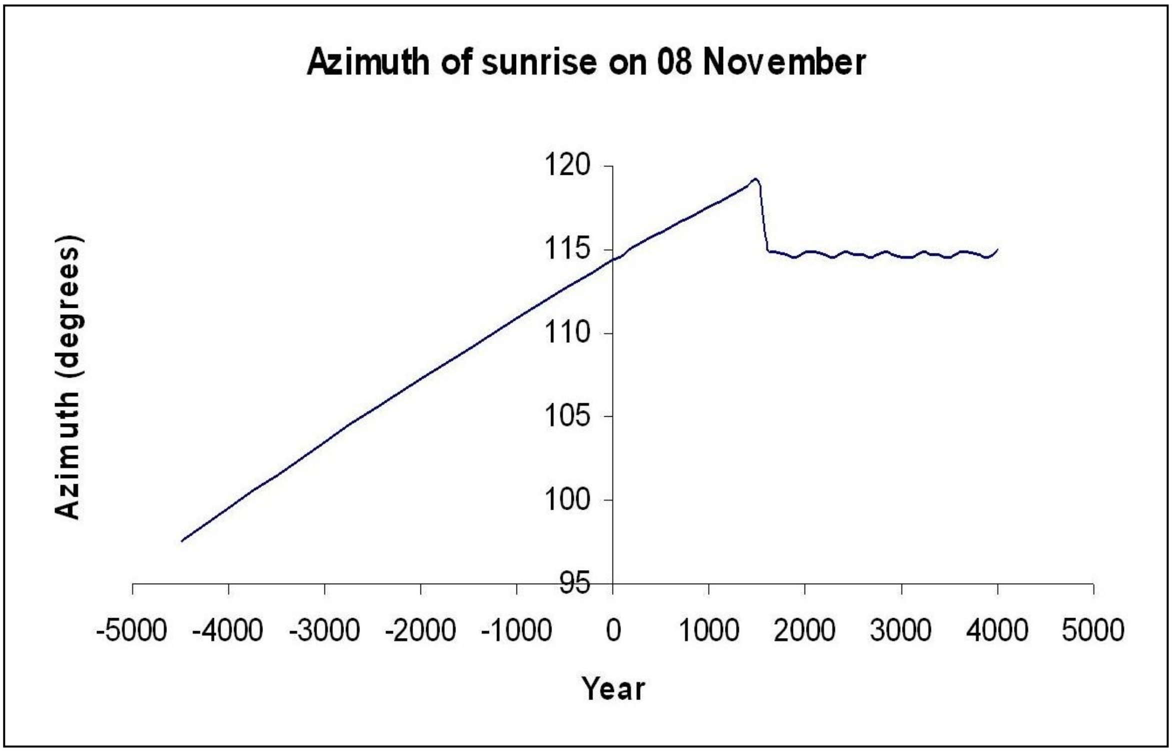
In the Julian calendar 400 years was 146,100 days, an average of 365.2500 days per year. The Gregorian calendar has an average of 365.2425 days per year. This is close, but not exactly equal to the tropical year of 365.24219 days. By changing from the Julian to the Gregorian calendar the mean length of the calendar year was reduced from 365d 6h 0m 0s to 365d 5h 49m 12s, and the mean error in the solar year reduced from 11m 14s (one day per 128 years) to just 26s (one day per 3323 years).

This long-term error in the Gregorian calendar can be seen as a trend line in the 3000-year plot of the shadow of the Guernsey Liberation Monument:



Plots of the shadow lengths of the Guernsey Liberation Monument. The top diagram shows the effect of leap years for 20 years (the year 2000 AD is a leap year). The middle diagram shows the effect of leap years for 500 years (leap years are omitted in the years 2100, 2200 and 2300, but 2400 is a leap year). The bottom diagram shows the long-term trend (solid line) caused by the loss of about one day in 3000 years because of the Gregorian calendar.

A calculation of azimuth (direction) of sunrise for a given date (here 08 November) thousands of years in the past, as well as the future, shows the effects of both the Julian and the Gregorian calendars. The Julian calendar, with its uniform four-year leap-year system, produces a straight line. There is a jump in the azimuth when the Gregorian calendar was introduced in 1582, and thereafter there is the more irregular variation caused by the new calendar. The Julian calendar was in error by one day every 128 years, whereas the Gregorian calendar is in error by one day every 3226 years.



The Gregorian calendar in England

Of course, the Papal Bull had no effect in Protestant Countries, such as England. Indeed, in 1570, just 12 years previously, a similar Bull by Pope Pius V had excommunicated Queen Elizabeth I, and released her Catholic subjects from their loyalty to her! Pope Gregory had also encouraged Elizabeth's enemy, Mary, Queen of Scots. So it was not surprising that England was loath to accept the new Papal calendar.

Nevertheless, Queen Elizabeth did attempt to have the calendar introduced, against the wishes of her bishops. The Archbishop of Canterbury wrote to the Queen giving worthy excuses, designed to delay any decision. He said that before the bishops could agree with the introduction of the new calendar, it would be necessary to consult widely, with the Church in England as well as with other churches. It was also stated that if England agreed to the change then it would, in effect, be submitting to the authority of the Pope.

Scotland did accept the Gregorian calendar in 1600, by the *Act of the Estates*. The fact that much of the world used the new calendar, while England (and Guernsey, of course) used the old one, must have led to confusion. Indeed, it became common to refer to dates between 1 January and 24 March in terms of both systems, as there was ambiguity about the start of the new year.

So by 1750 it was decided that the Gregorian calendar should, after all, be accepted. *The Calendar (New Style) Act, 1750* (Act 24, George II, Chapter 23) introduced the calendar into Britain and the British Colonies (including the USA) in 1752. In Guernsey, the Act *(Regulating the Commencement of the Year, and for correcting the Calendar now in use*) was registered in the Royal Court on 28 December 1751. By that time the Julian calendar was 11, rather than 10 days adrift of its position at the time of the Council of Nicea.

The effect of the Act was to change the start of the year from 25 March to 1 January (1751 therefore having only 282 days), and dropping eleven days by making 3 September 1752 become 14 September 1752.

The new calendar was designated *New Style*, as opposed to the *Old Style* Julian Calendar.

It was pointed out that if the new calendar had not been introduced, the gradual movement of the Vernal Equinox with respect to the calendar would have eventually resulted in Easter (which depends on the date of the Vernal Equinox) being celebrated at Christmas! This would clearly have been a nonsense.

Other countries accepted the new calendar over the years, with Greece being the latest one, in 1923. (However, they also modified their version of the calendar to make the years 2900 and 3300 leap years, but 2800 and 3200 not leap years. Therefore. Greece may in due course be one day different from the rest of the world!)

"Give us back our eleven days!"

It is often said that people in England rioted when the calendar changed from the Old Style to the New Style, crying "*Give us back our eleven days*!" The reason frequently given is that they were concerned that their lives were being shortened by 11 days.

However, Peter Jarvis of Oxford has suggested that people were not so stupid, and that the real reason was that agricultural rents and tithes were calculated on an annual basis, but fell due on the four quarter days (Midsummer, Michaelmas, Christmas Day and Lady Day). Therefore people paid the landlords and the clergy an extra 11 days' rent for nothing. Undoubtedly, if such a proposal was made today, then we could expect demonstrations perhaps similar to those in 1752.

Unfortunately, this explanation also seems incorrect. Examination of the Act, as registered in the Royal Court (which was copied out by hand from the printed version transmitted by the Privy Council), shows that it went to great lengths to ensure that payments were only made for services actually received. And indeed, the quarterly payment days were changed by 11 days to reflect the days lost because of the calendar change. Thus the Lady Day payments, normally due on 25 March, became due on 5 April.

Owen Gingerich of the Center for Astrophysics, Cambridge, Massachusetts, says that: "*The Bill met with a mixture of militant Protestantism and resentment of change, and "Give us back our Eleven Days" became a campaign slogan.*"

It seems to me likely, therefore, that the more simple explanation is that people were highly sceptical about such a radical change to their lives, and rallied against it, using the phrase as a slogan. They may, of course, also have been unsure of the exact terms of the Act (and perhaps those leading the opposition may have encouraged such uncertainty).

As a civil servant I saw this process happening time and again when new proposals were made by States of Guernsey committees. People used all sorts of spurious arguments in support of their opposition to carefully formulated proposals.

In Part 2 we consider a few other calendars, including some no longer in use, but nonetheless of historical importance.

In the following three boxes are some notes about the origin of the names of the months and the days of the week, and the evolution of *New Year's Day*.

The origin of the names of the months

January	*Janus*, two-faced Roman god, concerned with beginnings.
February	*Februare* - to purify. *Februa* - Festival of purification.
March	*Martius*. from Mars, the Roman god of War.
April	Possibly from *aperire*, to open. Or *Aphrodite*, Greek god of love.
May	*Maia*, the daughter of Atlas, and mother of Mercury.
June	*Juno*, chief Roman goddess.
July	*Julius* Caesar. Formerly *Quintilis*, the fifth month.
August	Caesar *Augustus*. Formerly Sextilis, the sixth month.
September	Seventh month.
October	Eighth month.
November	Ninth month.
December	Tenth month.

The origin of the days of the week

The week of 7 days most likely has a mystical, rather than an astronomical basis. However, it has been noted that the lunar quarters approximate 7 days, and that the number 7 is related to the number of "wandering stars" (Sun. Moon, and the five naked-eye "planets": Saturn, Jupiter, Mars, Venus, and Mercury). The French names are indeed related to these.

	English meaning	French	'Planet'
Sunday	*Sun*	Dimanche*	*Sun*
Monday	*Moon*	Lundi	*Moon*
Tuesday	*Tiw*, northern god of War = Mars	Mardi	*Mars*
Wednesday	*Woden*, Anglo-Saxon god of war	Mercredi	*Mercury*
Thursday	*Thor*, Scandinavian god of thunder	Jeudi	*Jupiter*
Friday	*Frigg*, Norse. Anglo-Saxon god of love	Vendredi	*Venus*
Saturday	*Saturn*	Samedi	*Saturn*

* Dimanche from the Latin *Dies Dominicus*, the Day of the Lord.

New Year's Day

By the 6th century it was felt better to base the starting point of the calendar on the Nativity, rather than on the foundation of Rome. Dionysius Exiguus concluded that Christ was born in the year 753 AUC, and that this year should become 1 AD (*Anno Domini*). Now, however, it is believed that Christ was born in the year 4 BC.

25 December was accepted as the date of the birth of Christ because it was nine months after Lady Day, 25 March, the day of the Annunciation, which itself coincided with the Vernal Equinox. 1 January was accepted as the start of the year, rather than 25 December, because it was the Feast of Circumcision. Circumcision took place on the child's 8th day, including the day of birth. Therefore 1 January could be regarded as the date of Christ's "birth" in the Church.

New Year's Day only became standardised on 1 January in the 16th century, with the introduction of the Gregorian calendar. Even then it did not apply everywhere. For example, England (and Guernsey) used 1 January as the start of the year only from the 18th century. Before then, New Year's Day was 25 March.

The mistake in the date of Christ's birth results in some peculiar consequences.

The epoch of our calendar should really be 1 January 3 BC. This would mean that the new Millennium started on 1 January 1998. And the 2000th anniversary of Christ's birth was 25 December 1997!

There has, of course, been some debate about when the new Millennium should have been celebrated. In the Gregorian calendar the epoch is 1 January 1 AD, and this is the date that the year 1 AD (if it had existed) would have started. Therefore, 2000 AD started on 1 January 2000 AD. Thus, the second Millennium ended on 31 December 2000, and the New Millennium started on 1 January 2001.

Part 2

In Part 1 we looked in some detail at the history of the Gregorian calendar, including its antecedent Julian calendar. Now let us consider a few other calendars, including some no longer in use, but nonetheless of historical importance.

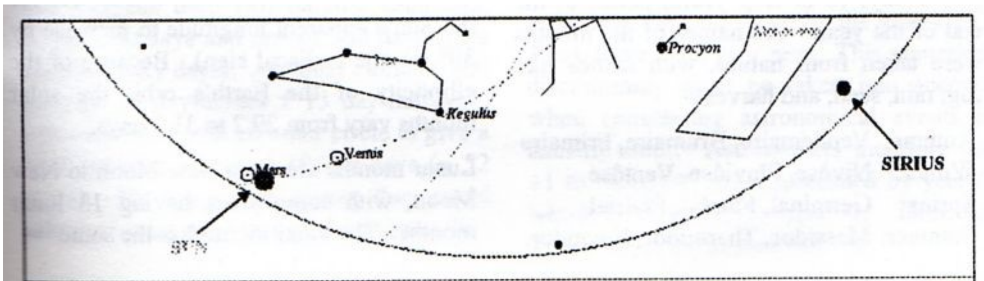
The Egyptian Calendar

The ancient Egyptian calendar is important to us as it was an ancestor of our present calendar. (The Egyptians also gave us the 24-hour day.) The early Egyptians used a lunar calendar, but eventually changed to a solar calendar with a 360-day year (12 months of 30 days). In the 8th century BC five extra days were added to the end of the year, to give it 365 days.

As this was about a quarter of a day less than the tropical year, the New Year moved through the seasons, with a "*sothis period*" of 1460 years. (The word *sothis* is related to the star Sirius.) However, in 239 BC the *Canopus Decree* introduced a leap year every few years.

The Egyptian New Year was dependent upon the flooding of the Nile, in early July. The *heliacal* rising of Sirius occurred a few days before the flooding. Sirius was therefore considered as a herald, and was worshipped. A *heliacal* rising is the rising of a star or planet just before sunrise. The object is seen for just a few minutes before sunlight intervenes.

It occurs at the same time each year. The star chart below shows, with due allowance for precession, the almost simultaneous rising of Sirius and the Sun, as seen from the latitude of Giza in early July in the year 8000 BC.



The heliacal rising of Sirius, 1 July 8000 BC

Neugebauer has suggested that "*This calendar is, indeed, the only intelligent calendar which ever existed in human history.*" His reason appears to be that the Egyptian calendar facilitated astronomical calculations, because it was continuous and uncomplicated, unlike lunar calendars. Therefore, it was used by the Greeks, and was apparently even used by Copernicus in his lunar and planetary tables.

The Islamic Calendar

'The Islamic Calendar is a lunar calendar, based on the lunar phase cycle. Therefore, the cycle of 12 lunar months regresses through the seasons with a period of about 33 years. In this period there are 11 leap years, giving an average length of month only 8 seconds less than the average synodic month.

Days are reckoned from sunset to sunset. The days are numbered, not named, except for the fifth day, *Jum'a*, which starts at sunset on Thursday and ends at sunset on Friday.

The month begins with the first visibility of the crescent Moon after New Moon (about 15 hours).

The epoch is the date of the migration of the Prophet Mohammed from Mecca to Medina, and is taken to be 15 July AD 622 (Julian Calendar).

The Hebrew Calendar

The Hebrew Calendar is a luni-solar calendar, based on calculation, not observation as in the case of the Islamic calendar. It is based on the *Metonic cycle* of 235 lunations, which equals 19 years. The epoch is the *Era of Creation*, which is 7 October 3760 in the Julian proleptic calendar (ie the Julian calendar extended backward). Years have 12 or 13 months of 29 or 30 days. There is an intercalary month in each of the Metonic cycle years 3, 6, 8, 11, 14, 17 and 19. The rules are too complex to be described in full in this summary.

The days are reckoned from sunset to sunset. The days of the week have numbers, not names, except for the seventh day, which is Sabbath (sunset Friday to sunset Saturday).

The French Revolutionary Calendar

In November 1793, the French Republic introduced a new calendar, which was supposedly based on philosophical and scientific principles. New Year's Day was fixed as 22 September, which was not only the Autumnal Equinox, but was also the day after the establishment of the Republic.

The year had 12 months of 30 days, with five 5 days (6 in leap years) added at the end of the year. The names of the months were taken from nature, with names like fog, rain, seed, and harvest:

Autumn:	Vendémaire, Brumaire, Frimaire
Winter:	Nivôse, Pluviôse, Ventôse
Spring:	Germinal, Floréal, Prairial
Summer:	Messidor, Thermidor, Fructidor

The calendar came in for a certain amount of ridicule in the enemy country, England, and a parody interpreted the month names as:

Autumn:	wheezy, sneezy, freezy
Winter:	slippy, drippy, nippy
Spring:	showery, flowery, bowery
Summer:	hoppy, croppy, poppy!

The calendar was used until 31 December 1805, when Napoleon reinstated the Gregorian Calendar. Undoubtedly, one of the reasons for the lack of success of the French calendar was the fact that the week was extended from 7 to 10 days, with just one day's rest every 10 days instead of every 7.

The Indian Calendar

India uses many varieties of calendar. The Gregorian Calendar is used for administrative purposes, but the National Calendar is a luni-solar calendar, reformed in 1957. (Previously there were about 30 calendars in use in india.) It has leap years just like those of the Gregorian Calendar, but the epoch is the *Saka Era*, corresponding to the vernal equinox, AD 79. The months, which are named after the traditional Indian months, are offset from the beginning of the Gregorian months.

The official Indian Religious Calendar (by which holidays are determined) is a luni-solar calendar based on calculations of the actual positions of the Sun and Moon. There are *solar months* and *lunar months*. The solar month is defined as the time for the Sun's apparent longitude to increase by 30° (ie one zodiacal sign). Because of the ellipticity of the Earth's orbit the solar months vary from 29.2 to 31.2 days.

Lunar months are from New Moon to New Moon, with some years having 13 lunar months. The lunar month has the same name as the solar month in which it starts, but sometimes a solar month will not have any New Moon, so its name is skipped.

To complicate matters even further, there are many local variations, with local calendar makers using traditional astronomical ideas, and producing calendars which are not compatible with the official ones!

In India the question: “What’s date is it?” could have several answers.

The Mayan Calendar

The ancient Mayan calendar was even more complicated. It apparently had 365 days, 18 months to a year, 20 days to each month, plus one short month (*Uyeb*) of 5 days. These five days were very unlucky, and almost every activity had to be avoided during them. They were used in the “*long count*”, which was, therefore, based on a 365-day year (possibly with festivals adjusted from time to time to keep to seasons), but they were omitted in the “*short count*”, which was used for calculations involving longer periods of time.

The Mayans apparently had names for periods up to 460,800 million days!

The epoch was possibly 10 August 3113 BC. 13 *bakhtuns* (13 periods of 144,000 days, or 394.5 years), was calculated to end with the end of the world on 24 December 2011!

The Mayans used two parallel calendars, one of 260 days and one of 360 days (plus the 5 unlucky days). An inner circle of 260 days (= 20 day-names x 13 day-numbers) was combined with an outer circle to give a dual calendar wheel of 18,980 days (= 52 years). By using such means they could calculate solar and lunar cycles accurately.

The appearance of Venus was considered very important, and was accompanied by religious festivals with human sacrifices. Astronomers predicting these dates needed to be exact, as the usual penalty for getting it wrong was execution!

The Mayan calendar system has never been completely understood. As might be expected these uncertainties have led some people to infer various mystical inferences to it, as can be seen by examination of the Internet, where some people and organisations appear to be seeking like- minded individuals, and even to make money out of it.

The Chinese Calendar

In present-day China the Gregorian Calendar is used for administrative purposes, but the Chinese Calendar is used for traditional festivals and agricultural activities. It is a luni-solar calendar based on calculations of the positions of the Sun and Moon. There is no epoch, the names of the years following a 60-year cycle.

The year names are a combination of 10 “*Celestial Stems*” (which are Chinese characters) and 12 “*Terrestrial Branches*”, named after animals. Thus 1997 (when this article was originated) was the year *ding-chou* (*ding* being a Chinese character, and *chou* meaning ox).

The designation of BC years

The use of BC years causes a problem for astronomers. In the 8th century AD Bede counted the years backward from AD 1, preceding the year AD 1 by the year 1 BC. Thus, there is no year zero. This numerical discontinuity must be taken into account when considering astronomical events in ancient times. Astronomers therefore use +1 to designate AD 1, preceded by year 0, which is preceded by year -1. Thus, for example, 46 BC is year -45.

Julian Day numbers

In the 16th century BC, Scaliger tried to create a single system for designating years, by seeking an initial epoch which preceded any historical records. He used three cycles (see box).

Cycles used for Julian Day Numbers

Solar cycle	S	Period after which the weekdays and calendar dates repeat in the Julian Calendar (= 28 years).
Golden Numbers	G	Period after which the Moon phases repeat (approximately) on the same calendar dates (= 19 years).
Indiction cycle	I	Roman tax cycle (= 15 years).

Therefore, a particular year could be designated as a combination of the numbers represented by these cycles: S x G x 1. The cycle repeats after 7980 years (= 28 x 19 x 15), and this is the *Julian Year*. The epoch of his system was the year given by 1 x 1 x 1, which is year BC 4713 (= -4712), and Greenwich noon on 1 January of that year is the starting point for *Julian Day Numbers* used by astronomers. The Julian Day starts at noon. so midnight of that day is 0.5 less than the Julian Date at noon. Parts of a day are denoted by decimals.

The Julian Day Number is widely used by astronomers, and for converting from one calendar system to another. It is also easy to determine the day of the week, knowing the Julian Day Number (see box).

To calculate the day of the week

For the Gregorian Calendar:-

$$I = JD - 7 \times ((JD + 1)/7) + 2$$

where JD is the Julian Day Number and I is a number denoting the day of the week (Sunday = 1). Ignore remainders.

For example:-

For 20 May 1997, JD= 2450589, so I =3, and the day is Tuesday.

Calendar reform

The Gregorian calendar has a number of problems. The months, quarters, and half- years are all unequal (this particularly affects economic matters such as statistics, salaries, insurance, pensions, prices, and rents). And the days of the week are different for different months and different years.

A number of changes have therefore been advocated over the years, the most popular being the *Universal* or *World Calendar*.

This would have 12 months, with the same names as now. Each quarter would contain 91 days, with the first month having 31 days, and months 2 and 3 each having 30 days. Weeks would continue to consist of 7 days. Since 91 is exactly divisible by 7, the cycle of days of the week would repeat every quarter, with the first day of each quarter being a Sunday. Each quarter would have exactly 13 weeks.

The four quarters of 91 days gives a total of 364 days. Therefore, an extra day ("*Year's End Day*") would be added at the end of December (31 December). There would be leap years, as in the Gregorian Calendar, but with the extra day added at the end of June, rather than the end of February. These intercalary days would not be included in the cycle of days of the week.

The World Calendar was last considered by the United Nations in 1955, when agreement could not be reached. Although there continues to be a movement advocating the World Calendar, and other calendar reforms, there has been very little recent interest by governments, religious authorities, or the general public.

Therefore, it seems unlikely that the calendar will undergo any changes in the foreseeable future. If the World Calendar was adopted, the change could most conveniently take place in a year which begins on a Sunday (eg 2006).

However, modern technology creates more difficulties than benefits when dealing with such matters. Organisations had a huge problem coping with such a relatively simple matter as ensuring that computer software would work after the year 1999. Based on that experience it would appear that the problems of changing to a new calendar would be insuperable!

One small change, however, could improve still further the accuracy of the Gregorian calendar. William Herschel advocated missing a leap year every 4000 years, to give an average year of 365.24225, ie, only one day out in 16,667 years. It seems to me that this would be a sensible refinement of the calendar (see box). However, an even more sensible refinement would be to miss a leap year every 3200 years, giving an average day of 365.2421875, or an error of one day in 400,000 years.

Accuracy of various calendar years compared with the tropical year

The tropical year is:	365.24219 days	
	Calendar year	*One day out in*
Start with a year of:	365.0000000 days	4 years
Add one day per 4 years (Julian calendar):	365.2500000 days	128 years
Lose one day per 100 years:	365.2400000 days	457 years
And add one day per 400 years (Gregorian calendar):	365.2425000 days	3,226 years
Lose one day per 4000 years (Herchel's modification):	365.2422500 days	16,667 years
or lose one day per 3200 years (SPAWAR modification):	365.2421875 days	400,000 years

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