How Long Is A Year?

Dr. Bryan Mendez
Space Sciences Laboratory
UC Berkeley

Keeping Time

The basic unit of time is a ***Day***.

Different starting points:

- Sunrise,
- Noon,
- Sunset,
- Midnight

tied to the Sun's motion.

Universal Time uses midnight as the starting point of a day.

Length: sunrise to sunrise, sunset to sunset?

Day

Noon to noon –

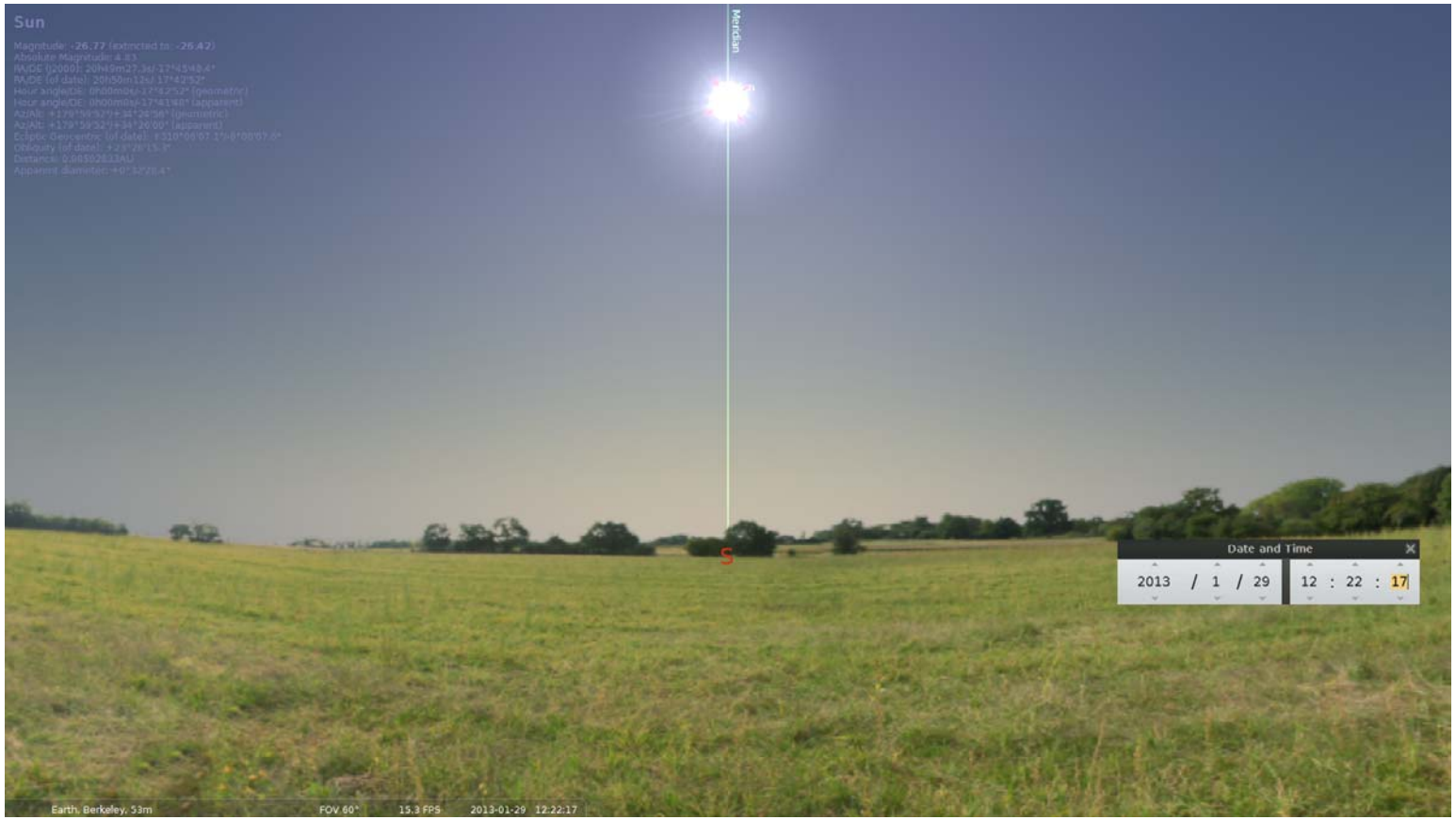
The seasonal motion of the Sun changes its rise and set times, so sunrise to sunrise would be a variable measure.

Noon to noon is far more constant.

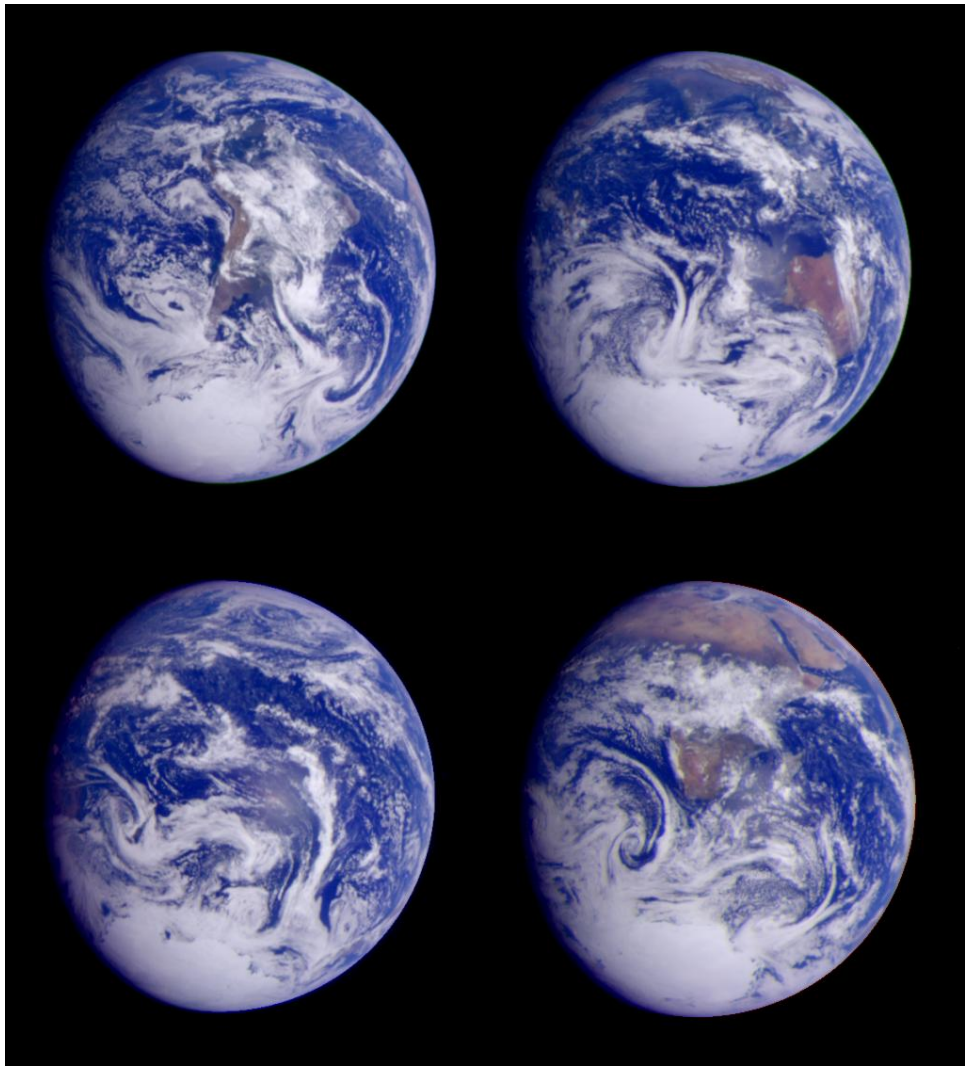
Noon: time of the Sun's ***transit*** of the ***meridian***

Stellarium

View and measure a day



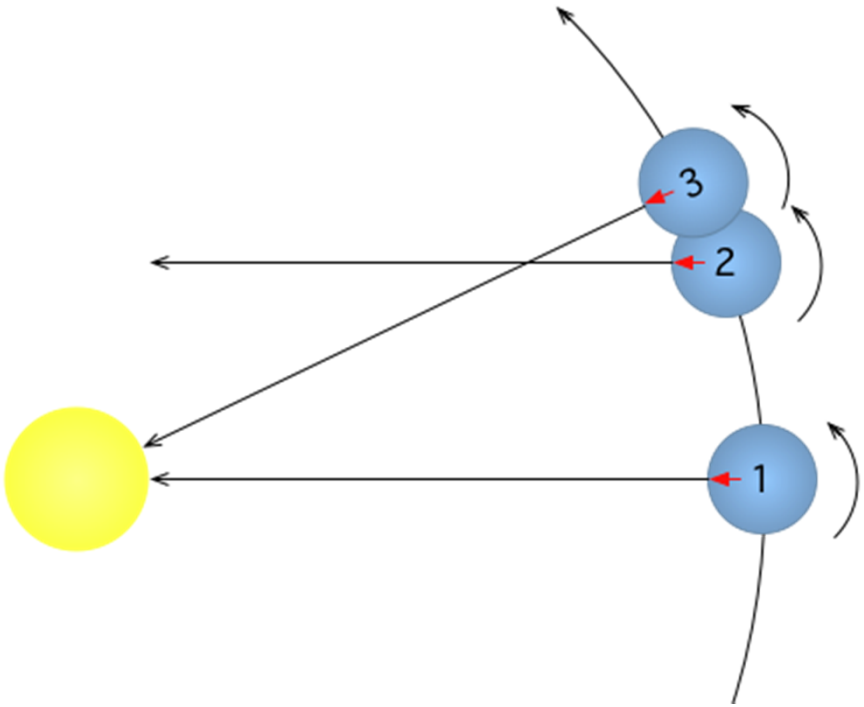
Day



A day is caused by Earth's motion: spinning on an axis and orbiting around the Sun.

Earth's spin is very regular *(daily variations on the order of a few milliseconds, due to internal rearrangement of Earth's mass and external gravitational forces primarily from the Moon and Sun).*

Synodic Day



Noon to noon = ***synodic*** or ***solar day*** (point 1 to 3). This is *not* the time for one complete spin of Earth (1 to 2).

Because Earth also orbits at the same time as it is spinning, it takes a little extra time for the Sun to come back to noon after one complete spin.

Because the orbit is elliptical, when Earth is closest to the Sun it is moving faster, and it takes longer to bring the Sun back around to noon. When Earth is farther it moves slower and it takes less time to rotate the Sun back to noon.

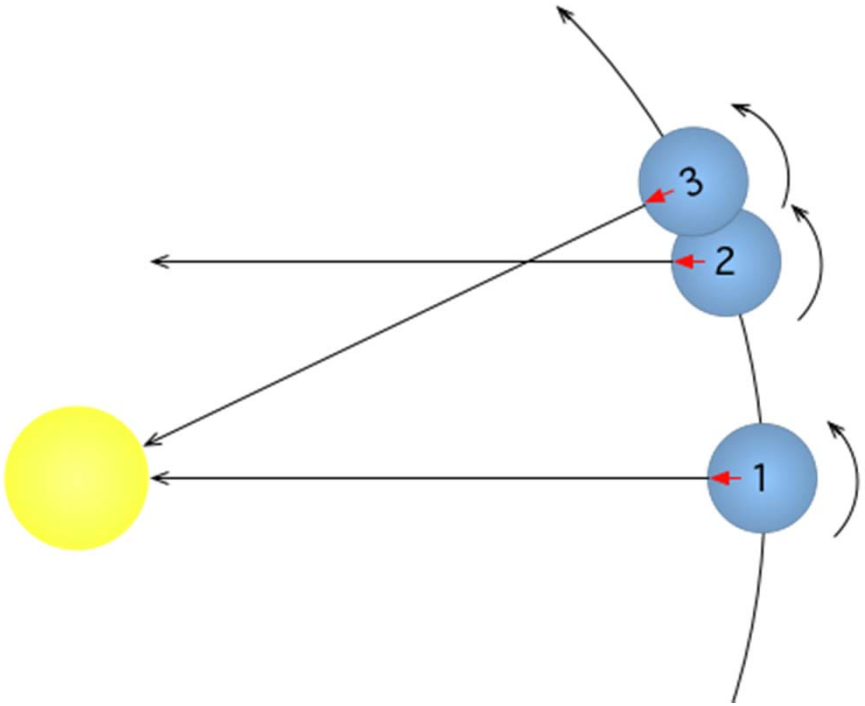
Mean Solar Day is an average of the amount time it takes to go from noon to noon throughout an orbit = **24 Hours**

Real solar day varies by up to 30 seconds depending on the time of year.

Sidereal Day

What if we measure the amount of time it takes for a star to go from one crossing of the meridian to another?

Sidereal Day



A ***sidereal day***

= 86,164.091 s

= **23 h 56 m 4.091 s**

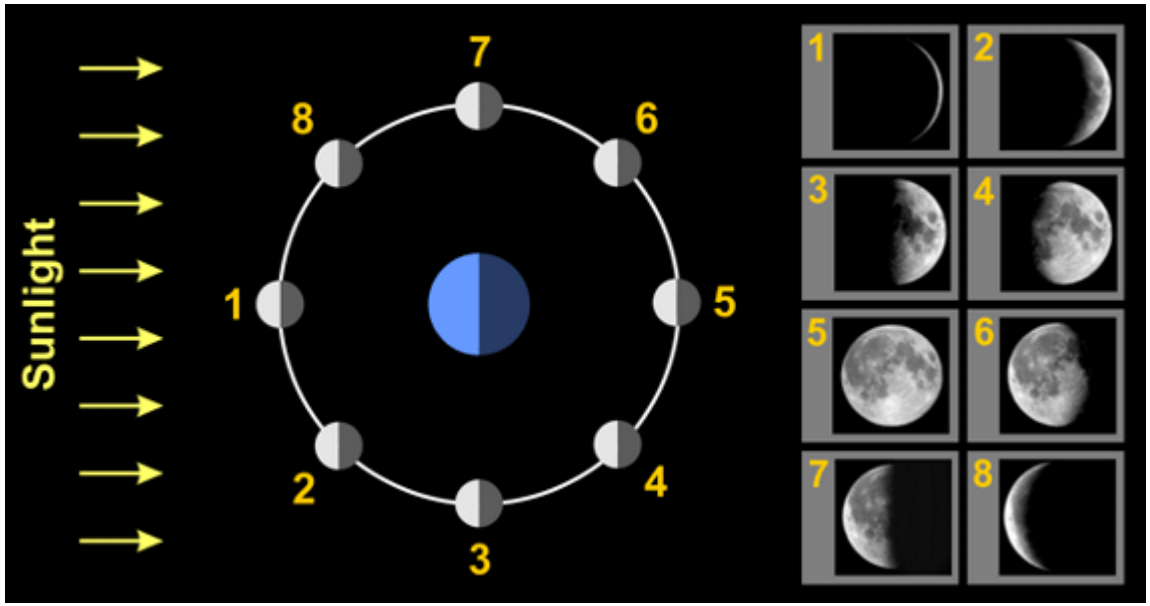
It is the true measure of the rotation period of Earth (1-2). The stars form a reference frame that is “fixed” while the reference frames of the Sun and Earth move.

Month

The oldest calendars on Earth were strongly tied to the Moon's cycle of phases

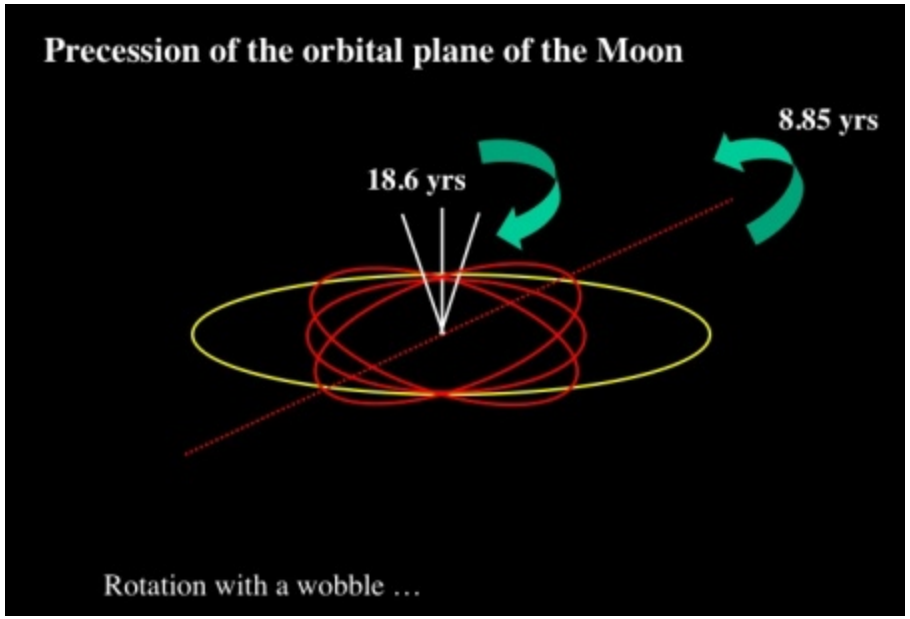
They almost always included a unit of time that marked this period of 29 to 30 days.

Month



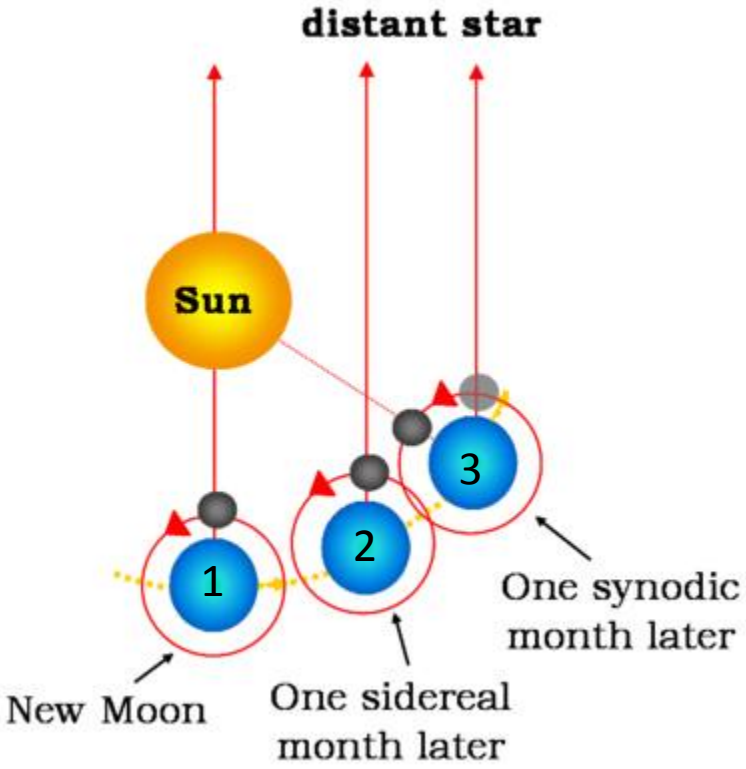
The Moon orbits Earth. Throughout the orbit we see differing amounts of its sunlit side, causing the sequence of phases, called a ***lunation***.

The arrangement of New Moon to New Moon takes on average **29.5306 days**.



The length varies because the Moon's orbit is elliptical and the orbit's shape precesses (8.85 yrs) and the orbital plane wobbles (18.6 yrs).

Sidereal Month



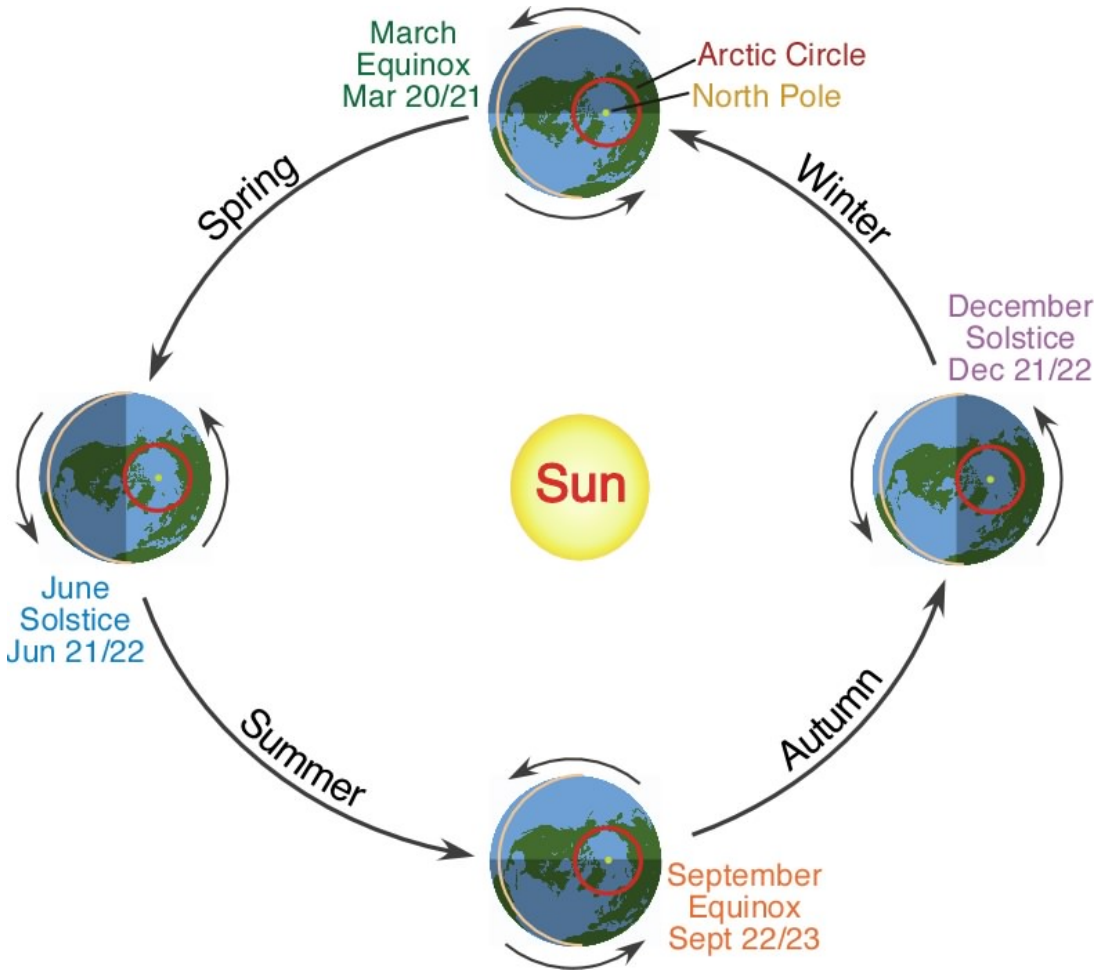
A *lunation* is a *synodic month*, because it measures an alignment of the Moon with the Sun (positions 1 to 3 in the diagram).

A ***sidereal month*** measures the length of time between arrangements of the Moon with the stars (i.e. from conjunction to conjunction with the Pleiades, points 1 to 2).

This is also the **orbital period of the Moon around the Earth = 27.32 days**. It also varies because of the Moon's orbital precession.

The synodic month is longer because the Earth moves very far along its orbit around the Sun after 27 days and it takes two more days for the Moon to "catch up" and come back to New Moon position (conjunction with the Sun).

Year

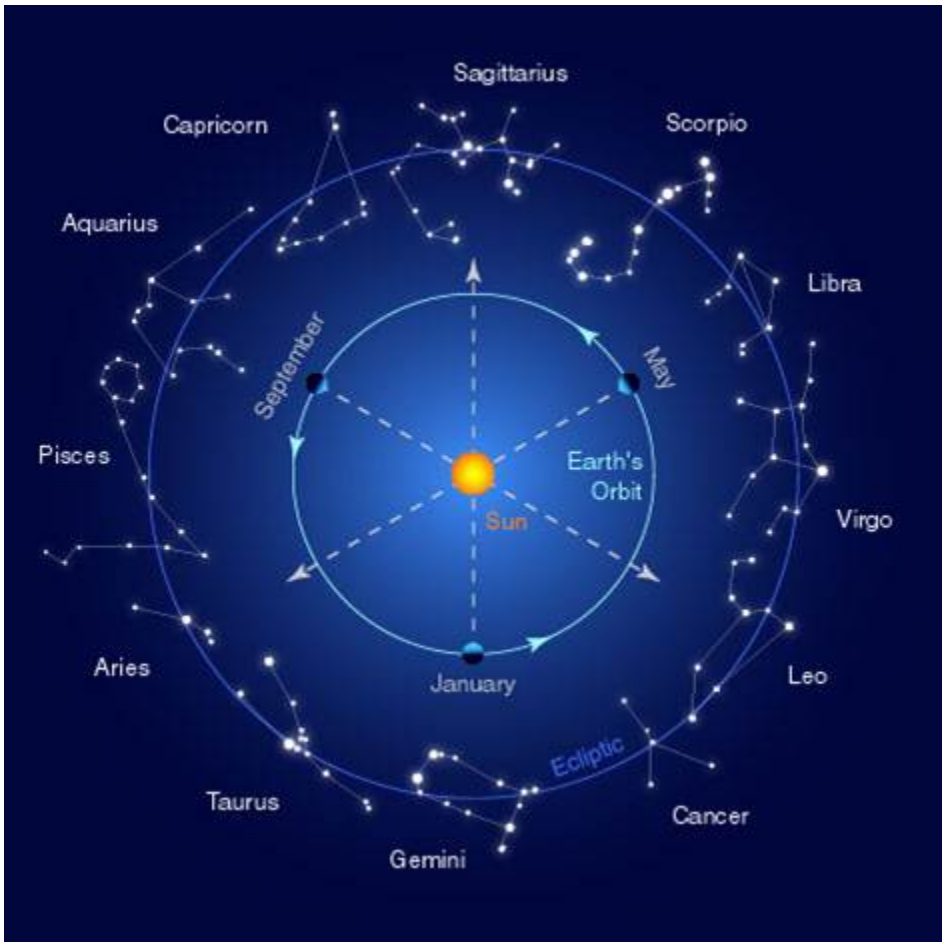


A ***solar year*** (***tropical year***, ***synodic year***) is the cycle of the seasons.

It is the amount of time between two alignments of the Sun with Earth, such as: from one summer solstice to the next, from one spring equinox to the next, or from one spring zenith passage to the next.

The modern value is
365d 5h 48m 45.19s
(365.2421897 days)

Sidereal Year

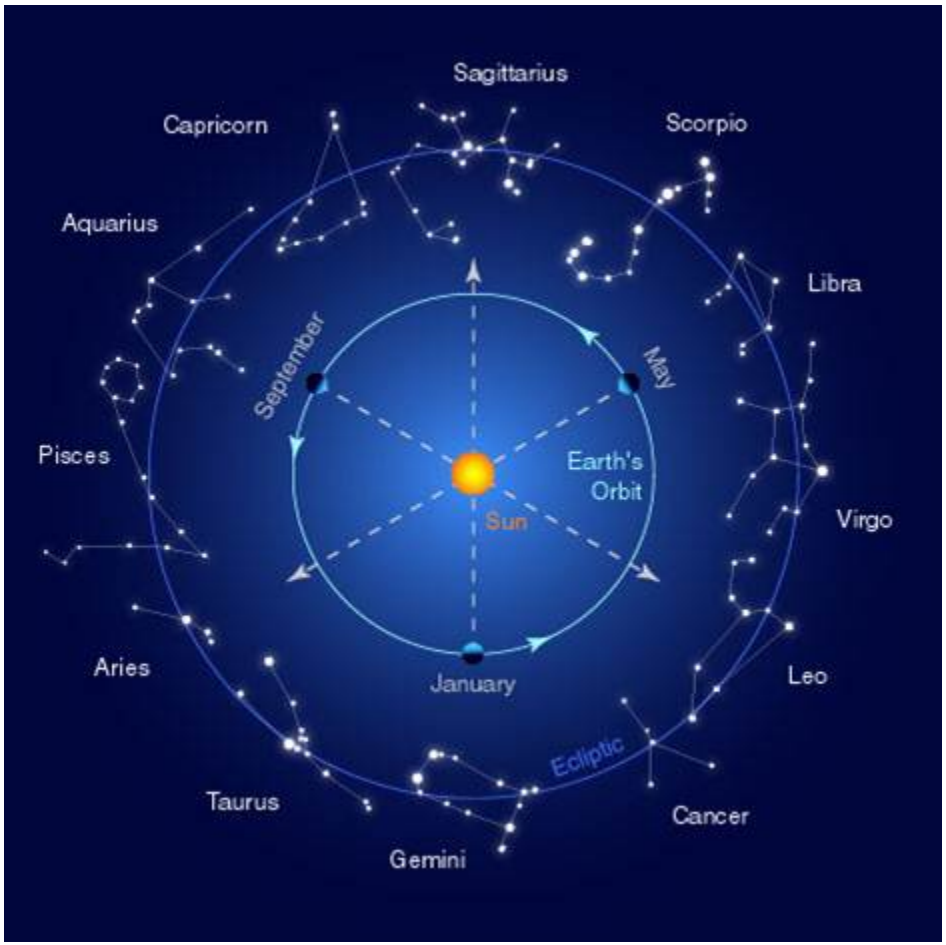


The time it takes for the Sun to return to the same position in the sky relative to the fixed stars. E.g. passage of the Sun from 0° ecliptic longitude all the way around to it again.

equal to the period of Earth's orbit around the Sun. **365d 6h 9m 9.76s** (31,558,149.76 seconds, 365.2563630 days)

Fun fact: take the sidereal year (in seconds) and divide by the sidereal day (in seconds) to compute the number of spins Earth makes in one orbit…

Sidereal Year



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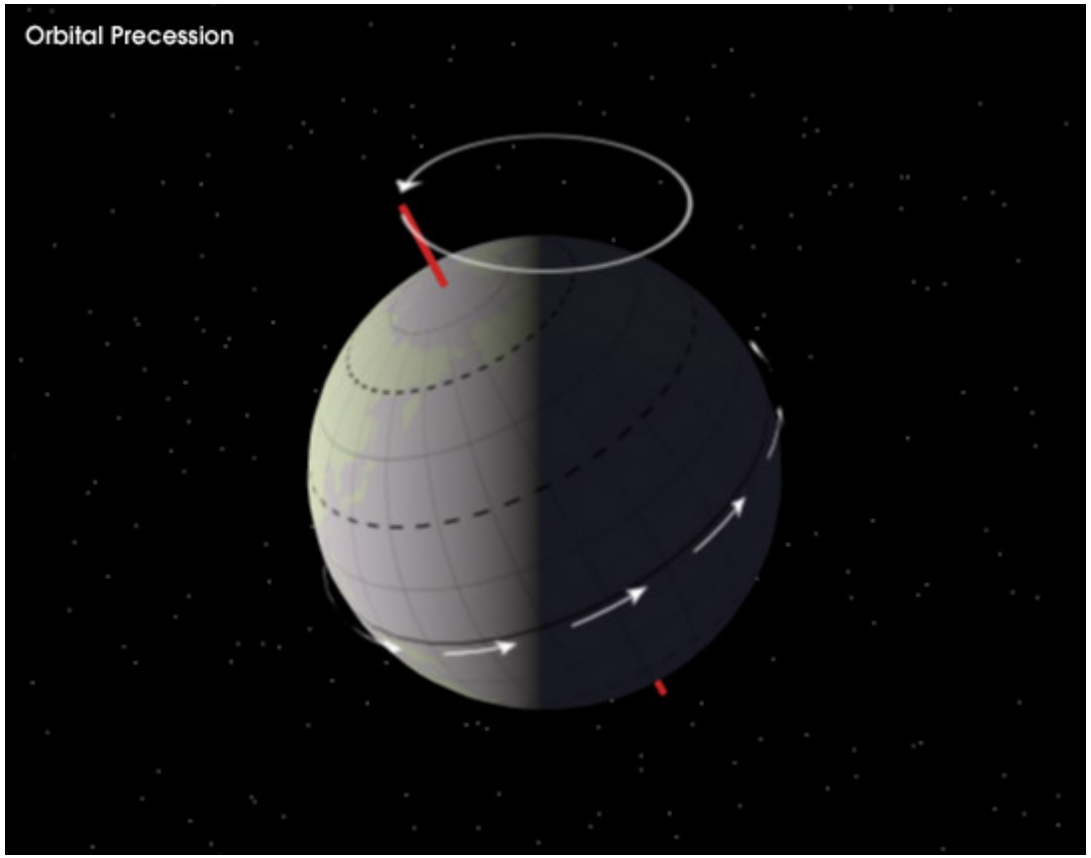
Precession of the Equinoxes



Earth's axis precesses because of the gravitational tug of the Moon on Earth.

The period of this motion is nearly 26,000 years (25,771 years) and *is not constant*.

It causes the solar year to be shorter than the sidereal year by **1 day every 71 cycles**.

It means that the constellations visible during our current seasons are now one month different from 2,000 years ago.

Lunar New Year

Moon's orbit is not in gravitational resonance with Sun. Therefore there are no rational cycles of the Moon with the Earth's orbit.

Calendars attempting to combine the cycle of the *Moon's phases* with the *Seasons* are doomed to be irregular.

The best cycle of the Moon with the Seasons is the Metonic cycle, named after the ancient Greek astronomer Meton of Athens:

6,940 days
= 19.0011 Tropical Years
= 235.0106 Lunations
(slips 1 day every 10 cycles).

Islamic Hijri Calendar 2013- 1434

Muharram (Nov/Dec)

Su	Mo	Tu	We	Th	Fr	Sa
				15 U 1	16 2	17 3
18 4	19 5	20 6	21 7	22 8	23 9	24 10
25 11	26 12	27 13	28 14	29 15	30 16	1 Dec 17
2 18	3 19	4 20	5 21	6 22	7 23	8 24
9 25	10 26	11 27	12 28	13 29	14 30	

Safar (Dec/Jan)

Su	Mo	Tu	We	Th	Fr	Sa
					14 U*	15 1
16 2	17 3	18 4	19 5	20 6	21 7	22 8
23 9	24 10	25 11	26 12	27 13	28 14	29 15
30 16	31 17	1 Jan 18	2 19	3 20	4 21	5 22
6 23	7 24	8 25	9 26	10 27	11 28	12 29

Rabi-I (Jan/Feb)

Su	Mo	Tu	We	Th	Fr	Sa
13 U 1	14 2	15 3	16 4	17 5	18 6	19 7
20 8	21 9	22 10	23 11	24 12	25 13	26 14
27 15	28 16	29 17	30 18	31 19	1 Feb 20	2 21
3 22	4 23	5 24	6 25	7 26	8 27	9 28
10 29	11 30					

Rabi-II (Feb/Mar)

Su	Mo	Tu	We	Th	Fr	Sa
	11 U*	12 1	13 2	14 3	15 4	16 5
17 6	18 7	19 8	20 9	21 10	22 11	23 12
24 13	25 14	26 15	27 16	28 17	1 Mar 18	2 19
3 20	4 21	5 22	6 23	7 24	8 25	9 26
10 27	11 28	12 29				

Jumada-I (Mar/Apr)

Su	Mo	Tu	We	Th	Fr	Sa
			13 U 1	14 2	15 3	16 4
17 5	18 6	19 7	20 8	21 9	22 10	23 11
24 12	25 13	26 14	27 15	28 16	29 17	30 18
31 19	1 Apr 20	2 21	3 22	4 23	5 24	6 25
7 26	8 27	9 28	10 29	11 30		

Jumada-II (Apr/May)

Su	Mo	Tu	We	Th	Fr	Sa
				11 U*	12 1	13 2
14 3	15 4	16 5	17 6	18 7	19 8	20 9
21 10	22 11	23 12	24 13	25 14	26 15	27 16
28 17	29 18	30 19	1 May 20	2 21	3 22	4 23
5 24	6 25	7 26	8 27	9 28	10 29	11 30

Rajab (May/Jun)

Su	Mo	Tu	We	Th	Fr	Sa
12 1	13 2	14 3	15 4	16 5	17 6	18 7
19 8	20 9	21 10	22 11	23 12	24 13	25 14
26 15	27 16	28 17	29 18	30 19	31 20	1 Jun 21
2 22	3 23	4 24	5 25	6 26	7 27	8 28
9 29						11/05 U*

Sha'ban (Jun/Jul)

Su	Mo	Tu	We	Th	Fr	Sa
	10 U 1	11 2	12 3	13 4	14 5	15 6
16 7	17 8	18 9	19 10	20 11	21 12	22 13
23 14	24 15	25 16	26 17	27 18	28 19	29 20
30 21	1 Jul 22	2 23	3 24	4 25	5 26	6 27
7 28	8 29	9 30				

Ramadan (Jul/Aug)

Su	Mo	Tu	We	Th	Fr	Sa
		9 U*	10 1	11 2	12 3	13 4
14 5	15 6	16 7	17 8	18 9	19 10	20 11
21 12	22 13	23 14	24 15	25 16	26 17	27 18
28 19	29 20	30 21	31 22	1 Aug 23	2 24	3 25
4 26	5 27	6 28	7 29	8 30		

Shawwal (Aug/Sep)

Su	Mo	Tu	We	Th	Fr	Sa
				8 U*	9 1	10 2
11 3	12 4	13 5	14 6	15 7	16 8	17 9
18 10	19 11	20 12	21 13	22 14	23 15	24 16
25 17	26 18	27 19	28 20	29 21	30 22	31 23
1 Sep 24	2 25	3 26	4 27	5 28	6 29	

Dhul Qa'dah (Sep/Oct)

Su	Mo	Tu	We	Th	Fr	Sa
6 30						7 U 1
8 2	9 3	10 4	11 5	12 6	13 7	14 8
15 9	16 10	17 11	18 12	19 13	20 14	21 15
22 16	23 17	24 18	25 19	26 20	27 21	28 22
29 23	30 24	1 Oct 25	2 26	3 27	4 28	5 29

Dhul Hijjah (Oct/Nov)

Su	Mo	Tu	We	Th	Fr	Sa
6 U*	7 1	8 2	9 3	10 4	11 5	12 6
13 7	14 8	15 9	16 10	17 11	18 12	19 13
20 14	21 15	22 16	23 17	24 18	25 19	26 20
27 21	28 22	29 23	30 24	31 25	1 Nov 26	2 27
3 28	4 29					

*Date of Saudi Umm Al-Qura calendar is 1-day ahead of predicted crescent visibility (Imkan e Ruyat)!

12 months matching lunar phases.

In some traditions the new month is not declared until it has been officially observed. Other traditions use “official” tables of lunar phases, which may become out of synch since the period of lunation is variable on short time scales.

Each Islamic year lasts 354 or 355 days and the cycle of the seasons repeats every 11,900.25 days (32.6 tropical years, 33.6 Islamic years).

Current year is 1434 since Muhammad emigrated from Mecca to Medina

Chinese Calendar

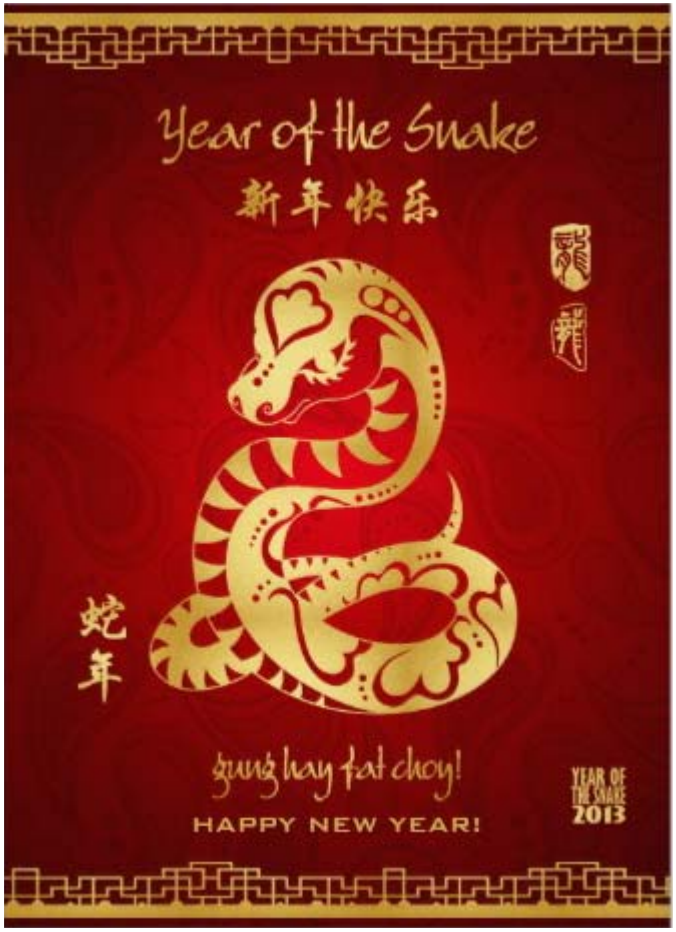
Earliest physical evidence for the use of the calendar goes back to the 1300s BCE. It has been modified significantly over the ages into its present form.

It is ***lunisolar***; it combines both lunar and solar rules in determining the length of the year.

Each year has 12 regular lunar months of 29 or 30 days (numbered 1-12 and sometimes named), each beginning with the new moon.

The winter solstice always occurs in the 11th month. So Chinese New Year will occur on the 2nd new moon following the Winter Solstice, unless there is a leap month following either month 11 or month 12, which is relatively rare.

Chinese Calendar



Every 2nd or 3rd year has a leap month that is numbered the same as the preceding month, but designated as such. A year will have a leap month if there are 13 new moons between winter solstices. The month that will have the repeated number is determined based on the number of so-called *principle solar terms* in that month. The first month in a leap year where there is no principle solar term is designated the leap month.

The Chinese designate 24 equally-spaced stations of the Sun along the ecliptic as “solar terms”, which includes the equinoxes and the solstices. Every other station is a “principle solar term:” those solar stations at ecliptic longitudes of 315, 345, 15, 45, 75, 105, 135, 165, 165, 195, 225, 255, 285 (the vernal equinox is at 0-degrees, and winter solstice at 270-degrees).

The next Chinese New Year occurs February 10, 2013.

Maya Tzolk'in

Used throughout Mesoamerica with different day names for different cultures. Probably invented by the Olmec civilization nearly 3,000 years ago.

260 days: 13 numbered days cycling with 20 named days

Not explicitly tied to any astronomical cycle, however:

- 6 days shy of 9 lunations
- Venus spends about 9 months as either the morning star or evening star (disappears for a while during superior and inferior conjunction).
- 260 days between solar zenith passage to winter solstice back solar zenith passage again at the ancient cities of Copan and Izapa (occurs on August 13, the start of the Long Count, GMT+2 correlation)
- 3 x 260 = 780 days = 1 synodic period of Mars
- 2 x 260 = 520 ~ 519 = 3 x 173 (period between Sun/Moon eclipse seasons)

Appears to have been used in predicting appearances of Mars or Eclipses and deciding if they would be good or bad omens based on their Tzolk'in dates.

Maya Haab

365 days, “solar calendar, ”
used since about 500 BCE in Mesoamerica.

18 named “months” (Winal) with 20 numbered days, plus one month of 5 days (Wayeb).

1 day slip every 4 years, 13 days every Calendar Round of 52 Haab (73 Tzolk’in),

1508 Haab = 1507 Tropical Years

A few inscriptions indicate knowledge of this, showing amounts of 754 Haab = 1508/2, which would indicate knowledge of the true length of the tropical year equal to 365.2422 days (*a difference of only 1 second*).

1,508 Haab
= 2,117 Tzolk’in
= 29 Calendar Rounds
= 1,507 Tropical Years

Julian Calendar

A solar calendar, invented by the Roman Empire to simplify their earlier lunar calendar.

Named for Julius Caesar. Introduced in 45 BC (709 AUC in the reckoning of Rome, i.e. 709 years since the founding of Rome).

Years are an average of 365.25 days, with a cycle of 3 years with 365 days followed by 1 year of 366 days.

Each year is divided into **12 months**:

Month Name (English)	Length (days)
January	31
February	28 (29 during leap years)
March	31
April	30
May	31
June	30
July	31
August	31
September	30
October	31
November	30
December	31

Relative to the Solar Year (365.2421897 days) it **slips one day every 128 Julian years**

In Roman use, years were not normally numbered but denoted by the names of the two consuls who took office during a particular year.

During Imperial Rome they also used the number of the year of the reign of the current emperor. Roman historians would sometimes use the AUC reckoning since the founding of Rome.

Julian Calendar

The *Anno Domini* era was invented in 525 AD by Dionysius Exiguus, a Roman monk. The idea was to number years since the incarnation of Jesus Christ. Exactly how he calculated that his current year was 525 is unknown, but some evidence points toward *astrological* reasons.

AD = Anno Domini (Year of our Lord)
= CE = Christian Era = Common Era

BC = Before Christ
= BCE = Before the Common Era

Anno Domini Era was not widely used until 731 when Saint Bede used it to date events in his *Ecclesiastical History of the English People.*

Note that modern theologians and scholars have determined that the likely date of the birth of Jesus Christ was sometime between 6—4 BC.

There was no year 0.
Year 1 AD was preceded by 1 BC.

The 7-day Week

The 7-day week has been used in Christian Europe in an unbroken way for nearly 2,000 years, given to the tracking of Easter Sunday as far back to at least 311 AD.

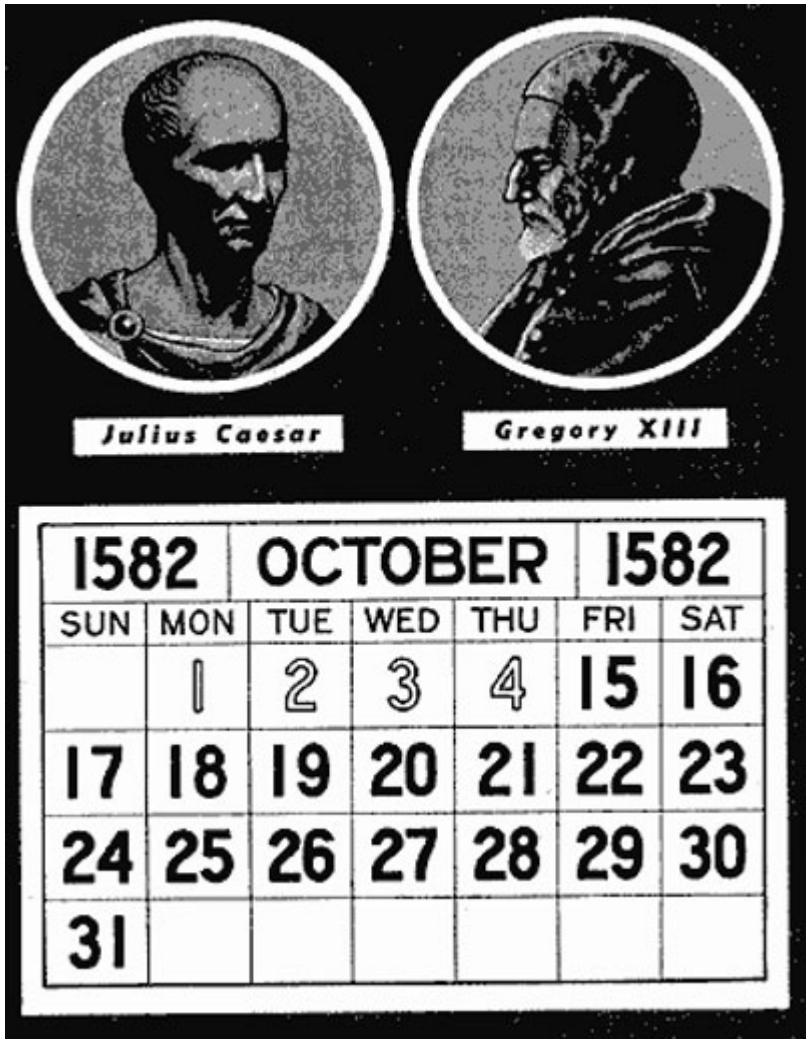
Probably began in ancient Babylonian or Jewish traditions. The 7 days are related to the creation story of *Genesis*: Earth is created by God in 6 days and he rests on the 7th.

It may have been used to track the phases of the Moon as 7 days is nearly 1/4th of a lunation.

There were 7 "planets" observed by the ancients: Sun, Moon, Mars, Mercury, Jupiter, Venus, Saturn and the Latin names for the week days maintain those associations:

Weekday Name (English)	Weekday Name (Latin)	Planet
Sunday	Dies Solis	Sun
Monday	Dies Lunae	Moon
Tuesday	Dies Martis	Mars
Wednesday	Dies Mercurii	Mercury
Thursday	Dies Jovis	Jupiter
Friday	Dies Veneris	Venus
Saturday	Dies Saturni	Saturn

Gregorian



By the late 16th century, 10 days slip between the date of the Spring equinox had accumulated such that it was occurring on March 11th rather than the 21st.

Since the date of the Spring Equinox is used by the Catholic Church to calculate the date of Easter, this slip was concerning to them and they wished to correct the error and keep the calendar more in synch with the Tropical Year.

Enacted by Pope Gregory XIII and took effect in October 1582 A.D.

The last day of the Julian calendar was Thursday, 4 October 1582 and this was followed by the first day of the Gregorian calendar, Friday, 15 October 1582 (the cycle of weekdays was not affected).

2013

JANUARY

Mo	Tu	We	Th	Fr	Sa	Su
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

FEBRUARY

Mo	Tu	We	Th	Fr	Sa	Su
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28			

MARCH

Mo	Tu	We	Th	Fr	Sa	Su
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

APRIL

Mo	Tu	We	Th	Fr	Sa	Su
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

MAY

Mo	Tu	We	Th	Fr	Sa	Su
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

JUNE

Mo	Tu	We	Th	Fr	Sa	Su
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

JULY

Mo	Tu	We	Th	Fr	Sa	Su
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

AUGUST

Mo	Tu	We	Th	Fr	Sa	Su
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

SEPTEMBER

Mo	Tu	We	Th	Fr	Sa	Su
30						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29

OCTOBER

Mo	Tu	We	Th	Fr	Sa	Su
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

NOVEMBER

Mo	Tu	We	Th	Fr	Sa	Su
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

DECEMBER

Mo	Tu	We	Th	Fr	Sa	Su
30	31					1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29

Gregorian

Every year exactly divisible by 4 is a leap year, except for those years exactly divisible by 100.

(Every 100th year is not a Leap Year, except every 400th which is.)

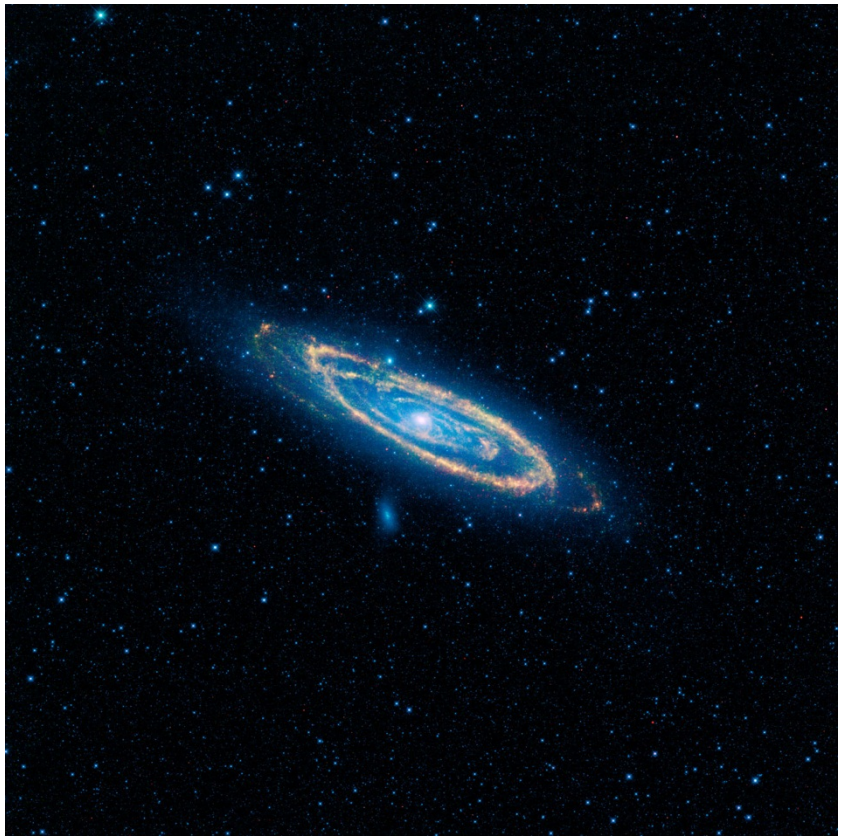
Average year length = 365.2425 days

Difference of 26.81 seconds from the Tropical Year

3,222.68 years for a 1 day slip to build up between the tropical and Gregorian cycles

It took centuries for countries around the world to adopt it. The last major nation to do so was China in 1929. Britain (including the American Colonies) adopted the Gregorian calendar in September 1752 such that Wednesday September 2, 1752 was the last day of the Julian calendar and Thursday, September 14, 1752 was the first day on the Gregorian calendar.

Julian Day Calendar



Modern astronomers use a calendar called the **Julian day number (JDN)** calendar. It is simply a count of days (and fraction thereof) since noon Universal Time on January 1, 4713 BCE on the proleptic Julian Calendar. 0h UT corresponds to a Julian date fraction of 0.5.

The calendar was proposed at the time of the adoption of the Gregorian Calendar (1583) by a French Historian named Joseph Scaliger. He took three cycles used with the Julian Calendar and multiplied them together: the 15-year indiction cycle (used for dating governmental documents in medieval Europe), the 19-year Metonic cycle that matches lunar phases to the tropical year, and the 28-year cycle of 7 week-days with Julian calendar dates (Leap day takes 28 years to cycle through the week days in the Julian Calendar). This is gives a period of 7,980 years for all three cycles to start together. He then looked back in time to when they all had last started together, which was January 1, 4713 BCE. Since that was well before recorded history in any culture it seemed a fitting place to start the calendar.

JDN is used to correlate calendars of different cultures. Many software programs use JDN for time keeping. Astronomers often use JDN in recording observation times.

JDN for the start of this Webinar was 2,456,322.375000

Astronomical Year

Exact definitions for time periods are needed in modern astronomy because the motions of Earth, the Moon, and the Sun are not constant.

Scientific time keeping now uses the second as the primary unit of time.

1 second = the duration of 9,192,631,770 periods of the microwave radiation corresponding to the transition between two hyperfine levels of the ground state of the cesium 133 atom.

originally defined astronomically as 1/86,400 of a mean solar day. But Earth's rotation rate is slowing, making the definition of 1 second imprecise over time.

1 minute = 60 seconds

1 hour = 60 minutes x 60 seconds/minute = 3,600 seconds

1 day (mean solar day) = 24 hours x 3,600 seconds/hour = 86,400 seconds

An astronomical year is defined to be exactly 365.25 days (31,557,600 seconds), where days are exactly 24 hours (86,400 seconds) long.