A leap forward

by Bob Riddle

The author's timepiece.

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Because 2016 is a leap year, the month of February will feature an extra day. Why do we add a day to the calendar every four years? A difference in timing exists between the calendar we use and the actual length of a year. A *year* is the time it takes the Earth to *orbit*, or *revolve*, once around the Sun. Our yearly calendar contains 365 days; however, it actually takes approximately 365.25 days for the Earth to complete one revolution around the Sun. We must take that extra quarter day into account to keep our calendar in sync with the Earth's actual length of revolution and, in particular, with the seasons on Earth. The quarter day is dropped for three consecutive years, and every fourth year, these quarter days are added back as one day at the end of February. Today, we follow a basic rule for determining whether it is a leap year: Any year divisible by 4 is a leap year, and a century year (e.g., 2000, 2100) is only a leap year when it is divisible by 400 (see Figure 1).

As far back in history as the Paleolithic era, humans have attempted to track time precisely; however, many centuries passed before a consistent method for synchronizing a human-made calendar with the natural cycle of an Earth revolution was established. It is possible that the first attempts at creating a calendar were based on the easily observable lunar cycle. What we now call a month was determined by how long it took the Moon to return to the same waxing-crescent phase over the western horizon. This period of the Moon's revolution with regard to phases is known as the *synodic month*, and it occurs over an average of 29.5 days (29.18–29.93 days). The Moon's actual period of revolution, with regard to the stars in the background, is the *sidereal month*, which is 27.3 days in length. The difference between the synodic and sidereal months is in the approximately two days needed for the Earth, Moon, and Sun to return to the same arrangement and Moon phase. Each lunar cycle was given a name related local customs or beliefs. The names of our modern months have their origin in names of Roman gods (e.g., Janus), rulers (e.g., Julius Caesar), or the number of the month in the year (e.g., October) (see Resources).

FIGURE 1 Rules for determining a leap year

Yes if the year is evenly divisible by 4

Yes if the year is evenly divisible by 400

No if the year is evenly divisible by 100

A year traditionally measured how many months, or lunar cycles, it took to return to the same time during the year, for example, the time at which crops could be planted or a change in seasons (see Figure 2). This measurement represents the *solar* or *tropical* year, because it spans one solstice or equinox to its next occurrence 12 months later. Since some months coincided with significant events, such as planting and harvesting; these events might have been the precursors of calendar dates such as religious events, New Year's, and even tax collection.

The method of counting lunar cycles has its limitations. When weather interfered with a Moon sighting, it was hard to keep track of where the Moon was in its cycle. Additionally, a year measured using the length of lunar months is not the same a year measured from vernal equinox to vernal equinox. A lunar-month calendar system would slowly fall out of sync with the solar year. An average lunar cycle lasted 30 days; 12 cycles comprised a 360-day year.

Many ancient cultures further divided the year based on local climate and seasonal change. The annual flooding of the Nile River from rains in mountains to the south and the use of a lunar cycle–based system led to refinements of the ancient Egyptian. Because the Nile flooded between June and October, the Egyptians had to know as accurately as possible when the flooding would begin and when it would be at its greatest. Over time, Egyptian astronomers noticed that the first sightings of the star Sirius in June, as it rose ahead of the Sun, corresponded with the beginning of the annual flooding of the Nile River. From these observations, and from carefully counting the days until Sirius and the Sun next appeared in the same respective positions, the Egyptians realized that the 360-day year was five days too short. The Egyptians thus added five days to each year, resulting in the 365-day year.

"Thirty days hath September ..."

Most of us know or have heard this poem, or some variation of it, which reminds us of how many days are in teach month (see Resources for similar poems). Have you ever wondered about how the number of days in each month was decided? Our modern-day calendar has a fascinating history of adjustments, rooted in part in ancient Roman methods.

The Romans used a 10-month calendar that started with what we now call March (Figure 3). Each month consisted of 30 or 31 days, creating a year that was approximately 300 days in length. Their calendar was divided into three parts focused primarily on planting, growing, and harvesting. To the Romans' agricultural society, the other 60 days of the ancient year were unimportant, and so those days were ignored. However, because of its length, this calendar fell out of sync with seasons, so an additional two *intercalary* months, January and February, were added at the beginning of the calendar. This shifted the names of the original months forward in the new, 12-month calendar; for example, in the 10-month calendar, September was the seventh month and October was the eighth month, but after inserting the extra two months, September became the ninth month and October became the 10th month. However, the Roman calendar was still not the same length as the seasonal year. It wasn't until the reigns of Julius Caesar and Augustus that the Roman calendar was modified to look more like our present-day calendar.

Taxes and debts, even back then, were a part of life. These were collected on the same day at regular intervals, based on the first sighting of the waxing-crescent Moon phase. This day was known as *Kalendae* or *Calends*, meaning "calling" or "announcement." *Calends* was also the name of the first day of the month.

It was from the Calends that the Romans would count days until the next Calends. Those next days were then divided into sections. The most familiar is probably the word *ides* from Shakespeare's famous warning to "beware the Ides of March." Ides is the

FIGURE 2 Lengths of an Earth year (Ottewell 1981)

Name of year	Length (days)	How measured
Anomalistic year	365.2596	Perihelion to perihelion
Sidereal year	365.2564	Relative to fixed stars in background
Calendar year	365	Number of days between January 1 and December 31
Tropical year	365.2422	Equinox to equinox

FIGURE 3 10-month Roman calendar

1. Martius: 31 days
2. Aprilis: 30 days
3. Maius: 31 days
4. Iunius: 30 days
5. Quintilis: 31 days
6. Sextilis: 30 days
7. September: 30 days
8. October: 31 days
9. November: 30 days
10. December: 30 days

15th day counted after the Calends. Ides were approximately mid-month or mid–lunar cycle. An additional two days, the *Nones* or *Nonae* roughly corresponded with the two quarter phases of the Moon.

It's all about time

Time is measured in a variety of ways, ranging from extremely accurate to rougher estimates. While the latter often uses the position of the Sun or the shadows the Sun casts, the former refers to how long it takes for 9,192,631,770 vibrations to be emitted by a heated cesium atom. This precise number gives us the length of time we know as one second.

One of the easiest ways to track time during the daylight hours is by following the changing position of shadows as the Earth rotates. Through the use of an easily made sundial (see Resources), students could approximate solar time. Regular use of the sundial also enhances student understanding of the effect the Earth's axial tilt and revolution have on the apparent path the Sun follows each day, seasons, and changing lengths of day and night. Additionally, an interesting relationship exists between the length of a shadow, the height of the Sun above the horizon, and latitude: The shadow is longer when the Sun is lower, and it is shorter when the Sun is higher. I was fortunate to explore this relationship during visits to Quito, Ecuador, when students there and at schools in the United States and United Kingdom combined their efforts to observe and measure the angle of the Sun hourly on the day of the equinox. The altitude of the Sun at midday local time was of special interest because of the difference in the appearance of the shadow at each latitude location (see Project SunShIP in Resources).

The Sun's shadow was also put to use by Eratosthenes (276 BCE–194 BCE), a Greek mathematician, astronomer, and librarian of the Library of Alexandria in Egypt. He is perhaps best known for using shadows to calculate the circumference of the Earth (see the Resources for a link to an explanation of what Eratosthenes measured). ■

Visible planets

Mercury will be visible over the eastern horizon before sunrise this month.

Venus will be visible over the eastern horizon before sunrise this month.

Mars will rise after midnight and will be visible over the southern horizon at sunrise.

Jupiter will rise after sunset and will appear over the western horizon at sunrise.

Saturn will rise after midnight and will be visible over the southeastern horizon at sunrise.

February

1	Last quarter Moon near Mars
	Cassini flyby of Titan
2	Groundhog Day
3	Waning crescent Moon near Saturn
6	Very thin waning crescent Moon near Venus and Mercury
	Mercury at western elongation
8	New Moon
	Lunar New Year
9	Very thin waxing crescent Moon near Neptune
10	Moon at descending node
	Moon at perigee: 364,358 km (226,401 mi.)
12	Mercury near Venus
14	*Cassini* flyby of Polydeuces

15 First quarter Moon
Galileo Day
Cassini flyby of Telesto, Epimetheus, and Titan
16 Waxing gibbous Moon near Aldebaran
Cassini flyby of Titan
21 Mercury at Aphelion
Waxing gibbous Moon near Regulus
22 Full Moon
23 Waning gibbous Moon near Jupiter
24 Moon at ascending node
27 Waning gibbous Moon near Spica
Moon at apogee: 405,383 km (251,893 mi.)
28 Neptune in conjunction with Sun
29 Waning gibbous Moon near Mars

Reference

Ottewell, G. 1981. *The astronomical companion*. Cambridge, MA: Sky Publishing Corporation.

Resources

Calendars Through the Ages—*www.webexhibits.org/calendars/calendar-ancient.html*
Carl Sagan and Eratosthenes—*http://youtu.be/0ZLI7WZZRJQ*
Cassini Solstice mission—*http://saturn.jpl.nasa.gov*
Days of the month poems—*http://leapyearday.com/content/days-month-poem*
Galileo Day—*www.galileoday.org*
Groundhog Day—*www.groundhog.org/about*
Hebrew calendar—*www.hebcal.com/holidays*
History of time measurement—*http://nrich.maths.org/6070*
How is time measured—*http://topics.info.com/How-is-time-measured_3093*
How to make sundials—*www.angelfire.com/my/zelime/sundials.html*
Make a sundial—*www.bbc.co.uk/norfolk/kids/summer_activities/make_sundial.shtml*
Number of days in a month—*www.quora.com/What-determines-how-many-days-are-in-a-month*
Project SunShIP—*http://sunship.currentsky.com/index.html*
Space Math: Changes in Earth's rotation and day length—*http://spacemath.gsfc.nasa.gov/Grade67/6Page58.pdf*
Time divisions—*www.scientificamerican.com/article/experts-time-division-days-hours-minutes*
What is the shape of the Earth?—*http://currentsky.com/activities/shape/index.html*
Why the number of days in a month isn't equal—*www.wisegeek.com/why-are-the-number-of-days-in-a-month-not-equal.htm*

For students

1. Make a sundial and explore the differences between local Sun time and standard clock time. *(Local time determined by the Sun is based on the observer's longitude and the position of the Sun above the horizon. Local Sun time can be measured with a sundial. Standard clock time is also based on longitude, but each unit of standard time covers an entire time zone that is 15° wide, regardless of the position of the Sun above the horizon.)*
2. What is the shape of the Earth (see Resources)?
3. What is the Earth's circumference? *(Eratosthenes's method measures the polar circumference [24,860 mi.; 40,008 km] of the Earth, which, due to the planet's oblate spheroid shape [i.e., flattening of the poles], is slightly less than the equatorial circumference [24,901 mi.; 40,074 km].)*
4. At the Space Math website (see Resources), students can use tabulated data for the number of days in a year (from 900 million years ago to the present) to estimate the rate at which an Earth day has changed, using a linear model.

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