YEARS, MONTHS, DAYS

The quest for the perfect calendar

> To everything there is a season, and a time to every purpose under the heaven.
>
> – Ecclesiastes 3:1

Every fall – or nearly every fall – talk-show host David Letterman dips into his bag of tried-and-true seasonal jokes and pulls out a nugget that goes something like this: “So, Happy New Year to all our Jewish friends out there. Today is Rosh Hashanah, the Jewish New Year. This marks the beginning of the year 5769 in the Jewish calendar” – as it would be in the 2009 version of the joke. “Now, are you like me? Are you still writing 5768 on your checks?” (Cue rim-shot from the drummer, and a guffaw from bandleader Paul Shaffer.) Of course, no one – not even Orthodox Jews living in Jerusalem – writes 5768 or 5769 on their checks. Instead, everyone from Seattle to Singapore uses – for civil purposes, at least – the Gregorian calendar, a remarkable invention that incorporates the ideas of the Babylonians and the Egyptians, modified by the Romans, and polished into its modern form by a sixteenth-century pope and a team of nearly forgotten astronomers and mathematicians. The Gregorian calendar is one of the most successful ideas in the history of civilization. (Richard Dawkins might call it a successful “meme” – a unit of cultural information that propagates over time.)

The Gregorian calendar is not the only timekeeping system invented by humankind – nor, as we’ll see, is it even (by some measures) the most accurate. But its story is a noteworthy one, an achievement centuries, even millennia, in the making. We saw in the previous chapter how early humans were captivated by – and began to follow – the regular motions of the night sky. By the time of the great ancient civilizations, such systematic observation had become a virtual industry; every culture would develop some sort of calendar for mapping out the year, based on their observations of the heavens and their own particular needs and priorities. The one that rules today – the Gregorian Christian calendar – exploits ideas from many different cultures, each with a unique perspective on the significance of the heavenly bodies and unique solutions to the problem of tracking their motions. In this chapter we'll take a look at some of the challenges confronting would-be calendar makers through the ages, as they tried to tame the myriad of motions displayed by the sun, moon, and stars.

The first rudimentary steps toward tracking those celestial motions, as we've seen, may have occurred as early as the Paleolithic period. But it is only with the rise of the first civilizations – marked by complex, agriculture-based urban settlements with full-blown writing systems – that we can be certain that people were keeping track of days, months, and years. Making sense of those celestial cycles, however, is complicated by the fact that neither the number of days in the lunar cycle nor the number of lunar cycles in a year is a nice round number (indeed, not even a whole number). The lunar month, as mentioned earlier, is about 291/2 days long (actually 29.5306); the average solar year (also known as the "tropical" year) is about 3651/4 days long (actually a smidgeon less, at 365.2422 days). That these cycles did not fit neatly into one another was well known: back in the fifth century B.C., the Greek poet Aristophanes, in his play *The Clouds*, had the moon complaining that the days refused to keep pace with her phases.

Incongruent Cycles

Try dividing the length of the year by the length of the lunar month, and again you get a fractional number, greater than 12 but less than 13 – the true figure is close to 12.3683. Over the millennia, different civilizations tried every possible trick for reconciling these incongruent cycles. Some simply rounded the length of the month up to 30 days, a practice adopted by the ancient Sumerians; 12 such months yield a 360-day year, just 5 days (roughly) short of the true solar year. Others used a more precise length for the lunar cycle and then assumed there were exactly 12 months in a year: the result is a year that is 354 days long – 11 days short (roughly) of the true solar year. Adopt such a calendar, and each New Year's celebration will be 11 days earlier than it was the year before. A midsummer celebration would become a midwinter celebration after just 16 years.

Any calendar system that uses the phases of the moon to track the months but also attempts to reconcile those months with the cycle of the seasons is called a *luni-solar* calendar. The Babylonians adopted one such system. A new month was determined by the first sighting of the crescent moon in the western sky – a practice that continues in Muslim nations to this day (notice how many Muslim nations feature the crescent moon on their flag). To keep the months in step with the solar year, the Babylonians employed a cycle in which seven 13-month years alternated with 12 years of just 12 months. The result was a 19-year cycle known as the Metonic cycle, after the Greek astronomer Meton of Athens, who lived in the fifth century B.C. (Meton discovered that 235 lunar months amount to almost exactly the same interval as 19 solar years; a calendar based on this cycle would deviate from the true solar year by just 1 day every 219 years.)*

Beginning in the second millennium B.C., the extra month would be added – "intercalated" – following either the sixth month (Ululu) or the twelfth month (Addaru) of the Babylonian calendar. We have a record dating from the nineteenth century B.C. of King Hammurabi's decree on just such an adjustment:

> This year has an additional month. The coming month should be designated as the second month Ululu, and wherever the annual tax has been ordered to be brought in to Babylon on the 24th of the month of Tashritu it should now be brought to Babylon on the 24th of the second month of Ululu.

The Jewish calendar is closely modeled on the Babylonian. (The mutual influence of the two cultures can be traced back to the sixth century B.C., when Babylon, under Nebuchadnezzar II, conquered Jerusalem; the Jewish people spent the next 70 years or so in exile.) The Jewish calendar, like the Babylonian, is built on the nineteen-year Metonic cycle, with its combination of 12-month and 13-month years. Within that cycle, the lengths of certain months can also vary, so that a "regular" year can be 353, 354, or 355 days long, while a leap year (containing an extra month) can be 383, 384, or 385 days long. (This is why the date of Jewish holidays such as Hanukkah leaps around so much with respect to the Gregorian calendar.)

The Rhythm of the River

The ancient Egyptians had different priorities from the Babylonians: in the Egyptian year, the most important event is the annual late-summer flooding of the Nile River. The floods bring life to the desert; the river is the focal point of Egyptian civilization. It is no wonder that the Greek historian Herodotus, describing the geography of Egypt in the fifth century B.C., referred to “the gift of the Nile.” The Egyptians could predict the annual flooding by carefully tracking the brightest star in the sky, Sirius (which they equated with the god Sothis, a serpent). Every spring, Sirius disappears for several weeks, hidden by the sun’s glare; to the Egyptians, this was the serpent’s journey through the underworld. The New Year was at hand when Sirius first became visible again in the predawn sky (in modern astronomical jargon, its “heliacal rising”); its return heralded the imminent flooding of the Nile. The importance of Sirius in Egyptian astronomy is reflected in its grandest monuments, including the Great Pyramid of Cheops in Giza. The narrow shafts that lead into the central chambers are believed to be aligned with the path that Sirius traces across the sky. (We’ve retained at least one colloquial saying from this bit of calendrical lore: the return of Sirius, the “Dog Star,” heralds the “dog days” of summer.)

With the annual flooding as their first concern, the Egyptians abandoned the moon in favor of a solar calendar. They still used months – 12 of them, each 30 days long – but their months rolled along independently of the actual phase of the moon. That, of course, adds up to only 360 days – so they added 5 days for religious celebration at the end of the year. The resulting year of 365 days is only about a quarter-day short of the true solar year. Interestingly, the Egyptians recognized that slight shortfall very early on; they realized that adding a quarter-day to the year (or an additional day every four years) would bring the calendar within just a few minutes of the true solar year. Yet centuries would pass before the change was adopted by the priests in charge of the calendar system. It wasn't until 238 B.C. that the Egyptian king Ptolemy III urged the adoption of a leap-year system. (Egypt's rulers at this time were Hellenistic Greeks, and Ptolemy himself – not to be confused with the famous astronomer who lived many centuries later – may have been advised on astronomical matters by Aristarchus of Samos, the noted Greek astronomer and mathematician who promoted the idea of a heliocentric universe some 18 centuries before Copernicus.) However, another two centuries would pass before the leap year was adopted. The conquest of Egypt by Rome finally forced the issue; the emperor Augustus made the Egyptians adopt the leap year to bring the Egyptian calendar in line with the Julian calendar used in Rome.

Caesar's Calendar

The Romans, like the early Egyptians, initially used a calendar of twelve lunar months, with extra days or months inserted from time to time to keep in sync with the seasons. The system was far from perfect: as writer David Ewing Duncan explains, it suffered both from neglect and from political manipulation. The priests in charge of the calendar, he writes, "sometimes increased the length of the year to keep consuls and senators they favoured in office longer, or decreased the year to shorten rivals' terms." They also used the calendar "to increase or decrease taxes and rents, sometimes for their personal financial advantage." By the time of Julius Caesar, the Roman calendar was in desperate need of reform. As the Greek historian Plutarch tells us, the Romans wanted to establish

> a certain rule to make the revolutions of their months fall in with the course of the year, so that their festivals and solemn days for sacrifice were removed by little and little, till at last they came to be kept at seasons quite the contrary to what was at first intended, but even at this time the people had no way of computing the solar year; only the priests could say the time, and they, at their pleasure, without giving any notice, slipped in the intercalary month.

Caesar's reform was "projected with great scientific ingenuity," Plutarch writes, for the emperor "called in the best philosophers and mathematicians of his time to settle the point," in the end adopting "a new and more exact method of correcting the calendar." Under the new system, Rome succeeded "better than any nation in avoiding the errors occasioned by the inequality of the cycles." At the heart of the Julian reform was the same idea suggested by Ptolemy III two centuries earlier – the adoption of a leap year every four years. Three out of every four years would be 365 days in length; the fourth would be 366 days long (giving an average of 3651/4 days). The Julian year consisted of alternating 30-day and 31-day months – months that started and ended independently of the phase of the moon – with only February as the oddball (with 28 days in a regular year and 29 in a leap year). To correct for the "drift" that had already accumulated up to that time, Caesar ordered two extra months inserted into the year that we would label as 46 B.C. – making that particular year some 445 days long. He called it the "*ultimus annus confusionis*": "the last year of confusion."

The new, improved calendar was more than a scholarly pursuit for Rome's elites. It also "injected a new spirit into how people thought about time," according to Duncan. Until the Julian reform, time

> had been thought of as a cycle of recurring natural events, or as an instrument of power. But no more. Now the calendar was available to everyone as a practical, objective tool to organize shipping schedules, grow crops, worship gods, plan marriages, and send letters to friends … The new Julian calendar introduced the concept of human beings ordering their own individual lives along a linear progression operating independent of the moon, the seasons, and the gods.

It is interesting to compare this "linear progression" to other conceptions of time from other cultures. What is emerging in Rome at the time of Caesar seems to be a uniquely Western sense of time, an image of time as something like tick-marks on a meter stick – very much like the mental picture most of us have today when we look at our watch or jot down an appointment in our calendar. This is a profound notion, and we will discuss it more in the chapters ahead.

It was at around this time that the people of Rome began to mark the New Year in January rather than March, probably in an effort to bring the date closer to the winter solstice. The Senate would eventually change the name of the seventh month (the fifth – Quintilius – in the old system) to Julius (July) in Caesar's honor. The emperor Augustus would later fiddle with the length of the months a bit more: if July was to have thirty-one days, so, surely, must August. The result did not change the length of the year, but it did give us the somewhat random distribution of month-lengths that we have today.

Centuries later, after the Roman Empire had adopted Christianity as its official religion, a monk named Dionysius Exiguus ("Dennis the Little," *c*. A.D. 470-544) gave the calendar a new starting point, labeling the years after the birth of Christ as A.D. – *anno Domini*, "the year of our lord." Of course, Dionysius could only estimate the year of Christ's birth; modern historians peg the event to 4 or 5 B.C. It also did not occur to Dionysius to include a year zero – the concept of zero had not yet taken hold in the West – and so the year 1 B.C. would be followed immediately by A.D. 1. (Incidentally, the term B.C., for "before Christ," was adopted only in the early seventeenth century. It is interesting to note that, while we abbreviate a Latin phrase for "A.D.," we abbreviate an English one for "B.C."; by the time the latter notation came into regular use, English was already beginning to replace Latin as a language regularly used by educated people.)

We've seen how the Romans eventually moved the New Year to January 1, a move that would gradually be adopted across the Western world (although it did not happen quickly – Britain and its colonies adopted January 1 only in 1752). But the choice of when to celebrate the New Year is, after all, an arbitrary decision. Many cultures took the spring, with its suggestion of rebirth and renewal, as the starting point. In South America, many native cultures used a heliacal rising, as the Egyptians did – but with the Pleiades rather than Sirius as the focus of attention. (In many native languages, the word for "year" and "Pleiades" is the same.) The key role played by the Pleiades can be seen in some of the surviving ancient structures of the region, especially those of the Inca. At Machu Picchu, for example, an oval-shaped stone building known as the Torreon has one of its windows aligned with the point on the horizon where the Pleiades rise. (The recently discovered Incan city at Llactapata, a "suburb" of Machu Picchu just across the Urubamba River, features buildings with the same orientation; its temple and observatory are aligned with the sun's position at the solstices and the equinoxes, as well as with the Pleiades.)

Mind you, the calendrical signals that determine the start of the New Year need not be celestial. For the Trobriand Islanders of the western Pacific, the year begins on Worm Day, when the palolo worm begins to spawn – generally between mid-October and mid-November.

Keeping Time by the Moon

The lunar month – the period from one new (or full) moon to the next – is perhaps even more obvious than the yearly cycle of the seasons; we saw in the last chapter how it may have inspired calendar-like tallying as early as the Paleolithic era. At the very least, the start (or end) of the lunar cycle can be observed with relative ease. Some cultures, such as those that embrace Islam, have based their calendar on the moon exclusively. The Islamic quest for accurate timekeeping – a requirement for their strict regimen of prayer – led Muslim nations in medieval times to become experts at astronomy. By the turn of the first millennium A.D., Muslim scientists had perfected astronomical instruments like the astrolabe and established great observatories across the Middle East. The oldest surviving Muslim observatory is the recently renovated structure at Maragha (present-day Maragheh) in northern Iran, dating from the thirteenth century. The Muslim year is strictly lunar, consisting of 12 cycles of the moon; the length of a "month" is alternately 29 or 30 days. The "year" runs only 354 days in length – some 11 days short of a solar year. For that reason, the Muslim year, including all the Muslim holidays, drifts relative to the seasons. Arab scholars were, nonetheless, well aware of the true length of the solar year. The scholar and poet Omar Khayyám (*c.* 1048-1131) calculated the length of the solar year at 365.24219858156 days; this is an accurate figure – the year is about 365.2422 days long – but, as Duncan puts it, Khayyám's calculation is "overly precise" because of the irregularity of the earth's rotation (meaning that all those extra decimal places have no practical value). Khayyám also worked out a calendar with 8 leap years every 33 years – a somewhat awkward system, but still more accurate than our Gregorian calendar.

Any discussion of calendars and ancient civilizations must make special note of the accomplishments of the Maya of Central America. In their quest for – one might say obsession with – accurate timekeeping, the Maya piled cycle on top of cycle: they marked not only the (approximately) 365-day cycle of the seasons, but also a slightly shorter cycle of 360 days known as the *tun* and a 584-day cycle associated with the movement of the planet Venus – for them, the planet associated with warfare. Perhaps even more fundamental to their way of tracking time was a 260-day "sacred round." The full rationale behind the Mayan fondness for this number will probably never be known, but Anthony Aveni suspects it is linked to its compatibility with so many other cycles in nature. As Aveni points out, 260 is roughly equal to the average number of days that Venus spends in the evening or morning sky (actually 263 days), and is very close to the average human gestation period (253 days). It is also, roughly, the average length of the agricultural season in many parts of Mexico. For all of these reasons, says Aveni, "the 260-day period emerged in the world of the Maya as the cycle par excellence to encapsulate the powers of all the gods – the gods of time, the sun, earth, moon, those of fertility, and rain." The number 260 could be thought of as "the Maya divine temporal common denominator."

The Mayan calendar implied a length for the solar year that is closer to the mark than ours, at 365.2420 days, just shy of the actual value of 365.2422 (the Gregorian value is 365.2425). As with Omar Khayyám's calculation for the length of the year, it is tempting to label the Mayan calendar as more "accurate" than ours, but there are some subtle reasons why we should resist making such a claim. For one thing, the earth's rate of rotation is not stable over thousands of years – more on that in the next chapter. As well, there is more to developing a calendar than estimating the length of the solar year. The scholars who developed the Gregorian calendar were also interested in keeping the date of the vernal (spring) equinox fixed from year to year, and our calendar, says astronomer and author Duncan Steel, does a better job of this than the Mayan calendar.* But such comparisons, he admits, are cases of "comparing apples with oranges."

For the Maya, the calendar and its cycles offered a mental leap across the abyss of time, a glimpse of eternity. To peer arbitrarily far into the past or future, you begin with the *tun* and simply expand it with multiples of 20: 20 *tuns* make a *katun* (7,200 days, or nearly 20 years); 20 *katuns* make a *baktun* (144,000 days, or more than 394 years); by the time we get to the *alatun*, we're talking about a period of some 63,000 years.

The Maya and "Organic Time"

What most distinguishes the Maya conception of time from the Western view, however, is not the variety of counting systems but the imagined nature of time itself. For us, time is *inanimate*: we feel that it passes at a constant rate, with no heed paid to man or machine. We can neither give it a boost nor slow it down. For the Maya, however, time was organic – and men and women were intimately involved in its passage. Mayan rulers, charged with keeping that temporal symphony in tune, were seen to embody the very essence of time. As David Stuart of Harvard University writes, that role "was fundamental to the cosmological underpinnings of divine kingship." In the Mayan world, "the king came to be explicitly identified with the temporal mechanisms of the cosmos."

The Maya, writes Anthony Aveni, had an "enduring obsession" with timing of events both human and celestial – and, indeed, could not conceive of a separation between the two:

> The Maya were fatalists at heart. They strove to find certain repeatable patterns recovered from the observations and recorded data of past sky events, which could then be used as a guide for predicting the future. For them, such patterns constituted realizable proof of the long-held Mayan belief that the future was present in the past – that the unfolding of events over time's near and distant horizon actually could be foretold by looking with introspection over one's historical shoulder.

The Mayan penchant for harnessing endless celestial cycles can be seen in one of their most famous surviving artifacts, the Dresden Codex. (Written in the twelfth century, the stone tablet is named for the German city where it was rediscovered some seven centuries later.) The Codex contains a record of 205 lunar cycles, over 11,968 days. With a mathematical notation based on the number 20 (rather than our base-10 system), the Codex could be used to predict both solar and lunar eclipses – knowledge that no doubt made the ruling elite seem even more powerful.

Mayan fatalism can be seen even in their names for the days. Each of the twenty named days in the Mayan calendar was essentially deified, and said to have a distinct personality; certain days were deemed good for some tasks and bad for others. A child born on a particular day would be expected to have certain character traits associated with the day and the god in question. For the Maya, the days "took on a life of their own," says Stuart, who also curates the Mayan collection at Harvard's Peabody Museum.

Because time was organic, it was also responsive to the actions of man. In fact, keeping time on its course was a community effort; everyone had to pitch in. The king, however, had the greatest responsibility. As divinely ordained ruler, he was seen as the embodiment of time, and it was his duty to use time to maintain the social, political, and cosmological order.

The burden of that temporal responsibility comes to life in one of the Peabody's most striking exhibits – a cast of a stone monument from the Mayan city of Copán, in Honduras, known as Altar Q, which Professor Stuart showed me on a recent visit to Harvard. The square stele is carved with the figures of sixteen kings – four to a side – spanning nearly four hundred years of history. Time wraps around this monument so that the sixteenth monarch is face to face with the first. The old king is passing what looks like a torch to the new king.

"This is the guy who actually dedicated the stone," Stuart explains, pointing to the sixteenth and final king. "He's the living king. His name was Yax Pasaj." Beside him are glyphs indicating the date of his inauguration and commemorating the symbolic passing of the throne from the founding king. Stuart grins. "Isn't that cool? Time has just come full circle."

Yax Pasaj was indeed the last king; the regime soon collapsed. Perhaps it was the result of the droughts, famine, and warfare that were swirling around Copán at this time (the eighth century A.D.). But Stuart can't help wondering if the calendar played a role: the king began his reign just as the *baktun*, the 394-year cycle, was drawing to a close. Perhaps the story of Copán ends with this particular ruler "because history did come full circle," Stuart suggests. "It would have been hard for any king who came after this to really put himself into this cosmological scheme." The Maya of Copán, he says, "may have seen it as a time when change was necessary."

The Oddball Cycle: The Week

We have spoken of days, months, and years, each of which are clearly delineated by the motion of the heavens. The week, in contrast, seems to be much more artificial. The modern week is both more rigid and yet less predictable than the month or the year. While the modern (Gregorian) year can have either 365 or 366 days, and a month can have anywhere from 28 to 31 days, the fixed 7-day week seems inert. And yet, while each January 1 marks the beginning of a new year and a new month (and sometimes a new decade, century, or millennium), six times out of seven it falls haphazardly in mid-week.

The roots of the week are much less obvious than the other calendrical units. It may have originated in an attempt to divide the month into four roughly equal parts: new moon / first quarter / full moon / third quarter – although technically this would give a week slightly greater than seven days in length (29.53 / 4 = 7.38 days). There was another celestial motivation in favor of the number seven: in ancient times, the number of "wandering bodies" known in the heavens included the sun, moon, and five planets (Mercury, Venus, Mars, Jupiter, and Saturn) – seven bodies in all. The seven-day week may owe its origins to the Babylonians, who made an astrological connection between the gods and the days of the week.

The idea of the week also hinges crucially on the notion of the Sabbath – a special day of rest associated most clearly with the creation story in Genesis, the first book of the Hebrew Bible. The word *Sabbath* appears to come from the Babylonian *sabattu*, an evil day associated with the moon god, Ishtar. Yet the Babylonians did seem to give special status to every seventh day, and a separate Babylonian word, *sibitu*, means simply “the seventh.” Most scholars agree that the seven-day week, with a weekly day of rest, is a Jewish idea, adapted with modification from the Babylonians in the years during and after the Exile.

Most other religions made connections, as the Babylonians did, between various gods and the days of the week. The modern English names for the days of the week can be traced back to Saxon names for those gods. Their Latin equivalents make it clear which god is being honored: the Latin *Dies Solis* is the Saxon Sun’s day, which has become our Sunday; *Dies Lunae* is Moon’s day or Monday; *Dies Martis* is the Saxon Tiw’s day (Tuesday); *Dies Mercurii* is Woden’s Day (Wednesday); *Dies Jovis* is Thor’s Day (Thursday); *Dies Veneris* is Frigg’s day (Friday); *Dies Saturni* is Seterne’s day (Saturday). One cannot help wondering how often Woden, the German (and Viking) god of poetry, would come up in everyday conversation had he not been immortalized in the “hump-day” of the Western calendar.

But why do the days run in that particular order? It is not the order of brightness: if it were, Jupiter and Saturn would come before Mars and Mercury. Nor is it based on the rate at which the bodies move against the background stars over time – what astronomers call the “sidereal period.” (That sequence, from longest to shortest, is Saturn, Jupiter, Mars, Sun, Venus, Mercury, Moon.) Nor is it based on the rate at which the bodies line up with the sun in the sky – the “synodic period.” (That order would be Mars, Venus, Jupiter, Saturn, Mercury, Moon; the sun’s synodic period is undefined.) The answer, most historians agree, involves a link between the days of the week and the hours of the day. When ancient astronomers divided the day into twenty-four hours, they associated a particular heavenly body with each hour, believing it “ruled” that hour. Saturn, the slowest-moving body, was believed to be the most powerful, and was thought to control the first hour of the first day (which was, in ancient times, Saturday). Then, using the sidereal sequence, Jupiter becomes associated with the second hour of the first day, Mars with the third, and so on. After linking the moon with the seventh hour, we cycle back to Saturn, which controls the eighth, fifteenth, and twenty-second hours (every seventh hour). Mars controls the twenty-fourth hour of the first day, and so the sun becomes linked to the first hour of the second day – Sunday. Continuing in this manner, cycling through the seven bodies and the twenty-four hours of each day, we get the modern sequence of the days of the week. Eventually – possibly in Roman times – the week gained independence from the month and the year, and Sunday replaced Saturday as the first day of the week.

It wasn’t only the heavens that dictated the structure of the week. Seven days is a convenient interval for a market cycle, a chance for farmers and merchants to come together and exchange goods. The choice of seven days wasn’t universal: some African tribes kept a five-day market cycle; for the Inca of South America it was eight days; it was ten for the ancient Chinese. Postrevolutionary France tried to establish a ten-day week in 1792, without success. The Romans had an eight-day market cycle in place when, in A.D. 321, the emperor Constantine established Sunday as the first day of an official seven-day week. (The Beatles song “Eight Days a Week,” the author Duncan Steel quips, may represent a yearning for a Roman girl from the time before Constantine.)

Julius Caesar’s calendar was a momentous achievement – but it was also deeply flawed. Its average year of 365.25 days was just slightly shorter – by about 11 minutes – than the true solar year. By the time lawyer and statesman Ugo Buoncompagni was elected Pope Gregory XIII (1502-85), that discrepancy added up to 10 full days. The Julian year was drifting with respect to the seasons, dragging all of its feasts and holy days with it. If nothing were done, Easter would eventually become a summer holiday.

The Problem of Easter

Before we examine Gregory’s solution, it’s worth taking a closer look at the timing of Easter, the most important festival in the Christian year. The holiday celebrates the resurrection of Jesus, which Christians believe occurred three days after his death on the cross. (Historians now place the death of Jesus sometime between A.D. 27 and 33.) The holiday is intimately linked to the Jewish Passover: the “Last Supper” shared by Jesus and his disciples before his execution is believed to have been a

Passover seder, based on the outline of events described in the New Testament of the Bible. It wasn't until the second century A.D. that Easter began to be celebrated; no doubt it evolved from older pagan holidays associated with the coming of spring. (The word *Easter* comes from the Norse god of the spring, Eostre.) Different sects, however, marked the holiday on different dates. Some groups followed the Jewish calendar, celebrating Easter on the same day that the Jews celebrate Passover – the fourteenth of Nisan – regardless of what day it fell on. Other Christian groups gave preference to the day of the week, marking the holiday on the Sunday that followed.

Eventually the latter approach prevailed: Christians decided to mark the crucifixion on Good Friday and celebrate the resurrection on the following Sunday. But which Sunday? The simplest solution would have been to choose the first Sunday after Passover – but there were several perceived reasons not to do so. One involves the nature of the Jewish calendar itself, and the wide range of dates on which Passover can fall. Passover is often said to fall on the "first full moon of spring," but that is an oversimplification. Because the Jewish calendar employs whole leap months rather than merely an extra day (as in the leap years of the Julian calendar), Passover can fall on a wide range of dates compared to the Julian (and, later, Gregorian) calendars. In the longer years – those that have thirteen months – Passover can fall as much as a full month after the equinox (as happened in 2008). The Church wanted to ensure that Easter followed the equinox by no more than a month.

There were also other factors in play: Christians wanted to distance themselves from the Jews, and didn't want their most sacred holiday too closely linked to a Jewish festival. As Duncan Steel writes, the Christians "invented a reason to disagree with the Jewish system." In the middle centuries of the first millennium A.D., Church leaders worked out several methods for computing the date of Easter, all of them rigged so that Easter and Passover would never coincide.

The Easter controversy was one of the hot topics for discussion when the leading figures of the Christian world gathered in Nicaea, in what is now northeastern Turkey, in A.D. 325. (Constantine presided over the meeting himself; though he would wait until he was close to death to be baptized, he had long been sympathetic to the growing religion.) More than 300 clerics and scholars took part in the council. Exactly what they concluded with regard to Easter is somewhat obscure – the original records have not survived – but there was evidently a push to have all of Christendom celebrate Easter on the same day. Even so, the controversy lingered; some groups relied on Egyptian scholars for advice on selecting the appropriate date, while others continued to rely on the Jewish calendar.

Ultimately, the Christian authorities decided to sidestep astronomical methods, relying instead on a mathematical model that would simulate the motion of the real sun, moon, and stars. Once an accurate model was established, the date of Easter could simply be calculated; there would be no need to consult either the astronomers at Alexandria or the priests in Jerusalem. At some point – certainly after Nicaea – it was agreed that Easter would be celebrated on the first Sunday after the fourteenth day of the "paschal moon" – with the paschal moon defined as the first lunar month whose fourteenth day falls after the vernal equinox (remembering that the lunar month begins with the new moon). Clear as mud, right? For what it's worth, this is roughly – though not precisely – the same as the first Sunday after the first full moon after the vernal equinox (with the additional caveat that if that full moon fell *on* a Sunday, Easter was to be delayed until the following Sunday). These rather convoluted rules achieved at least one goal: they ensured that Easter was never celebrated on the same day as Passover. Even so, different churches still managed to disagree as to the date of Easter – in part because the bishops in Alexandria and Rome could not agree on the date of the equinox on which the whole computation depended.

The struggle over Easter, incidentally, illuminates one of the greatest misconceptions about the relationship between the Catholic Church and science. In the wake of the Galileo affair, the Church was often seen as hostile to scientific enquiry. Yet throughout the Middle Ages – and well into modern times – the Church was actually one of the strongest supporters of precision astronomy and timekeeping, as a direct result of the Easter dilemma. In fact, dozens of churches and cathedrals, including those in Rome, Milan, Florence, and Bologna, also served as observatories; many were equipped with strategically placed apertures in walls or ceilings that allowed a beam of sunlight to strike a north-south "meridian line" on the floor. Such measurements helped establish the dates of the solstices and equinoxes, on which the Easter calculations depended.

The next critical step was taken by the monk Dionysius Exiguus. Sometime in the sixth century, he worked out a set of tables that would allow the date of Easter to be computed decades, even centuries, in advance. Dionysius's tables were indeed used for many centuries – but they were inherently flawed. First of all, his value for the length of the lunar cycle was ever-so-slightly off. But secondly, and more importantly, his value for the length of the year itself – inherited from the Julian calendar – was too short, and by Gregory's time the accumulated error added up to more than a week.

Gregory's Solution

In the mid-1570s, Pope Gregory XIII convened a calendar commission to tackle the problem. The commission included a physician named Aloysius Lilius (*c.* 1510-76), a Jesuit astronomer named Christopher Clavius (1538–1612) – known to historians as the "Euclid of the sixteenth century" for his mathematical insights – and a handful of lesser-known players. The commission members grappled with their charts and tables, trying to deduce the true length of the year, and struggled to make some combination of regular years and leap years average out to that length. It was the doctor, Lilius, who nailed down the winning formula. He realized that the Julian calendar was slipping by about 1 day every 134 years – or 3 days every 402 years. For simplicity's sake, he rounded that to 400. Suppose, he suggested, that the new calendar drops 3 days every 400 years. In the Julian calendar, "century years" like 1500, 1600, and 1700 would be leap years because they're divisible by 4. In the new plan, only those century years divisible by 400 (such as 1600) would be leap years; other century years – which would have been leap years under the Julian system – would have just 365 days in the new scheme. (Notice, by the way, that the first year to be affected by the new proposal would be 1700 – by which time all those involved in the reform would be safely in a timeless realm.)

Lilius is lucky that the plan worked as well as it did. He based his calculations on numbers set down in 1252, known as the “Alfonsine tables.” Named for the Spanish king Alfonso the Tenth, the tables presume a solar year of 365 days, 5 hours, 49 minutes, and 16 seconds – about 30 seconds longer than the true year. Lilius’s proposed reform, however, gives an average year that’s slightly closer to the mark, at 365 days, 5 hours, 48 minutes, and 20 seconds – just 26 seconds short of the true year. The Gregorian calendar still runs ever so slightly “fast” compared to the seasons, gaining one day every 3,300 years.

Pope Gregory XIII presides over the Commission for Calendar Reform, *c*. 1582. *(Scala / Art Resource, NY)*

The commission also grappled with the date of Easter, finally putting the centuries-old dilemma to rest – though their solution for the holiday’s computation seems, to the untrained eye, more complicated than ever. It still involves a mathematical model that simulates the moon’s motion, based on the nineteen-year Metonic cycle, as well as esoteric constructs known as “golden numbers” and “epacts,” which, happily, are beyond the scope of this discussion. In spite of all the arcane mathematical contortions, the date of Easter is still very nearly “the first Sunday after the first full moon of spring.” The Christian calendar remains a luni-solar calendar – one that keeps pace with the seasons but that also cele brates certain holidays, such as Easter, based on the phase of the moon.

Pope Gregory was swayed by the recommendation of Lilius and the commission, and issued a twenty-page compendium outlining the reform on January 5, 1578. It included, among other things, the declaration that the New Year would be marked on January 1, as it had been for Caesar, fifteen centuries earlier. The reform was finally enshrined in a papal bull issued on February 24, 1582.

The reform also ordered ten days to be dropped from the calendar in a one-off move to make up for the days that had been lost by the use of the Julian calendar for so many centuries. And so October 4, 1582, was followed by October 15. Some people were distressed at what seemed to be "lost" time. Merchants fretted over how to calculate profits and losses; bankers were befuddled by interest rates.

Most Catholic countries came on board right away. Italy, Spain, and Portugal adopted the Gregorian reform immediately; France and Belgium joined a few months later; Catholic portions of Germany and Switzerland made the switch within a couple of years. Protestant countries, including the Protestant states within Germany, opposed the reform; as David Ewing Duncan writes, one bitter theologian called Pope Gregory the "Roman Antichrist" and dismissed his calendar as "a Trojan horse designed to trick real Christians into worshipping on the incorrect holy days." As the decades passed and more nations and peoples adopted the reform, resistance became more and more futile. By 1700, most of Germany and Denmark had complied. Sweden joined, after much hand-wringing, in 1753.

"Give Us Back Our Eleven Days!"

England was especially problematic, with a Protestant Queen (Elizabeth I) constantly embroiled with Catholic agitators – although her most trusted adviser, John Dee (1527-1608), urged the adoption of a slightly altered version of the reform. Ultimately, another 170 years would pass before England (and by then, Britain) adopted the Gregorian calendar. A bill was drafted by a retired politician and former secretary of state, Philip Dormer Stanhope (1694-1773), the Earl of Chesterfield, and read before Parliament. The bill passed, and was signed by King George II on May 22, 1751 (though, as Duncan points out, Stanhope admitted that he himself "could not understand" the details of the argument it rested on).

To catch up to the Gregorian calendar, Britain and its colonies would have to drop eleven days – the ten that the Catholic countries had added under the Gregorian reform, and one more because those countries had marked 1700 as a leap year, while Britain, still on the Julian calendar, had not. And so September 2, 1752, was followed by September 14. From then on, as well, the New Year would begin on January 1 rather than March 25, as it had until that time. Again, ordinary people balked at the "lost" days; there were riots in London and Bristol, where protesters shouted, "Give us back our eleven days!"

The Eastern Orthodox Church also rejected the reform. To this day its members celebrate Easter on a different day from other Christians around the world. However, many Orthodox countries did accept the reform for civil purposes in the early years of the twentieth century. Russia came on board after the revolution, in 1918; China held out until the Communist takeover in 1949.

It's not clear if human civilization will last another thousand years (as Yogi Berra supposedly quipped, "It's tough to make predictions, especially about the future"). But if people are still around to relish in late-night talk shows, then I suspect a thirty-first-century David Letterman will still be able to recycle the old checkbook joke. If there is any calendar, I bet it will be the Gregorian. I wouldn't be surprised, in fact, if the calendar outlasts the various religions that gave rise to it. Gregory's calendar may be around long after the last pope has been forgotten.

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* As is so often the case, the credit did not go the person who first came up with the idea; besides the Babylonians, the Chinese recognized the nineteen-year cycle centuries before the time of Meton. In just the same way, the "Pythagorean theorem" was almost certainly known to the Babylonians a thousand years before the Greek thinker gave his name to it.

* The vernal equinox marks the beginning of spring for those of us in the northern hemisphere; in the southern hemisphere it marks the start of autumn.