The Julian Calendar and why we need to know about it

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Introduction

The Julian calendar is important to historians because it was used worldwide for over 16 centuries, and in various parts of the world for another three centuries after that. And it's important to genealogists because it was used to record events in many countries as recently as the early 1900s. For these reasons, it's necessary to understand the Julian calendar and to know when and how the conversion to our current Gregorian calendar was done.

On the surface, converting between the two calendars appears to be straightforward. But further analysis shows that there are several subtle but significant issues. For example, George Washington's birthday is conventionally celebrated on February 22. But as a result of the switch from the Julian calendar to the Gregorian one, his birthday was in fact February 23 in the 19th century, February 24th in the 20th and 21st century, and will continue to advance in future centuries.

This paper will present the Julian calendar by first giving a historic perspective of the Roman calendars from which it was derived. It will then explain the workings of the Julian calendar, and the reforms that were made to convert it to the more accurate Gregorian calendar. It will then describe the implications of these reforms, and the problems that they can cause for genealogists and historians.

The Calendar Requirement

The calendar has only one basic requirement -- that the seasons don't migrate through the years. We are used to going to the beach in July, and if after a few years it doesn't warm up sufficiently until November we might not be too happy.

The seasons are determined by the position of the Earth in its orbit around the sun. At one point in its orbit, the Earth's axis is tilted with the north pole toward the sun, and at the diametrically opposite point it is tilted with the north pole away from the sun. At these two points the northern hemisphere is experiencing summer and winter respectively. And approximately midway between these two points is spring and fall. This is illustrated in Figure 1.

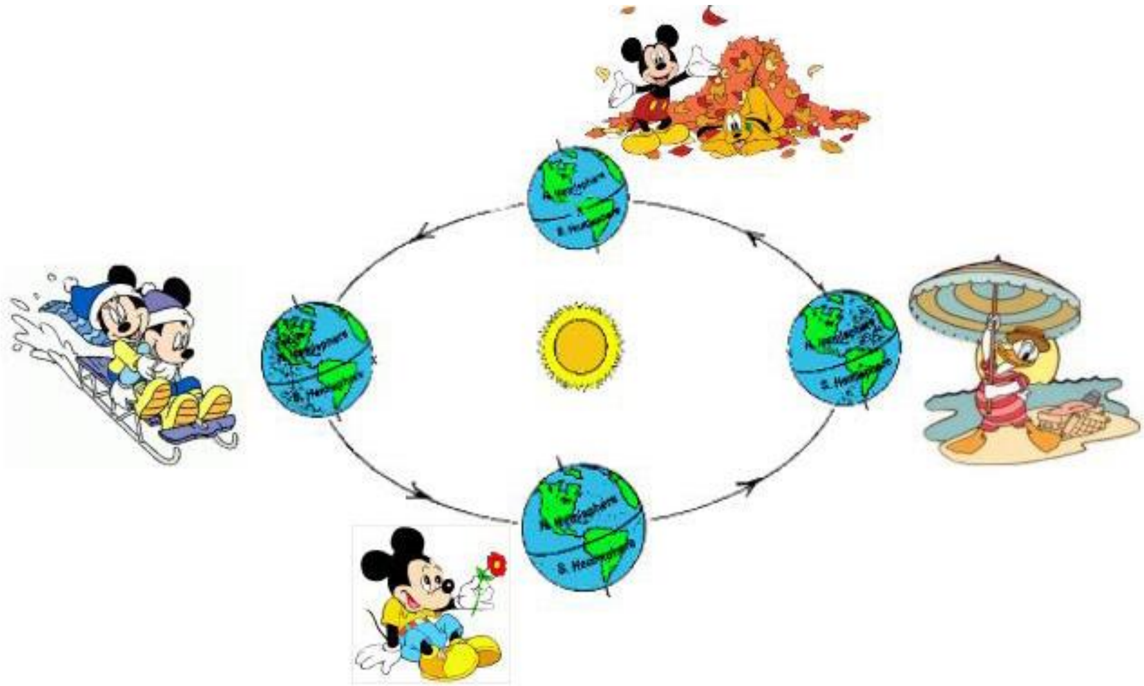


FIGURE 1. The earth's orbit and the seasons

Why is it so difficult to design a calendar and get it right? The astronomers tell us that the earth goes around the sun once every 365.2422 days. And it is that fractional part (.2422) that causes all the problems. We wouldn't want to start a new year after a fractional number of days. So we have to compromise and pick some integral number of days that is close to 365.2422.

If we pick a number that is too low, the seasons will occur later and later each year. Let's assume that we start the year in winter, and that we choose 300 days for the length of a year. After the first year, the earth will not yet have reached the correct point for the second winter. So the winter season won't start until 65 days into the second year. And it won't start until 130 days into the third year. On the other hand, if choose too high a number, say 400, the seasons will come earlier and earlier each year.

Of course we could improve on things by picking numbers closer to 365.2422, such as 365 or 366. That will certainly slow down the drift but it won't eliminate it. If we wait long enough, even the best designed calendar will start to experience drift.

Historical Perspective

The seeds of the current Gregorian calendar lie in the calendars used in ancient Rome. The first Roman calendar was introduced in approximately 753 BCE (before the common era) by Romulus, the legendary first king of Rome. Romulus's calendar had only ten months with each month having either 30 or 31 days as follows:

Martius -- 31 days
Aprilis -- 30 days
Maius -- 31 days
Iunius -- 30 days
Quintilis -- 31 days
Sextilis -- 30 days
September -- 30 days
October -- 31 days
November -- 30 days
December -- 30 days

Calendar of Romulus, ca 753 BCE

It's not clear where the name Aprilis came from, but the other three of the first four months were named after Roman gods. And starting with the fifth month, the names reflect the order of the month in the calendar: the fifth month was Quintilis meaning five in Latin, then Sextilis meaning six, all the way up to December meaning ten.

The total number of days in the ten months was 304, and that was certainly a problem. The year would end long before the earth was in the right position to start the next year. So they simply waited around until their astronomers determined that it was time to start the next year. That left about 61 winter days unaccounted for, as they were not in any month.

That didn't work for long, and by 713 BCE the calendar was modified by Numa Pompilius, the legendary second king of Rome. He added two months at the end of the calendar, Ianuarius and Februarius, to get rid of the unaccounted-for days. He also introduced an intercalary month that occurred after Februarius in certain years. These years became known as leap years. In addition, he deleted one day from all the months that had 30 days so that they had 29 days instead.

Here is Numa's calendar:

Martius -- 31 days
Aprilis -- 29 days
Maius -- 31 days
Iunius -- 29 days
Quintilis -- 31 days
Sextilis -- 29 days
September -- 29 days
October -- 31 days
November -- 29 days
December -- 29 days
Ianuarius -- 29 days
Februarius -- 28 days (23 or 24 days in leap year)
Intercalarius -- 0 days (27 days in leap year)

Calendar of Numa Pompilius, ca 713 BCE

This resulted in a total of 355 days in a common year and 377 days in a leap year. So it's apparent that they would have to have a leap year just about every other year. However there was no hard and fast rule as to when there would be a leap year. Instead it was left to the whim of the king, and he often chose the leap years for political gain rather than for sound astronomical reasons. This calendar was certainly unstable, but it was used for the next 700 years.

Sometime later (certainly by 450 BCE) the starting point of the calendar had been shifted from Martius to Ianuarius. All other aspects of the calendar remained the same, so it was still basically the Numa calendar. This change of starting point meant that the month names were now misnomers, no longer corresponding to their position in the calendar. In 450 BCE the calendar was as follows:

Ianuarius -- 29 days
Februarius -- 28 days (23 or 24 days in leap year)
Intercalarius -- 0 days (27 days in leap year)
Martius -- 31 days
Aprilis -- 29 days
Maius -- 31 days
Iunius -- 29 days
Quintilis -- 31 days
Sextilis -- 29 days
September -- 29 days
October -- 31 days
November -- 29 days
December -- 29 days

Calendar of 450 BCE

Eventually the abuse of the leap years became so bad that the harvest festival was coming before the summer planting season. How could you reap what you had not yet sowed? So in 45 BCE Julius Caesar reformed the calendar and introduced the first stable calendar. He incorporated fixed rules for determining which years were leap years. He eliminated the intercalary month and replaced it with a single intercalary day. He also had a regular pattern of alternating between 31 and 30 day months. And he did a one-time insertion of three months in 46 BCE to give the seasons a chance to catch up. See appendix 1.

Julius's calendar is as follows:

Ianuarius -- 31 days
Februarius -- 29 days (30 days in leap year)
Martius -- 31 days

Aprilis -- 30 days
Maius -- 31 days
Iunius -- 30 days
Quintilis -- 31 days
Sextilis -- 30 days
September -- 31 days
October -- 30 days
November -- 31 days
December -- 30 days

Calendar of Julius Caesar

In Julius's calendar the rule for leap years was that every third year shall be a leap year. It is believed that Julius intended for it to be every fourth year but the people who implemented it made a calculation error in the way they counted to four (a so-called fence-post error). See Figure 2.

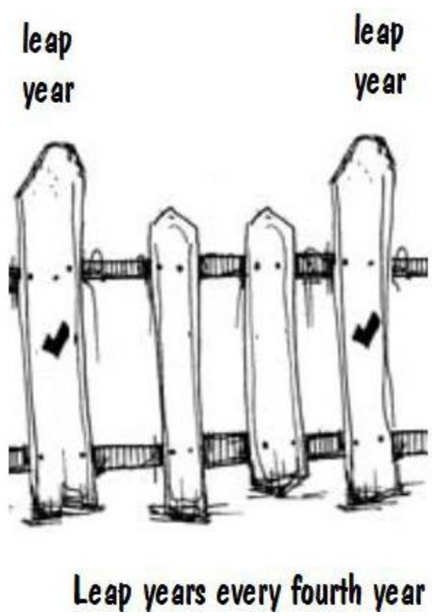


FIGURE 2. Fence-Post Error in counting to 4

But in spite of that error, we now had a year that was 365.3333 days on average, a number that is getting close to the correct number of 365.2422.

Julius didn't have much time to enjoy his new calendar because he was killed on the Ides of Martius (March 15) in 44 BCE, one year after his calendar went into effect. But his successor, Augustus Caesar, made some refinements to the calendar, and it was Augustus's refinements that would become known as the Julian calendar and be used world-wide for the next 16 centuries. He changed the leap-year cycle to every four years instead of every three. He renamed Quintilis to Iulius, to honor his predecessor. And since he was doing that, he decided to give homage to himself as well and changed Sextilis to Augustus. But that would mean that his month had one fewer day than Julius's month, and Augustus wasn't happy about that. So he removed a day from Februarius and added it to Augustus, making it a 31-day month, same as Iulius. But since September had 31 days as well, that would make three consecutive months with 31 days. So he interchanged the number of days in September and October, as well as interchanging the number of days in November and December. Augustus's revised calendar, is as follows:

Ianuarius -- 31 days
Februarius -- 28 days (29 days in leap year)
Martius -- 31 days
Aprilis -- 30 days
Maius -- 31 days
Iunius -- 30 days
Iulius -- 31 days
Augustus -- 31 days
September -- 30 days
October -- 31 days
November -- 30 days
December -- 31 days

Calendar of Augustus Caesar, which became known as the Julian calendar

These month names and number of days in each month have remained the same up to the present day.

There was one more thing for Augustus to do, and that was to compensate for the errors introduced by having the three-year cycle for leap years. See appendix 2.

Below is a summary of the calendar changes from Romulus to Augustus.

	Romulus 753 BCE	Numa 713 BCE	by 450 BCE	Julius 45 BCE	Augustus 8 BCE
Ianuarius			29	31	31
Februarius			28 (23/24)	29 (30)	28 (29)
Intercalarius			0 (27)		
Martius	31	31	31	31	31
Aprilis	30	29	29	30	30
Maius	31	31	31	31	31
Iunius	30	29	29	30	30
Quintilis	31	31	31	31	31 Iulius
Sextilis	30	29	29	30	31 Augustus
September	30	29	29	31	30
October	31	31	31	30	31
November	30	29	29	31	30
December	30	29	29	30	31
Ianuarius		29			
Februarius		28 (23/24)			
Intercalarius		0 (27)			

Number of days in each month. Parenthetical numbers refer to leap years

The Julian Error and the Gregorian Fix

With Augustus's correction, the Julian calendar now had an average of 365.25 days per year. That seemed to be as close as they could get to the true number of 365.2422. Let's see just how significant that error is.

A difference of 0.0078 days per year comes to 1 day every 128 years. That's about 3 days every 400 years. By the 1500s, that amounted to about 10 days. And the holidays were becoming noticeably misaligned with the seasons.

To get back in step, in October 1582 Pope Gregory XIII decreed that 10 days be stricken from the calendar. But that was only the first part of his fix. The second part would be to make sure we remain in step. He did that by decreeing that century years (those ending in 00) not be leap years unless they are evenly divisible by 400. That means that every 400 years we would have 3 fewer leap years, which translates to 3 fewer days. That is close to the error that we just calculated above.

There is a third part to Gregory's fix, and that will be discussed later. The calendar, with these three fixes, would become known as the Gregorian calendar.

FIGURE 3: Striking days from the calendar

Figure 3 is a cartoon depicting the striking of days from the calendar in October 1582, and the reaction of the populace. The cartoon is cute but it contains two errors. The first is probably just a typo -- it shows the stricken days being from the 4th of October to the 14th, for a total of 11 days. That's one day too many. In reality, the 4th of October was not stricken -- the first stricken day was the 5th of October.

The second error is more significant. The cartoon shows the days being crossed out but still taking up space on the calendar. That means that if October 4th was on a Thursday, the next day would be Monday October 15. And if that were done, it would break the sanctity of the Sabbath occurring every seven days, a sanctity that is observed in several major religions (Christianity, Judaism, Islam). Certainly the head of the Catholic church was not about to break the continuity of the revered seven-day count.

So rather than having the stricken days remaining on the calendar and taking up space, they do not appear on the calendar at all. The correct calendar for October 1582 is shown in Figure 4.

1582		OCTOBER			1582	
SUN	MON	TUE	WED	THU	FRI	SAT
	1	2	3	4	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

FIGURE 4. Calendar for October 1582

Let's not do it all at once

Gregory decreed that the cutover date for the calendar should be October 4, 1582. And the Catholic world was eager to obey. On that day Italy, Poland, Portugal, and Spain all switched over. By the end of that year France, Holland, and part of Belgium made the switch. The following year Austria, the rest of Belgium, and Catholic Germany fell in line. And they were joined by Czechoslovakia and Catholic Switzerland in 1584, Hungary in 1587, and Transylvania in 1590.

The Protestant and Greek Orthodox countries were not that anxious to switch. Protestant Germany switched piecemeal during the 1600s. Denmark, Iceland, the rest of the Netherlands, Norway, and Protestant Switzerland switched in the year 1700. Canada, Great Britain, Ireland, and the eastern US switched in 1752. Japan switched in 1873 and Egypt in 1875. Then between 1911 and 1923 Albania, Bulgaria, China, Estonia, Greece, Latvia, Lithuania, Romania, Russia, and Yugoslavia all switched over. And bringing up the rear was Turkey, in 1927.

Even within the land that would become the United States, the cutover was not simultaneous. It depended on which country the specific territory was owned by. Texas, Florida, California, Nevada, Arizona, and New Mexico all switched with Spain in 1582 (although one report I read stated that the Spanish colonies didn't switch until two years after Spain). Mississippi switched with France in 1582. The eastern seaboard switched with Great Britain in 1752. And Alaska switched in 1867 when it became part of the US.

There was a price to be paid by waiting to do the cutover. The longer you waited, the worse it got. In 1582 the correction was 10 days. The year 1600 was a leap year in both the Julian and Gregorian calendars, so nothing changed until the year 1700. From March 1, 1700 to February 28, 1800 the error was 11 days. From March 1, 1800 to February 28, 1900 the error was 12 days. And from March 1, 1900 to February 28, 2100 the error is 13 days. See appendix 3.

Figure 5 shows the calendar for September 1752 in the US, when the switch was made and 11 days were dropped. And figure 6 shows the calendar for 1918 in Russia when it switched over, dropping 13 days.

SEPTEMBER 1752

Su	Mo	Tu	We	Th	Fr	Sa
		1	2	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

FIGURE 5. September 1752 in the US

FIGURE 6. January/February 1918 in Russia

Several places on earth had unique cutovers -- namely Alaska, Sweden, and Nova Scotia.

Alaska got caught on the dateline. Prior to 1867 it was part of Russia. Russia had not yet switched over to the new calendar. Russian time zones were all west of the dateline, and in fact the dateline was drawn around Alaska to ensure that it was also on the west side. In 1867 Alaska was acquired by the US. The US had already switched over. And US time zones are all east of the dateline. When Alaska changed hands, the dateline was redrawn with Alaska changing sides. So Alaska lost 12 days due to the switch being in the 1800s but it repeated 1 day by crossing the dateline (see Figure 7).

FIGURE 7. Alaska loses 11 days and repeats 1

Sweden had a mind of its own. In an attempt to have a gradual conversion, Sweden decided not to have leap years from 1700 to 1740. That way there would be no jolt to the calendar, no populace demanding to be compensated for 11 lost days. But after skipping the leap year in 1700, they abandoned the plan. This put them out of step with both the Julian and Gregorian calendars, so their dates didn't correspond with anyone else's. In 1712 they reverted back to the Julian calendar by having 30 days in February that year to make up for the leap day that they missed in 1700. And then in 1753 they gave up and switched all-at-once to the Gregorian calendar.

And Nova Scotia couldn't make up its mind. It switched to the Gregorian calendar in 1605. It then switched back to the Julian calendar in 1710. And then switched back to the Gregorian calendar in 1752.

In spite of all this switching, there are places on earth in which the Julian calendar is still used. It is used in the Eastern Orthodox Church for calculating Easter and other feasts. It is used by the Berber people in North Africa and on Mount Athos. And Ethiopia uses the Alexandrian calendar which is based on the Julian calendar.

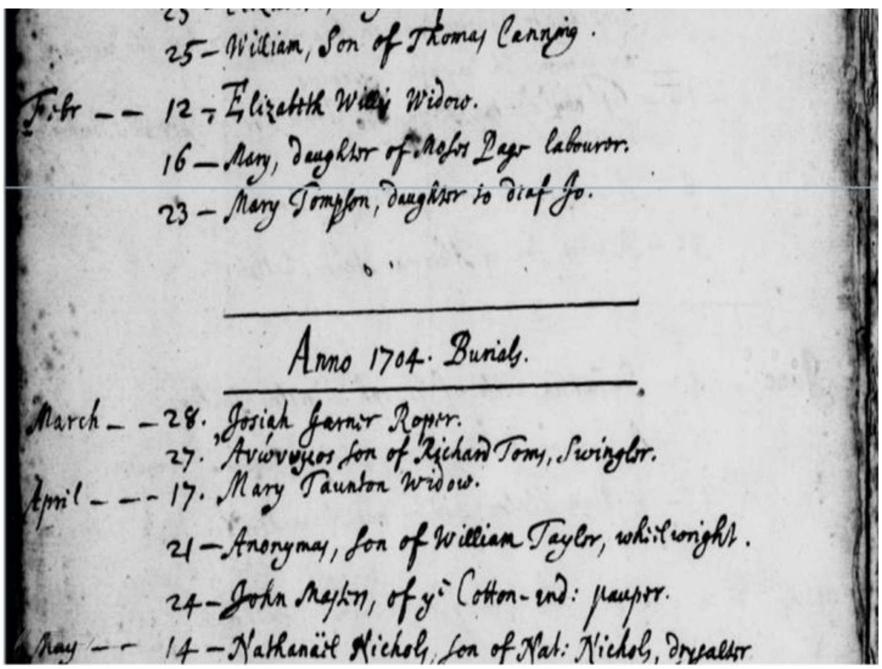
The Start of the Year

There are two distinct events that we associate with a new year. One is the partying with the drinking of champagne, the throwing of confetti, and the blowing of noisemakers. That day is referred to as New Year's Day, and has always been on January 1. But then there is the day that the year number changes, and that can be distinct from New Years Day. Let's call that Number-Change Day. In the Gregorian calendar, Number-Change Day is also on January 1, and coincides with New Year's Day. The same was true for the Roman calendars. But that's not the case for the Julian calendar.

In the initial Julian calendar, Number-Change Day was on January 1. But when local calendars were aligned to the Julian calendar, each kept its own Number-Change Day. Specifically:

Alexandrian calendar (Egypt): August 29/30
Several local provincial calendars: September 23 (Augustus's birth)
Byzantine year: September 1
Eastern Orthodox Church liturgical year: September 1
Russia from 998 CE: March 1
Russia from 1492 CE: September 1
Russia from 1700 CE: January 1
Western Europe during middle ages: December 25 / March 25
England pagan times: December 25
England from 1089 to 1155: January 1
England from 1155 to 1751: March 25

The Number-Change Day was reflected in parish registers. Figure 8 shows a register with the year number entered just before March 28 (obviously the year change was on March 25).


25 – William, Son of Thomas Canning.
Febr — 12 – Elizabeth [illegible] Widow.
16 – Mary, daughter of [illegible] labourer.
23 – Mary Tompson, daughter to [illegible].

Anno 1704. Burials.

March — 28. Josiah Farmer Roper.
27. [illegible] son of Richard Toms, [illegible].
April — 17. Mary Taunton Widow.
21 – Anonymus, son of William Taylor, wheelwright.
24 – John [illegible], of ye Cotton-end: pauper.
May — 14 – Nathanael Nichols, son of Nat: Nichols, [illegible]

FIGURE 8. A parish register showing the year number change in March

As mentioned before, there were three steps to a Gregorian conversion, but so far we have talked about only two. We said that to get back in step with the seasons, the calendar had to suddenly skip ahead by 10+ days. And to remain in step with the seasons, the calendar had to stop observing leap years three times in every 400 years.

The third step was to unify the Number-Change Day. As part of the switch, the year number was to be incremented on January 1, along with the New Year's Day celebration.

Double Dating

Dates between New Year's Day and Number-Change Day have two years associated with them. The first is the year in the Julian calendar, which was the calendar in use in the country. The second is the year that it would have been if the year number had changed on January 1. To avoid confusion, both years are sometimes entered into a record. This is called Double Dating or Dual Dating.

Here is an example of a (fictitious) parish register in which double dating is used.

1661
March 26: John Smith
...
December 31: Mary Jones
1661/1662
January 1: Tom Brown
...
March 24: William Anderson
1662

More realistically, Figure 9 shows a tombstone that lists the date of death as "Febrey 15th Anno 1703/4." That means it was 1703 in the Julian calendar in use, but it would have been 1704 if they had changed the year number on January 1.

FIGURE 9. Tombstone with double dating

One more example is that of George Washington's birth record from the Washington family Bible (Figure 10). It lists his date of birth as "11th day of February 1731/2."

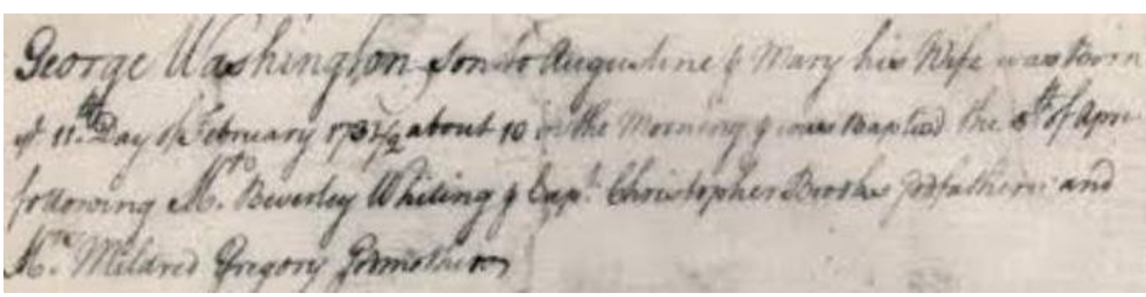


FIGURE 10. George Washington's birth record

George Washington's Birthday

We just saw George Washington's birth record, and it reports that he was born on February 11, 1731/2 in the Julian calendar. The Gregorian switch occurred in the US on September 2, 1752. And George would turn 21 five months later, on February 11, 1753.

But if we count the days of his life up to February 11,1753, we see that he had been alive 11 days shy of 21 years. That presented a problem.

To solve the problem, the switch-over decree made special provisions to use the Julian calendar for computing time durations that started before the switch occurred. So George's 21st birthday was on February 11, 1752/3 Julian, which is February 22, 1753 Gregorian. He'd have to wait 11 more days before they would sell him alcohol.

George died in 1799, but had he lived to 1801, his birthday would have been on February 11 Julian which would now be February 23 Gregorian. Note the change in his Gregorian birthday from February 22 to February 23. And in the 1900s and 2000s, his birthday would be February 24.

Now George is not unique. You might have ancestors who were born at a time and place that the Julian calendar was used. How do you enter their dates of birth on your family tree? If you enter it using the Julian calendar date, there is no confusion. But then it would be inconsistent with other dates in your tree that are Gregorian. If you enter it as the converted Gregorian date, which converted value do you use? The converted value changes each time the century changes. I'm not going to answer this question, but I do want to make you aware of the problem. It's up to you to decide which date to use.

Birthdays were not the only problem caused by the conversion. Suppose you pay rent on the first day of every month, and you made a payment on September 1, 1752. Due to the switch-over, September 2 of that year is followed immediately by September 14. Your next payment is due on October 1, but that's only 19 days from your previous payment.

Special provisions were made stating that monthly or yearly payments would become due "at and upon the respective natural days and times as the same should ... have been payable ... in case this act had not been made" (Provision 6 of the switch-over decree). That translates into saying that you continue to use the Julian calendar to determine when such payments are due.

The Gregorian Error

As was previously mentioned, the average Julian year is 365.25 days and the true length of a year is 365.2422 days. That difference caused the Julian seasons to advance 1 day every 128 years.

The average Gregorian year comes out to be 365.2425 days. That difference causes the seasons to advance 1 day every 3,333 years. So all we've done is kick the can down the road, although we did kick it quite far this time.

Note that the error is close to 1 day in 4,000 years. That suggests a rather simple modification to the leap-year rule to fix the problem. Namely skip the leap years in millennium years that are divisible 4,000. We haven't had such a year yet (at least not since 1582) and we won't have one until the year 4000. So we don't have to make any decisions on this for another 2,000 years. And at that time there will be no major jolt to the system, no 10 days to account for, and nobody will complain about when their rent will be due. All that will happen is that the month of February in the year 4000 will have only 28 days, and nobody is going to be harmed by that.

If such an amendment were made, what would the new error be? In that case the average length of a year would become 365.24225. That's getting very close to the magic number of 365.2422, and the difference would now cause the seasons to advance 1 day in 20,000 years.

That amendment is very simple. There is a more complicated (but more accurate) change that was proposed by the Greek Orthodox Church in the 1920s, but they never implemented it. They realized that they could do better than the century rule which drops three leap years every 400 years. Instead they proposed dropping 7 leap years every 900 years. They would do that by requiring that in order for a century year to be a leap year, it needs to give a remainder of 200 or 600 when divided by 900. Of course that was the complicated part, and nobody was going to go along with that. You can probably see immediately that the year 1600 was a leap year according to the Gregorian rules, but it will take you more effort to figure out that it was not a leap year under the proposed Greek rules.

Although it's too complicated to be viable, let's see what the error would be under the Greek rules. Under those rules, the average length of a year is 365.24222 days. That's awfully close to the true value of 365.2422 days. In fact, the difference is small enough that the error can no longer be calculated because the 365.2422 number has some slight variance in it (it is not the same every year).

Telling One Year From Another

Throughout this paper we have been designating years with numbers. For example, we said that the Julian calendar came about in 45 BCE. But of course people in the year 45 BCE didn't refer to the year that way because they had no way of knowing that anything special was going to happen 45 years later. So how did they talk about their years?

Consular Dating (510 BCE to 541 CE):

The years in the Roman calendars and the early Julian calendar were designated by giving the names of the two consuls who took office in that year. For example, the two consuls who took office in 59 BCE were Caesar and Bibulus. So that year was referred to as the year of Caius Iulius Caesar & Marcus Calpurnius Bibulus. That was quite a mouthful.

This method of year-dating started with the first year of the Republic in 510 BCE and continued until 541 CE when the emperor stopped appointing consuls.

A list of the consul pairs for each year can be found in wikipedia at http://en.wikipedia.org/wiki/List_of_Roman_consuls

Regnal Dating (541 CE to 800 CE)

Regnal dating refers to specifying the year number of the presiding monarch's reign. It is said to have started with Augustus, who informally counted how many times he had held office as a consul or an emperor. It continued in this informal manner until about 200 CE when the emperors started talking about their regnal year openly. But it wasn't adopted as the official year designation until 541 CE, when consular dating ended for lack of consuls.

The then-current Julian calendar was used worldwide, and different regions had different monarchs. So although they were all using the same Julian month and day, they all had different numeric values for the year depending on how long their monarch had been in power. This obviously led to much confusion.

Common Era Dating (800 CE to present)

A system of numbering the years using BC (Before Christ) and AD (Anno Domini) was devised by Dionysius Exiguus in the year 525 CE. But it was not widely used until Saint Bede mentioned it in his Historia Ecclesiastica in 731 CE. By 800 CE it had pretty-much replaced regnal dating.

The BC/AD notation was religion specific since it referenced Christ. So later religion-neutral synonyms for BC and AD were introduced, namely BCE (before the common era) and CE (common era). This is the notation that is used throughout this paper.

Conclusion

As this paper illustrated, there are several non-obvious issues that historians and genealogists need to take into consideration when working with dates in the Julian calendar. To simplify this in some measure, I have created a tool (figure 11) on my website for doing conversions between the two calendars. The address of that tool is http://stevemorse.org/jcal/julian.html. The tool adjusts by the required number of days and also takes the year-number-change day into consideration.

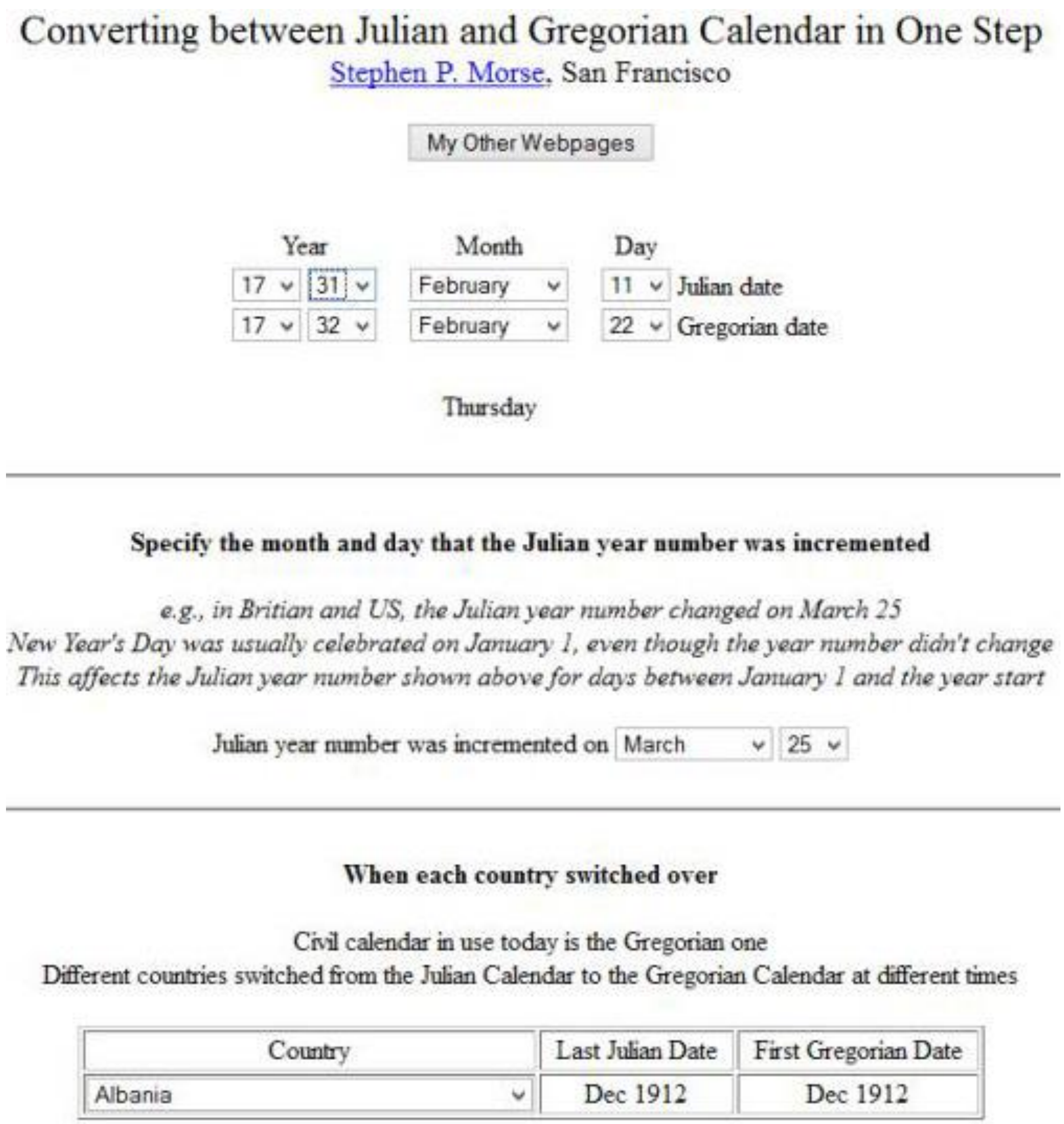


FIGURE 11. Tool for converting between Julian and Gregorian calendars

Appendix

There were three one-time additions/substractions made to the calendar to compensate for accumulated errors made up until that time. They are the additions made by Julius Ceasar in 46 BCE, the subtractions made by Augustus Caesar in 8 BCE, and the subtractions made by Pope Gregory XIII in 1582.

Appendix 1 -- Julius's Compensation to the Calendar (46 BCE)

Julius compensated for past abuses of leap years by adding three months (total of 94 days) to the year 46 BCE, which was the year preceding the start of Julius's calendar. These three months were the following:

Intercalarius (27 days)
This was the normal leap month of the calendar at that time
It occurred after the month of Februarius

Intercalarius Prior and Intercalarius Posterior (67 days)
These two months were one-time additions to the calendar
The individual lengths of these months is unknown
They occurred between the months of November and December

Appendix 2 -- Augustus's Compensation to the Calendar (8 BCE)

The first leap year in Julius's calendar was in 45 BCE. But subsequent leap years occurred every three years instead of every four years. So from 44 BCE to 8 BCE the calendar had accumulated 12 leap years instead of 9. Specifically, the leap years after 45 BCE were 42 BCE, 39 BCE, 36 BCE, ... 9 BCE whereas they should have been 41 BCE, 37 BCE, 33 BCE, ... 9 BCE.

To undo these extra three leap years, Augustus ordered that leap years be skipped in 5 BCE, 1 BCE, and 4 CE. The calendar would then continue with the four-year cycle starting in 8 CE

Appendix 3 -- Gregory's Compensation to the Calendar (1582 CE)

Even the four-year cycle wasn't accurate enough, and by 1582 the calendar had accumulated ten days too many. Gregory compensated for that by skipping ten days in 1582. But different countries adopted this correction at different times, and the number of days skipped were different, depending on the century in which the correction was adopted (11 days in the 1700s, 12 days in the 1800s, 13 days in the 1900s).