19

The Chinese Calendar

The complexity of calendars is due simply to the incommensurability of the fundamental periods on which they are based ... Calendars based on [*the synodic month*]*, depending only on lunations, make the seasons unpredictable, while calendars based on* [*the tropical year*] *cannot predict the full moons, the importance of which in ages before the introduction of artificial illuminants was considerable. The whole history of calendar-making, therefore, is that of successive attempts to reconcile the irreconcilable, and the numberless systems of intercalated months, and the like, are thus of minor scientific interest. The treatment here will therefore be deliberately brief.*

Joseph Needham: *Science and Civilisation in China* (1959)[1]

The Chinese calendar is a lunisolar calendar based on astronomical events, not arithmetical rules. Days begin at civil midnight. Months are lunar, beginning on the day of the new moon and ending on the day before the next new moon. Years contain 12 or 13 such months, with the number of months determined by the number of new moons between successive winter solstices. The details of the Chinese calendar have varied greatly—there have been more than 50 calendar reforms—since its inception in the fourteenth century B.C.E.; some of its history, in particular its effect on the development of mathematics in China, is described in [14]; other historical details can be found in [6], [18], and [25].[2] The version we implement here is the 1645 version, established in the second year of the Qīng dynasty;[3] detailed calculations of earlier forms of the Chinese calendar are given in [17] (see also

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[1] 作者可以不认同引文的见解

[2] The three most significant of calendar reforms were the following. In 104 B.C.E., the rule that the lunar month without a major solar term is intercalary was established (page 311), and *mean* values were used for both solar and lunar months, much like the old Hindu lunisolar calendar described in Chapter 10. In 619 C.E., the use of *true* new moons was introduced. In 1645 C.E., the use of *true* solar months was introduced.

[3] Specifically, we follow the principles of Baolin Liú, the former calendrist of the Purple Mountain Observatory, Nanjing, China, as given in [15]; for a summary of this manuscript, see [7]. Our functions accurately reproduce the third printing of [2], of which Liú is the primary author, for 1907 onward; they reproduce Xú's table [34] for 1907 onward, except for 2033; Xú used the first printing of [2], which was later corrected (Xú takes the month beginning on August 25 as a leap month, forcing the solstice into the tenth month, thus violating Liú's basic principle given on page 310).

For years 1645–1906, our functions very occasionally err because of disagreements by a few minutes in the astronomical calculations (the Chinese used seventeenth-century models of the solar system until

[24]). We discuss some common misconceptions about the Chinese calendar later in Section 19.5. The Japanese, Korean, and Vietnamese lunisolar calendars are nearly identical to the Chinese; we describe them in Sections 19.9–19.11.

19.1 Solar Terms

It is better to have no decent calendar than have Westerners in China.
Yáng Guāngxiān (1664)[4]

The Chinese year, called a nián (年), consists of true lunar months, but the arrangement of those months depends on the sun's course through the 12 zodiacal signs. Specifically, the Chinese divide the solar year into 24 solar terms or *jiéqì*: 12 *major solar terms* called *zhōngqì* (中气) and 12 *minor solar terms* known by the general term jiéqì (节气). These terms correspond to 15° segments of solar longitude, with the major terms starting at $k \times 30°$ of solar longitude and the minor terms starting at $k \times 30° + 15°$ of solar longitude, $k = 0, 1, \ldots, 11$; the names of the 24 terms are shown in Table 19.1.

The dates of the terms in Table 19.1 are only approximate; the true motion of the sun varies, and thus to implement the Chinese calendar we need to calculate the precise date of a given solar longitude. We use the solar longitude function (14.33) to determine the index of the last major solar term on or before a given date:

$$\textbf{current-major-solar-term}\,(date) \stackrel{\text{def}}{=} \left(2 + \left\lfloor \frac{s}{30°} \right\rfloor\right) \bmod [1\,..\,12] \tag{19.1}$$

where

$$s = \textbf{solar-longitude}\,(\textbf{universal-from-standard}\,(date, \textbf{chinese-location}\,(date)))$$

We define

$$\textbf{chinese-location}\,(t) \stackrel{\text{def}}{=} \tag{19.2}$$

$$\begin{cases} \boxed{39°55' \mid 116°25' \mid 43.5\text{ m} \mid \frac{1397}{180}^{\text{h}}} & \textbf{if } year < 1929 \\ \boxed{39°55' \mid 116°25' \mid 43.5\text{ m} \mid 8^{\text{h}}} & \textbf{otherwise} \end{cases}$$

where

$$year = \textbf{gregorian-year-from-fixed}\,(\lfloor t \rfloor)$$

because before 1929 the local mean time of Beijing was used—since Beijing is at longitude 116°25′ east, the time difference from U.T. was $7^{\text{h}}45^{\text{m}}40^{\text{s}} = 1397/180$

1913, and thus their calculated times of solar and lunar events were not as accurate as ours); nevertheless, our calculated dates for Chinese New Year agree with Xú's table for 1644–2050.

[4] Yáng had attempted to amend the calendar, but his inadequate knowledge resulted in frequent errors [14]. He had had the Jesuits, who had—through superior astronomical calculations—achieved positions of importance in determining the calendar, framed and sentenced to death before the errors caused by his ignorance caused him to be sent into exile and the Jesuits to be released [3].

Table 19.1 The solar terms of the Chinese year: major solar terms, zhōngqì (中气), are given in boldface; minor solar terms, jiéqì (节气), are given in lightface. Adapted from [7].

Index	Chinese Name	Japanese Pronunciation	English Meaning	Solar Longitude	Approximate Starting Date
1.	Lìchūn (立春)	Risshun	Beginning of Spring	315°	February 4
1.	**Yǔshuǐ** (雨水)	Usui	**Rain Water**	**330°**	**February 19**
2.	Jīngzhé (惊蛰)	Keichitsu	Waking of Insects	345°	March 6
2.	**Chūnfēn** (春分)	Shunbun	**Spring Equinox**	**0°**	**March 21**
3.	Qīngmíng (清明)	Seimei	Pure Brightness	15°	April 5
3.	**Gǔyǔ** (谷雨)	Kokuu	**Grain Rain**	**30°**	**April 20**
4.	Lìxià (立夏)	Rikka	Beginning of Summer	45°	May 6
4.	**Xiǎomǎn** (小满)	Shōman	**Grain Full**	**60°**	**May 21**
5.	Mángzhòng (芒种)	Bōshu	Grain in Ear	75°	June 6
5.	**Xiàzhì** (夏至)	Geshi	**Summer Solstice**	**90°**	**June 21**
6.	Xiǎoshǔ (小暑)	Shōsho	Slight Heat	105°	July 7
6.	**Dàshǔ** (大暑)	Taisho	**Great Heat**	**120°**	**July 23**
7.	Lìqiū (立秋)	Risshū	Beginning of Autumn	135°	August 8
7.	**Chǔshǔ** (处暑)	Shosho	**Limit of Heat**	**150°**	**August 23**
8.	Báilù (白露)	Hakuro	White Dew	165°	September 8
8.	**Qiūfēn** (秋分)	Shūbun	**Autumnal Equinox**	**180°**	**September 23**
9.	Hánlù (寒露)	Kanro	Cold Dew	195°	October 8
9.	**Shuāngjiàng** (霜降)	Sōkō	**Descent of Frost**	**210°**	**October 24**
10.	Lìdōng (立冬)	Rittō	Beginning of Winter	225°	November 8
10.	**Xiǎoxuě** (小雪)	Shōsetsu	**Slight Snow**	**240°**	**November 22**
11.	Dàxuě (大雪)	Taisetsu	Great Snow	255°	December 7
11.	**Dōngzhì** (冬至)	Tōji	**Winter Solstice**	**270°**	**December 22**
12.	Xiǎohán (小寒)	Shōkan	Slight Cold	285°	January 6
12.	**Dàhán** (大寒)	Taikan	**Great Cold**	**300°**	**January 20**

hours. After 1928, however, China adopted the standard time zone and calendar makers used the 120° meridian, or 8 hours after U.T.[5]

Although not needed for date conversion, a printed Chinese calendar usually indicates the major and minor solar terms. The solar longitude functions in Section 14.4 also allow us to calculate the moment after the start of a given R.D. date when the solar longitude will be a given value:

$$\textbf{chinese-solar-longitude-on-or-after}\,(\lambda, t) \stackrel{\text{def}}{=} \tag{19.3}$$

$$\textbf{standard-from-universal}\,(sun, \textbf{chinese-location}\,(sun))$$

where

$$sun = \textbf{solar-longitude-after}\,(\lambda, \textbf{universal-from-standard}\,(t, \textbf{chinese-location}\,(t)))$$

from which we can determine the start of the major solar term on or after a given date:

$$\textbf{major-solar-term-on-or-after}\,(date) \stackrel{\text{def}}{=} \tag{19.4}$$

$$\textbf{chinese-solar-longitude-on-or-after}\,(l, date)$$

where

$$s = \textbf{solar-longitude}\,(\textbf{midnight-in-china}\,(date))$$

$$l = \left(30 \times \left\lceil \frac{s}{30} \right\rceil\right) \bmod 360$$

We can also compute the index of the last minor solar term prior to a given date:

$$\textbf{current-minor-solar-term}\,(date) \stackrel{\text{def}}{=} \tag{19.5}$$

$$\left(3 + \left\lfloor \frac{s - 15^\circ}{30^\circ} \right\rfloor\right) \bmod [1 \,..\, 12]$$

where

$$s = \textbf{solar-longitude}\,(\textbf{universal-from-standard}\,(date, \textbf{chinese-location}\,(date)))$$

and the date of the minor solar term on or after a given date:

$$\textbf{minor-solar-term-on-or-after}\,(date) \stackrel{\text{def}}{=} \tag{19.6}$$

$$\textbf{chinese-solar-longitude-on-or-after}\,(l, date)$$

[5] Actual practice for 1928 is uncertain.

where

$$s = \textbf{solar-longitude}\,(\textbf{midnight-in-china}\,(\textit{date}))$$

$$l = \left(30 \times \left\lceil \frac{s - 15^\circ}{30} \right\rceil + 15^\circ\right) \bmod 360$$

One of the solar terms, the winter solstice (dōngzhì), plays a dominant role in the calendar, and we need to determine the date it occurs; because days end at civil midnight, the U.T. moment of midnight is given by

$$\textbf{midnight-in-china}\,(\textit{date}) \stackrel{\text{def}}{=} \tag{19.7}$$

$$\textbf{universal-from-standard}\,(\textit{date}, \textbf{chinese-location}\,(\textit{date}))$$

Now, using (14.43), we have

$$\textbf{chinese-winter-solstice-on-or-before}\,(\textit{date}) \stackrel{\text{def}}{=} \tag{19.8}$$

$$\underset{\textit{day} \geqslant \lfloor \textit{approx} \rfloor - 1}{\textbf{MIN}} \left\{ \textbf{winter} < \textbf{solar-longitude}\,(\textbf{midnight-in-china}\,(\textit{day} + 1)) \right\}$$

where

$$\textit{approx} = \textbf{estimate-prior-solar-longitude}\,(\textbf{winter}, \textbf{midnight-in-china}\,(\textit{date} + 1))$$

19.2 Months

Although there is a very large literature, still growing almost daily, on the Chinese calendar, its interest is, we suggest, much more archaeological and historical than scientific. A calendar is only a method of combining days into periods suitable for civil life and religious or cultural observances.

Joseph Needham: *Science and Civilisation in China* (1959)

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Chinese months begin on the day of the new moon in Beijing, and thus we must be able to calculate that. We use the function **new-moon-at-or-after** (see page 231) to tell us the moment in universal time of the first new moon on or after a given date and the function **standard-from-universal** to convert to standard Beijing time (Section 14.2). With these functions we can write

$$\textbf{chinese-new-moon-on-or-after}\,(\textit{date}) \stackrel{\text{def}}{=} \tag{19.9}$$

$$\lfloor \textbf{standard-from-universal}\,(t, \textbf{chinese-location}\,(t)) \rfloor$$

where

$$t = \textbf{new-moon-at-or-after}\,(\textbf{midnight-in-china}\,(\textit{date}))$$

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Similarly, we use **new-moon-before** (page 230) in

$$\textbf{chinese-new-moon-before}\,(\mathit{date}) \stackrel{\text{def}}{=} \tag{19.10}$$

$$\lfloor \textbf{standard-from-universal}\,(t, \textbf{chinese-location}\,(t)) \rfloor$$

where

$$t = \textbf{new-moon-before}\,(\textbf{midnight-in-china}\,(\mathit{date}))$$

Once we can calculate the solar terms and new moons, we are ready to compute the arrangement of months in a Chinese year. The basic rule that determines the calendar is

> *The winter solstice* (*dōngzhì*) *always occurs during the eleventh month of the year.*

To enforce this rule for a given Chinese year, we must examine the winter-solstice-to-winter-solstice period, called a *suì* (岁). Hence, we must compute the dates of two successive winter solstices. For example, in 1989 the winter solstice occurred at 9:23 p.m. U.T. on December 21, which was December 22 (R.D. 726458) in Beijing. The next winter solstice was at 3:08 a.m. U.T. on December 22, 1990 (R.D. 726823), which was the same date in Beijing. The list of the new moons in Beijing with R.D. dates d such that $726458 < d \leqslant 726823$ is

(i)	R.D. 726464	(December 28, 1989)
(ii)	R.D. 726494	(January 27, 1990)
(iii)	R.D. 726523	(February 25, 1990)
(iv)	R.D. 726553	(March 27, 1990)
(v)	R.D. 726582	(April 25, 1990)
(vi)	R.D. 726611	(May 24, 1990)
(vii)	R.D. 726641	(June 23, 1990)
(viii)	R.D. 726670	(July 22, 1990)
(ix)	R.D. 726699	(August 20, 1990)
(x)	R.D. 726729	(September 19, 1990)
(xi)	R.D. 726758	(October 18, 1990)
(xii)	R.D. 726788	(November 17, 1990)
(xiii)	R.D. 726818	(December 17, 1990)

These 13 dates are the beginnings of months on the Chinese calendar during the suì from December 23, 1989 to December 22, 1990.

The average length of a lunar month is about 29.53 days; the length varies from approximately 29.27 to 29.84. Because there can be 365 or 366 days between successive solstices, there will be either 12 or 13 new moons. To have fewer than 12 new moons is impossible because the longest period containing at most 11 new moons is just short of 12 consecutive lunar months and considerably less than 365 days; more than 13 new moons is also impossible because the shortest period containing at least 14 new moons contains 13 full lunar months, which is much more than 366 days. The 12 or 13 months thus found form the months following the eleventh month of the preceding Chinese year to the eleventh month of the Chinese year in question.

Months on the Chinese calendar are numbered 1 to 12; a leap month duplicates the number of the preceding month. The possible numberings of the 12 or 13 months from a winter solstice to the following winter solstice are thus as shown in Figure 19.1. It is clear from this figure that if there are only 12 new moons, they must be numbered $12, 1, 2, \ldots, 11$; but if there are 13 new moons, which one is the leap month? The answer follows from the rule that

> *The leap month of a 13-month winter-solstice-to-winter-solstice period is the first month that does not contain a major solar term—that is, the first lunar month that is wholly within a solar month.*

There *must* be such a lunar month because the period from one winter solstice to the next contains only 12 major solar terms, yet there are 13 lunar months. (This is an application of the famous "Dirichlet box principle" or "pigeonhole principle"—see, for example, [16, sec. 4.8].) A solar month can also fall entirely within a lunar month—that is, a lunar month can contain *two* major solar terms. Such an occurrence in a 13-month Chinese year can cause two or more lunar months without major solar terms; in a 12-month Chinese year it can cause one or more months without major solar terms.

We can test for a leap year by computing the year's first new moon, computing its last new moon, and rounding

$$\frac{\textit{last-new-moon} - \textit{first-new-moon}}{29.53}$$

to the nearest integer; if the value obtained is 12, the year is a leap year with 13 months.

There cannot be more than one leap month in a suì, but how do we know that a Chinese year cannot require two leap months? That is impossible because the two-solar-year period between the winter solstice of year $y - 2$ and the winter solstice of year y can contain either 24 or 25 lunar months; since the period from the winter solstice of year $y - 1$ to the winter solstice of year y has 13 months, the period from the winter solstice of year $y - 2$ to the winter solstice of year $y - 1$ can have only 12 lunar months and hence no leap month. Thus, the first month in a winter-solstice-to-winter-solstice period without a major solar term will be the leap month, and no second leap month is possible.

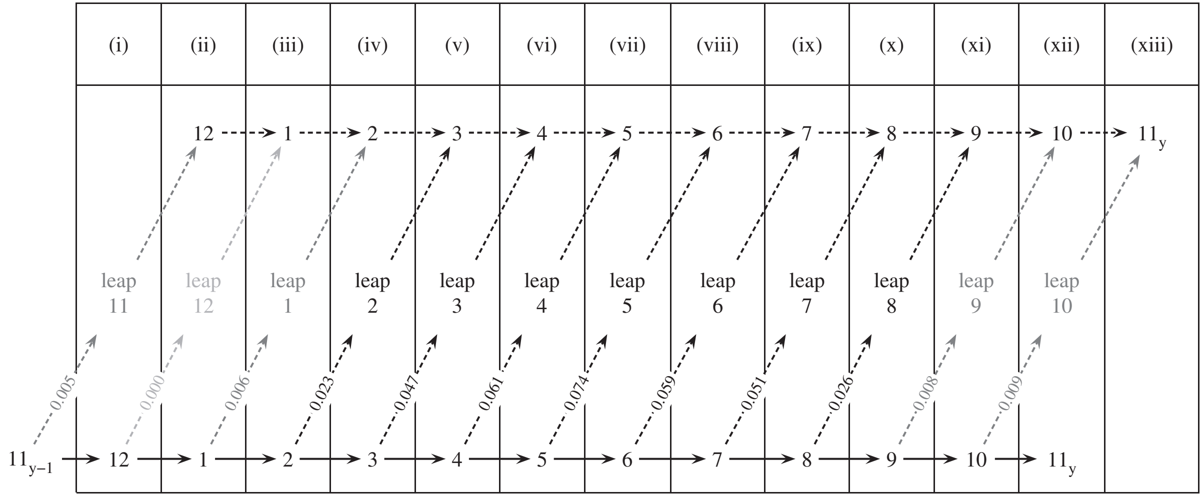

Figure 19.1 The theoretical possible numberings of the lunar months (i)−(xiii) for the Chinese calendar in the solstice-to-solstice period of year y. Each column corresponds to the new moon beginning a lunar month and contains the number of that lunar month. The winter solstice of Gregorian year $y-1$ occurs in the lunar month numbered 11_{y-1}, that is, in the month before the new moon (i), and the winter solstice for Gregorian year y occurs in the lunar month numbered 11_y, that is, in the month of the new moon (xii) or (xiii). The solid arrows show the only possible numbering when there are 12 new moons between the successive solstices. The dashed lines show possible numberings when there are 13 new moons between successive solstices. Before 1645, when *mean* solar terms were used, any month could be followed by a leap month. The relatively swift movement of the sun in the winter means that in current practice, because *true* solar terms are used, leap months 9, 10, 11, or 1 are rare (these numberings are shown in gray); leap month 12 is exceptionally rare (this rare numbering is shown in light gray). The dashed lines from a month i to a following leap month i are labeled with the approximate probability that a randomly chosen month i is followed by a leap month; these probabilities are based on data from [3] for the Chinese calendar for the thousand years 1645−2644.

To determine whether a given month lacks a major solar term, we write a function that compares the major solar term at a given date with that at the beginning of the next month:

$$\textbf{chinese-no-major-solar-term?}\,(date) \stackrel{\text{def}}{=} \tag{19.11}$$

$$\textbf{current-major-solar-term}\,(date)$$
$$= \textbf{current-major-solar-term}\,(\textbf{chinese-new-moon-on-or-after}\,(date + 1))$$

Applying this function to the first day of a month tells us whether the month lacks a solar term. Because we want only the first month missing a major term to be a leap month, we also need the following function:

$$\textbf{chinese-prior-leap-month?}\,(m', m) \stackrel{\text{def}}{=} \tag{19.12}$$

$$m \geqslant m' \text{ and}$$
$$\left\{ \begin{array}{l} \textbf{chinese-no-major-solar-term?}\,(m) \text{ or} \\ \textbf{chinese-prior-leap-month?}\,(m', \textbf{chinese-new-moon-before}\,(m)) \end{array} \right\}$$

which determines (recursively) whether there is a Chinese leap month on or after the lunar month starting on fixed day m' and at or before the lunar month starting at fixed date m.

Figure 19.2 shows the structure of the Chinese calendar for a hypothetical year. Notice that the winter solstice is in the eleventh month, as required, and the month following the tenth month is a leap month containing no major solar term. Major terms and new moons are considered *without regard to their time of day.* Thus, for example, even if the major term, dōngzhì, occurred in Beijing *before* the new moon on that date, dōngzhì is considered to be in that month, not the previous month. In contrast, in the modern Hindu calendars (Chapter 20) the predicted time of day of an event is critical.

Continuing our example of 1989–90, we have the following dates for the major solar terms:

12.	Dàhán	R.D. 726487	(January 20, 1990)
1.	Yǔshuǐ	R.D. 726517	(February 19, 1990)
2.	Chūnfēn	R.D. 726547	(March 21, 1990)
3.	Gǔyǔ	R.D. 726577	(April 20, 1990)
4.	Xiǎomǎn	R.D. 726608	(May 21, 1990)
5.	Xiàzhì	R.D. 726639	(June 21, 1990)
6.	Dàshǔ	R.D. 726671	(July 23, 1990)
7.	Chǔshǔ	R.D. 726702	(August 23, 1990)
8.	Qiūfēn	R.D. 726733	(September 23, 1990)
9.	Shuāngjiàng	R.D. 726764	(October 24, 1990)
10.	Xiǎoxuě	R.D. 726793	(November 22, 1990)
11.	Dōngzhì	R.D. 726823	(December 22, 1990)

Collating this list with the list of new moons, we find

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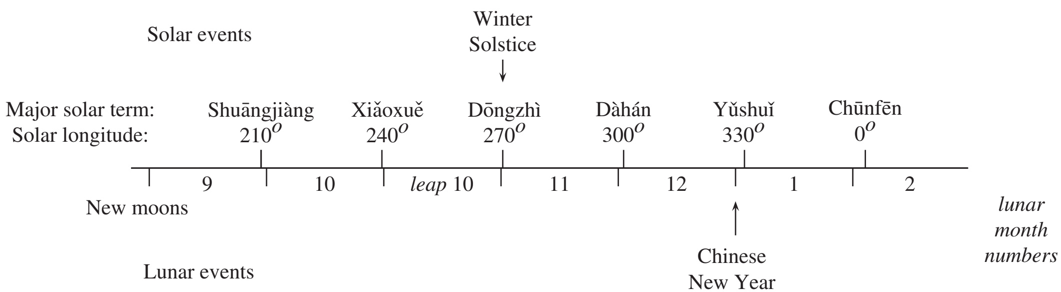

Figure 19.2 The Chinese calendar for a hypothetical year. Division into the major solar terms is shown above the time line and new moons are shown below. Solar and lunar events are specified by the day of occurrence irrespective of the exact time of day. Chinese month numbers are in italic.

	(i)	R.D. 726464	(December 28, 1989)
12.	Dàhán	R.D. 726487	(January 20, 1990)
	(ii)	R.D. 726494	(January 27, 1990)
1.	Yǔshuǐ	R.D. 726517	(February 19, 1990)
	(iii)	R.D. 726523	(February 25, 1990)
2.	Chūnfēn	R.D. 726547	(March 21, 1990)
	(iv)	R.D. 726553	(March 27, 1990)
3.	Gǔyǔ	R.D. 726577	(April 20, 1990)
	(v)	R.D. 726582	(April 25, 1990)
4.	Xiǎomǎn	R.D. 726608	(May 21, 1990)
	(vi)	R.D. 726611	(May 24, 1990)
5.	Xiàzhì	R.D. 726639	(June 21, 1990)
	(vii)	R.D. 726641	(June 23, 1990)
	(viii)	R.D. 726670	(July 22, 1990)
6.	Dàshǔ	R.D. 726671	(July 23, 1990)
	(ix)	R.D. 726699	(August 20, 1990)
7.	Chǔshǔ	R.D. 726702	(August 23, 1990)
	(x)	R.D. 726729	(September 19, 1990)
8.	Qiūfēn	R.D. 726733	(September 23, 1990)
	(xi)	R.D. 726758	(October 18, 1990)
9.	Shuāngjiàng	R.D. 726764	(October 24, 1990)
	(xii)	R.D. 726788	(November 17, 1990)
10.	Xiǎoxuě	R.D. 726793	(November 22, 1990)
	(xiii)	R.D. 726818	(December 17, 1990)
11.	Dōngzhì	R.D. 726823	(December 22, 1990)

Hence month (vii), from June 23 to July 21, 1990, is a leap month; that is, the numbering of the 13 months (i)–(xiii) must be (see Figure 19.1)

Month 12	R.D. 726464	(December 28, 1989)
Month 1	R.D. 726494	(January 27, 1990)
Month 2	R.D. 726523	(February 25, 1990)
Month 3	R.D. 726553	(March 27, 1990)
Month 4	R.D. 726582	(April 25, 1990)
Month 5	R.D. 726611	(May 24, 1990)
Leap month 5	R.D. 726641	(June 23, 1990)
Month 6	R.D. 726670	(July 22, 1990)
Month 7	R.D. 726699	(August 20, 1990)
Month 8	R.D. 726729	(September 19, 1990)
Month 9	R.D. 726758	(October 18, 1990)
Month 10	R.D. 726788	(November 17, 1990)
Month 11	R.D. 726818	(December 17, 1990)

Thus the date of the Chinese New Year in this suì is found to be R.D. 726494.

Describing the process outlined above algorithmically, we find the Chinese New Year in the suì containing *date*:

$$\textbf{chinese-new-year-in-sui}\,(\mathit{date}) \stackrel{\text{def}}{=} \tag{19.13}$$

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$$\begin{cases} \textbf{chinese-new-moon-on-or-after}\,(m_{13}+1) \\ \qquad \textbf{if } \text{round}\left(\dfrac{\textit{next-}m_{11} - m_{12}}{\textbf{mean-synodic-month}}\right) = 12 \text{ and} \\ \qquad\quad \{\, \textbf{chinese-no-major-solar-term?}\,(m_{12}) \text{ or} \\ \qquad\quad\ \ \textbf{chinese-no-major-solar-term?}\,(m_{13}) \,\} \\ m_{13} \quad \textbf{otherwise} \end{cases}$$

where

$$\begin{aligned} s_1 &= \textbf{chinese-winter-solstice-on-or-before}\,(\textit{date}) \\ s_2 &= \textbf{chinese-winter-solstice-on-or-before}\,(s_1 + 370) \\ m_{12} &= \textbf{chinese-new-moon-on-or-after}\,(s_1 + 1) \\ m_{13} &= \textbf{chinese-new-moon-on-or-after}\,(m_{12} + 1) \\ \textit{next-}m_{11} &= \textbf{chinese-new-moon-before}\,(s_2 + 1) \end{aligned}$$

This latter function allows us to find the Chinese New Year on or before a given *date*:

$$\textbf{chinese-new-year-on-or-before}\,(\textit{date}) \stackrel{\text{def}}{=} \tag{19.14}$$

$$\begin{cases} \textit{new-year} & \textbf{if } \textit{date} \geqslant \textit{new-year} \\ \textbf{chinese-new-year-in-sui}\,(\textit{date} - 180) & \textbf{otherwise} \end{cases}$$

where

$$\textit{new-year} = \textbf{chinese-new-year-in-sui}\,(\textit{date})$$

We first find the Chinese New Year in the suì containing the given *date*; if that New Year is after *date* (which can happen if *date* is late in the Chinese year), we go back to the previous suì.

19.3 Conversions to and from Fixed Dates

Ancient Chinese texts say that "the calendar and the pitch pipes have such a close fit, that you could not slip a hair between them."

Giorgio de Santillana and Hertha von Dechend: *Hamlet's Mill* (1969)

By tradition, Chinese years go in cycles of 60, each year having a special sexagenary name (discussed in the next section); the first year of the first cycle commences in year −2636 (Gregorian). Thus we define

$$\textbf{chinese-epoch} \stackrel{\text{def}}{=} \tag{19.15}$$

$$\textbf{fixed-from-gregorian}\left(\boxed{-2636 \mid \textbf{february} \mid 15}\right)$$

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This is the traditional date of the first use of the sexagesimal cycle, February 15, −2636 (Gregorian) = March 8, 2637 B.C.E. (Julian).

Although it is not traditional to count these cycles, we do so for convenience to identify a year uniquely. The conversion between Chinese dates and R.D. dates can now be done by a method nearly identical to our function **chinese-new-year-in-sui**. Notice that most of the work lies in determining the month number and whether it is a leap month:

$$\textbf{chinese-from-fixed}\,(date) \stackrel{\text{def}}{=} \tag{19.16}$$

cycle	*year*	*month*	*leap-month*	*day*

where

$$\begin{aligned}
s_1 &= \textbf{chinese-winter-solstice-on-or-before}\,(date)\\
s_2 &= \textbf{chinese-winter-solstice-on-or-before}\,(s_1 + 370)\\
m_{12} &= \textbf{chinese-new-moon-on-or-after}\,(s_1 + 1)\\
\mathit{next}\text{-}m_{11} &= \textbf{chinese-new-moon-before}\,(s_2 + 1)\\
m &= \textbf{chinese-new-moon-before}\,(date + 1)\\
\mathit{leap\text{-}year} &= \text{round}\left(\frac{\mathit{next}\text{-}m_{11} - m_{12}}{\textbf{mean-synodic-month}}\right) = 12\\
\mathit{month} &= \left(\text{round}\left(\frac{m - m_{12}}{\textbf{mean-synodic-month}}\right) - \begin{cases} 1 & \textbf{if } \mathit{leap\text{-}year} \text{ and} \\ & \quad \textbf{chinese-prior-leap-month?} \\ & \qquad (m_{12}, m) \\ 0 & \textbf{otherwise} \end{cases}\right) \bmod [1 \,..\, 12]\\
\mathit{leap\text{-}month} &= \mathit{leap\text{-}year} \text{ and } \textbf{chinese-no-major-solar-term?}\,(m) \text{ and}\\
&\quad \text{not } \textbf{chinese-prior-leap-month?}\\
&\qquad (m_{12},\ \textbf{chinese-new-moon-before}\,(m))\\
\mathit{elapsed\text{-}years} &= \left\lfloor 1.5 - \frac{\mathit{month}}{12} + \frac{date - \textbf{chinese-epoch}}{\textbf{mean-tropical-year}} \right\rfloor\\
\mathit{cycle} &= \left\lfloor \frac{1}{60} \times (\mathit{elapsed\text{-}years} - 1) \right\rfloor + 1\\
\mathit{year} &= \mathit{elapsed\text{-}years} \bmod [1 \,..\, 60]\\
\mathit{day} &= date - m + 1
\end{aligned}$$

The calculation of *elapsed-years* is done by finding the elapsed years to the midsummer of the desired Chinese year so that the irregular character of leap years cannot affect the truncation.

Finally, to convert a Chinese date to an R.D. date, we find a midyear date of the given cycle and year, then find the prior Chinese New Year, go forward to the appropriate month, and add the day of the month:

$$\textbf{fixed-from-chinese}\left(\boxed{\mathit{cycle}\ \big|\ \mathit{year}\ \big|\ \mathit{month}\ \big|\ \mathit{leap}\ \big|\ \mathit{day}}\right) \stackrel{\text{def}}{=} \tag{19.17}$$

$$\mathit{prior\text{-}new\text{-}moon} + \mathit{day} - 1$$

where

$$\mathit{mid\text{-}year} = \left\lfloor \textbf{chinese-epoch} + \left((\mathit{cycle} - 1) \times 60 + \mathit{year} - 1 + \frac{1}{2}\right) \times \textbf{mean-tropical-year} \right\rfloor$$

$$\mathit{new\text{-}year} = \textbf{chinese-new-year-on-or-before}\ (\mathit{mid\text{-}year})$$

$$p = \textbf{chinese-new-moon-on-or-after}\ (\mathit{new\text{-}year} + (\mathit{month} - 1) \times 29)$$

$$d = \textbf{chinese-from-fixed}\ (p)$$

$$\mathit{prior\text{-}new\text{-}moon} = \begin{cases} p & \textbf{if } \mathit{month} = d_{\textbf{month}} \text{ and } \mathit{leap} = d_{\textbf{leap}} \\ \textbf{chinese-new-moon-on-or-after}\ (p+1) & \textbf{otherwise} \end{cases}$$

19.4 Sexagesimal Cycle of Names

The learned and indefatigable missionaries in China, to whose labours and researches the history and antiquities of that country are so much indebted . . . have taken it for granted, that the lunar calendar, of the time of Confucius, or of the times to which these observations refer, and the sexagesimal cycle also, mutatis mutandis *were absolutely one and the same with the lunar calendar, and with the sexagesimal cycle, of their own time. This assumption was a great mistake: and it could not fail to lead them wrong, in their attempts to verify and confirm these eclipses in particular.*

Edward Greswell: *On the Two Miracles, Affecting the Sun, in the Time of Joshua, and in the Time of Hezekiah, Respectively: and on their Effect upon the Measures of Time in General, and on the Lunar Measure of Time in Particular, and on the Precession of the Equinoxes* (1847)

The Chinese calendar uses a cycle of 60 names (see [26] for a history of their ritual foundations) for years. The name is formed by combining a *celestial stem*, tiān gān (天干), with a *terrestrial branch*, dì zhī (地支). The celestial stems,

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(1) Jiǎ (甲)	(6) Jǐ (己)
(2) Yǐ (乙)	(7) Gēng (庚)
(3) Bǐng (丙)	(8) Xīn (辛)
(4) Dīng (丁)	(9) Rén (壬)
(5) Wù (戊)	(10) Guǐ (癸)

are untranslatable, though they are sometimes associated with the 5 elements (tree, fire, earth, metal, and water), each in its male and female form. These stems have another use as well—they correspond to "A, B, C, D, ..." For example, because written Chinese uses word symbols, rather than an alphabet, jiǎ, yǐ, bǐng, and dīng are used as letter grades on Chinese exam papers.

The terrestrial branches

(1) Zǐ (子)	(Rat)	(7) Wǔ (午)	(Horse)
(2) Chǒu (丑)	(Ox)	(8) Wèi (未)	(Sheep)
(3) Yín (寅)	(Tiger)	(9) Shēn (申)	(Monkey)
(4) Mǎo (卯)	(Hare)	(10) Yǒu (酉)	(Fowl)
(5) Chén (辰)	(Dragon)	(11) Xū (戌)	(Dog)
(6) Sì (巳)	(Snake)	(12) Hài (亥)	(Pig)

are also untranslatable; the English names—traditional animal totems—given for the 12 branches corresponding to the years of the Chinese "Zodiac" are not translations from the Chinese.

The names are assigned sequentially, running through the decimal and duodenary lists simultaneously. The first name is jiǎzǐ, the second is yǐchǒu, the third is bǐngyín, and so on. Because the least common multiple of 10 and 12 is 60, the cycle of names repeats after the sixtieth name, guǐhài. Representing the name as a pair of numbers giving the celestial stem and the terrestrial branch (which must have the same parity), respectively, and using equation (1.70), we can thus obtain the nth name of the sexagenary cycle of names by means of the function

$$\textbf{chinese-sexagesimal-name}\,(n) \stackrel{\text{def}}{=} \boxed{n \bmod [1\,..\,10] \;\big|\; n \bmod [1\,..\,12]} \tag{19.18}$$

Determining the number of names from the sexagesimal name $\boxed{\mathit{stem}_1 \;|\; \mathit{branch}_1}$ to the next occurrence of the sexagesimal name $\boxed{\mathit{stem}_2 \;|\; \mathit{branch}_2}$ is an instance of formula (1.74):

$$\textbf{chinese-name-difference}\left(\boxed{\mathit{stem}_1 \;|\; \mathit{branch}_1}, \boxed{\mathit{stem}_2 \;|\; \mathit{branch}_2} \right) \stackrel{\text{def}}{=} \tag{19.19}$$

$$\left(\mathit{stem\text{-}difference} + 25 \times (\mathit{branch\text{-}difference} - \mathit{stem\text{-}difference}) \right) \bmod [1\,..\,60]$$

where

$$\begin{aligned} \mathit{stem\text{-}difference} &= \mathit{stem}_2 - \mathit{stem}_1 \\ \mathit{branch\text{-}difference} &= \mathit{branch}_2 - \mathit{branch}_1 \end{aligned}$$

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Because the name of the first year of any cycle is jiǎzǐ, the name of the Chinese *year* in any cycle is given by

$$\textbf{chinese-year-name}\,(\mathit{year}) \stackrel{\text{def}}{=} \tag{19.20}$$

$$\textbf{chinese-sexagesimal-name}\,(\mathit{year})$$

This representation can be inverted to give the year within a cycle corresponding to a given sexagesimal name by using formula (1.74).

At one time the Chinese used the same sequence of 60 names to name months and days as well. Extrapolating backward from known dates, we find the number of elapsed months on the Chinese calendar at the start of a name cycle to be

$$\textbf{chinese-month-name-epoch} \stackrel{\text{def}}{=} 57 \tag{19.21}$$

Because leap months were unnamed, we can write

$$\textbf{chinese-month-name}\,(\mathit{month}, \mathit{year}) \stackrel{\text{def}}{=} \tag{19.22}$$

$$\textbf{chinese-sexagesimal-name}\,(\mathit{elapsed\text{-}months} - \textbf{chinese-month-name-epoch})$$

where

$$\mathit{elapsed\text{-}months} = 12 \times (\mathit{year} - 1) + \mathit{month} - 1$$

For days, the repeating sequence of 60 names acts like a "week." We find that a day-cycle began on R.D. 46, so that day 0 (or, 60) of the cycle is:

$$\textbf{chinese-day-name-epoch} \stackrel{\text{def}}{=} \text{R.D. } 45 \tag{19.23}$$

which allows us to write

$$\textbf{chinese-day-name}\,(\mathit{date}) \stackrel{\text{def}}{=} \tag{19.24}$$

$$\textbf{chinese-sexagesimal-name}\,(\mathit{date} - \textbf{chinese-day-name-epoch})$$

Just as we did for the 7-day week in **kday-on-or-before**, we can apply formula (1.63) to compute the R.D. date of the last date with a given sexagesimal name on or before a given R.D. date:

$$\textbf{chinese-day-name-on-or-before}\,(\mathit{name}, \mathit{date}) \stackrel{\text{def}}{=} \tag{19.25}$$

$$\textbf{chinese-name-difference}\,(\textbf{chinese-day-name}\,(0), \mathit{name}) \bmod [\mathit{date} \,..\, \mathit{date} - 60)$$

The 60-element cycle of stem-branch combinations is applied to Chinese hours as well as to years, months, and days. Because the Chinese hours are intervals that are 2 ordinary hours in length (from odd hour to odd hour), the 60-element cycle

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repeats in 5 days, and the 12-element cycle of branches repeats daily from 11 p.m. to 11 p.m. The 12 branches are therefore used on Chinese medicine labels—the herbalist tells the patient to take the medicine every day in time slots yín and shēn, for example.

19.5 Common Misconceptions

Cuiusvis hominis est errare; nullius nisi insipientis in errore perseverare. [*Any man can make a mistake; only a fool keeps making the same one.*]

Attributed to Cicero

Not much has been written in Western languages about the Chinese calendar, but much of what has been written is ill-informed, out of date, oversimplified, or wrong.

For instance, it is not true that the 19-year Metonic cycle is used to determine leap years; for example, the Chinese year 4664 (overlapping Gregorian years 1966−67) was a leap year but, 19 years later, the Chinese year 4683 (overlapping Gregorian years 1985−86) was a common year. Since 1645 the true, not the mean, behavior of the moon and sun is used in calculations and, as a consequence, months 11 and 12 can be followed by a leap month (rarely—but it can happen: in 2033 on the Chinese calendar there will be a leap month 11 and in 1890 on the Japanese lunisolar calendar, identical to the Chinese except for the location at which the calculations are done, there was a leap month 12). Thus, Chinese New Year is *not* always the second new moon after the winter solstice, as is sometimes claimed (in [33], for example). Far enough in the future, as the perihelion moves, winter leap months will become more and more common, including leap twelfth months.

There is a popular "rule" that says that Chinese New Year is the new moon closest to lìchūn (the beginning of spring), which occurs on approximately February 4 (see, for example, [22]). Most of the time this is true, but if there is a new moon around January 21 (and hence again around February 20), the rule is difficult to apply. In such close situations the rule can fail, as it did for 1985.

It is not traditional to count cycles or years; years are generally given as regnal years and by sexagesimal name. Our code describes the Chinese New Year that began on January 28, 1998 as year 15 in cycle 78, making it year $60 \times (78-1)+15 = 4635$ in Chinese chronology. This era agrees with that used in Fritsche [8]. However, the popular press at the time described that new Chinese year as year 4696. The difference in year numbers stems from different choices of epoch and a likely error in calculation. We chose the traditional date of the first use of the sexagesimal cycle, February 15, −2636 (Gregorian) = March 8, 2637 B.C.E. (Julian); hence $1998 - (-2636) = 4634$ Chinese years elapsed prior to January 28, 1998. Others, including Sun Yat-sen, choose to number years from 2697 B.C.E., the first year of Emperor Huángdì, the traditional ancestor of the Chinese nation; this starting point would correctly give 4694 elapsed years as of January 28, 1998. Then, erroneously adding 1 to compensate for a year 0 on the Gregorian calendar gives 4695 elapsed years and hence year number 4696, as reported in the press. In any case, because the epoch in 2637 B.C.E. corresponds to year 61 of Huángdì, the sexagesimal name of a Chinese year is independent of the epoch.

The calculations are done for the 120° east meridian (after 1928). Calendars for other Asian countries may use other points of reference—see Section 19.9, for example.

19.6 Holidays

Please note … Islamic and Chinese new year dates are approximate.[6]
American Express Publishing Company: *1995 Pocket Diary*

The last day of the Chinese lunisolar year, followed by the first day of the next year, is a major celebration on the Chinese calendar. We have already seen how to determine the Chinese New Year on or before a given fixed date. It is easy to use this to determine Chinese New Year in a given Gregorian year:

$$\textbf{chinese-new-year}\,(g\text{-}year) \stackrel{\text{def}}{=} \tag{19.26}$$

$$\textbf{chinese-new-year-on-or-before}\left(\textbf{fixed-from-gregorian}\left(\boxed{g\text{-}year \;\big|\; \textbf{july} \;\big|\; 1}\right)\right)$$

We ask for the New Year on or before a summer date because that New Year is the one found in the first suì examined in **chinese-new-year-on-or-before**. The more obvious choice of asking for the New Year on or before December 31 results in two suìs being examined because December 31 always falls at the end of the Chinese year.

Chinese New Year falls in the range January 21 through February 21 on the Gregorian calendar. Figure 19.3 shows the relative frequency with which it falls on the various Gregorian dates for 1645–2644.

Because the Chinese calendar is consistently aligned with the sufficiently accurate Gregorian calendar, the determination of holidays is handled, as on the Hebrew calendar, by observing that fixed dates on the Chinese calendar occur in fixed seasons of the year. Specifically,

$$\begin{aligned}&\text{Chinese New Year occurring in the winter of Gregorian year } y\\ &\qquad = y + 1 - \textbf{gregorian-year-from-fixed}(\textbf{chinese-epoch})\end{aligned}$$

For example, the Chinese year that began in the winter of year 0 (Gregorian) was 2637 (cycle 44, year 57). This means that holidays occurring in the spring, summer, and fall of Gregorian year y occur in the Chinese year $y+2637$, whereas holidays in the winter occur in either Chinese year $y+2637$ or $y+2636$, depending on whether they are before or after January 1; such holidays need to be handled like Islamic holidays (Section 7.2).

[6] In the next section we will see that Chinese New Year can be determined exactly, in contrast with the observation-based Islamic New Year (Section 18.3), which cannot.

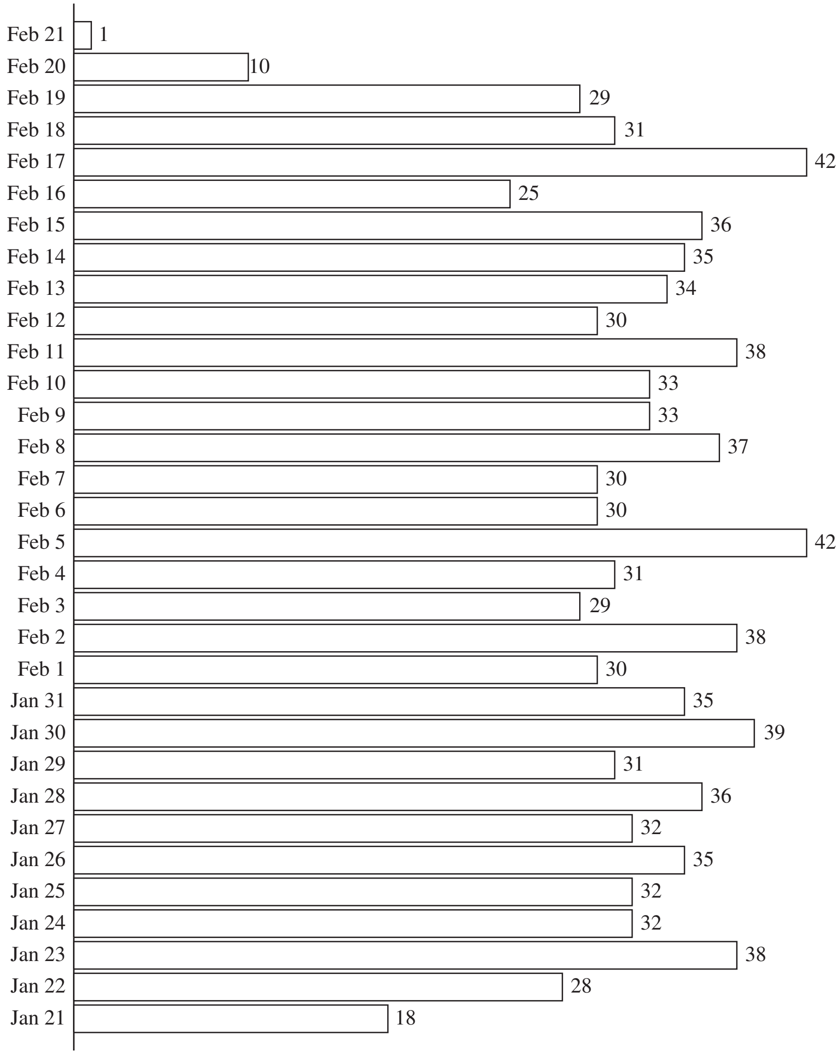

Figure 19.3 Distribution of Chinese New Year dates, 1645–2644 (suggested by Helmer Aslaksen). The single year that has Chinese New Year on February 21 is 2319.

Aside from Chinese New Year, the main fixed-Chinese-date holidays on the Chinese calendar are the Lantern Festival (fifteenth day of first month); the Dragon Festival (fifth day of the fifth month); Qǐqiǎo or Qīxī, called "Chinese Valentine's Day" (seventh day of the seventh month); Hungry Ghosts (fifteenth day of the seventh month); the Mid-Autumn Festival (fifteenth day of the eighth month); and the Double-Ninth Festival (ninth day of the ninth month). Buddha's Birthday is celebrated in many Asian countries on the eighth day of the fourth month of the Chinese calendar, but the date of observance is not uniform (in Japan, for instance, it is celebrated as the "Flower Festival" on April 8). Holidays are never observed in leap

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months. For example, to find the R.D. date of the Dragon Festival in a Gregorian year, we would use

$$\textbf{dragon-festival}\,(\textit{g-year}) \stackrel{\text{def}}{=} \tag{19.27}$$

$$\textbf{fixed-from-chinese}\left(\boxed{\textit{cycle}\mid\textit{year}\mid 5\mid \text{false}\mid 5}\right)$$

where

$$\begin{aligned}
\textit{elapsed-years} &= 1 + \textit{g-year} \\
&\qquad - \textbf{gregorian-year-from-fixed}\,(\textbf{chinese-epoch}) \\
\textit{cycle} &= \left\lfloor \frac{1}{60} \times (\textit{elapsed-years} - 1) \right\rfloor + 1 \\
\textit{year} &= \textit{elapsed-years} \bmod [1 \,..\, 60]
\end{aligned}$$

In addition to the fixed-date holidays, two holidays are determined by solar terms, Qīngmíng and Dōngzhì (the winter solstice). To determine the exact dates for Gregorian year *g-year* we look for the next (major or minor) solar term after a date shortly before the approximate date of the term of interest. For example,

$$\textbf{qing-ming}\,(\textit{g-year}) \stackrel{\text{def}}{=} \tag{19.28}$$

$$\left\lfloor \begin{array}{l}\textbf{minor-solar-term-on-or-after} \\ \quad\left(\textbf{fixed-from-gregorian}\left(\boxed{\textit{g-year}\mid\textbf{march}\mid 30}\right)\right)\end{array}\right\rfloor$$

Qīngmíng is the annual “tomb sweeping” festival in which people pay their respects to their dead ancestors by tidying their graves and burning paper offerings. It was banned in China in 1949 because of its feudal links, but reinstated as a public holiday in 2008.

Many interesting holiday customs are described in [5] and [31].

19.7 Chinese Age

Since the system of counting age differs in English and Chinese, “-years old” is only an approximate rendering.

Elizabeth Latimore Boyle and Pauline Ng Delbridge:
Cantonese: Basic Course

According to the Chinese custom, a person’s age is considered to be 1 immediately at birth; a person becomes a year older with each subsequent Chinese New Year, and thus a child born a week before the New Year is considered to be age 2 a week after birth! This difference in the meaning of “age” has caused difficulties in gathering and interpreting sociological data [23]. To compute the age of a person according to this custom, given the Chinese date of birth and the present fixed *date*, we would use

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$$\textbf{chinese-age}\,(\mathit{birthdate}, \mathit{date}) \stackrel{\text{def}}{=} \tag{19.29}$$
$$\begin{cases} 60 \times \left(\mathit{today}_{\textbf{cycle}} - \mathit{birthdate}_{\textbf{cycle}}\right) + \mathit{today}_{\textbf{year}} - \mathit{birthdate}_{\textbf{year}} + 1 \\ \qquad\qquad \textbf{if } \mathit{date} \geqslant \textbf{fixed-from-chinese}\,(\mathit{birthdate}) \\ \textbf{bogus} \quad \textbf{otherwise} \end{cases}$$

where

$$\mathit{today} = \textbf{chinese-from-fixed}\,(\mathit{date})$$

19.8 Chinese Marriage Auguries

I am only sorry that my daughter has so little merit, and that she has not had all the education desirable. I fear she is good for nothing, yet, nevertheless, since the augury is favourable, I dare not disobey you, and I accept your present, I salute you, and I consent to the day appointed for the wedding.

The Guernsey Magazine: A Monthly Illustrated Journal of Useful Information, Instruction, and Entertainment (1877)

Chinese years that do not contain the minor term Lìchūn ("Beginning of Spring" around February 4) are called "widow" years or "double-blind" years and are deemed unlucky for marriage. Because of the lunisolar nature of the Chinese calendar, widow years occur about 7 times in 19 years, mimicking the Metonic cycle; for example, 2005, 2008, and 2010 are widow years. By contrast, years in which Lìchūn occurs both at the start of the year and at the end (which also happens about 7 times in 19 years) are "double-bright" years and offer "double happiness" for newlyweds; 2004, 2006, and 2009 are such years, for example. Years missing the first Lìchūn but containing the second are "blind"; years containing the first but not the second are called "bright." Let 3 mean a double-bright year, 2 a bright year, 1 a blind year, and 0 a widow year:

$$\textbf{double-bright} \stackrel{\text{def}}{=} 3 \tag{19.30}$$

$$\textbf{bright} \stackrel{\text{def}}{=} 2 \tag{19.31}$$

$$\textbf{blind} \stackrel{\text{def}}{=} 1 \tag{19.32}$$

$$\textbf{widow} \stackrel{\text{def}}{=} 0 \tag{19.33}$$

We can determine the character of a year on the Chinese calendar from

$$\textbf{chinese-year-marriage-augury}\,(\mathit{cycle}, \mathit{year}) \stackrel{\text{def}}{=} \tag{19.34}$$
$$\begin{cases} \textbf{widow} & \textbf{if } \mathit{first\text{-}minor\text{-}term} = 1 \text{ and } \mathit{next\text{-}first\text{-}minor\text{-}term} = 12 \\ \textbf{blind} & \textbf{if } \mathit{first\text{-}minor\text{-}term} = 1 \text{ and } \mathit{next\text{-}first\text{-}minor\text{-}term} \neq 12 \\ \textbf{bright} & \textbf{if } \mathit{first\text{-}minor\text{-}term} \neq 1 \text{ and } \mathit{next\text{-}first\text{-}minor\text{-}term} = 12 \\ \textbf{double-bright} & \textbf{otherwise} \end{cases}$$

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where

$$
\begin{aligned}
\textit{new-year} &= \textbf{fixed-from-chinese}\left(\boxed{\textit{cycle} \mid \textit{year} \mid 1 \mid \text{false} \mid 1}\right)\\
c &= \begin{cases} \textit{cycle}+1 & \textbf{if } \textit{year}=60\\ \textit{cycle} & \textbf{otherwise}\end{cases}\\
y &= \begin{cases} 1 & \textbf{if } \textit{year}=60\\ \textit{year}+1 & \textbf{otherwise}\end{cases}\\
\textit{next-new-year} &= \textbf{fixed-from-chinese}\left(\boxed{c \mid y \mid 1 \mid \text{false} \mid 1}\right)\\
\textit{first-minor-term} &= \textbf{current-minor-solar-term}\,(\textit{new-year})\\
\textit{next-first-minor-term} &= \textbf{current-minor-solar-term}\,(\textit{next-new-year})
\end{aligned}
$$

19.9 The Japanese Calendar

It has often been remarked that the Japanese do many things in a way that runs directly counter to European ideas of what is natural and proper. To the Japanese themselves our ways appear equally unaccountable.

B. H. Chamberlain:: *Things Japanese* (1911)[7]

The development of calendars in Japan closely paralleled that in China with similar improvements to the traditional Japanese calendar in years following those improvements to the Chinese calendar. For example, the use of true new moons began in China in 619 C.E., but in Japan in 697 C.E.; true solar months have been used in the Chinese calendar since 1645 and in the Japanese calendar since 1798. Since 1844, the traditional Japanese calendar has followed the principles described in this chapter except that the calculations are based on locations in Japan. Although Japan officially changed over to the Gregorian calendar in 1873, the traditional calendar continues to be published and used, if only for astrological purposes. During 1873–1887 calculations were done using Tokyo's longitude, 139°46′ east, which is $9^{\mathrm{h}}19^{\mathrm{m}}4^{\mathrm{s}}$ $(= 9\frac{143}{450})$ after U.T. Since 1888, longitude 135° east (9 hours after U.T.) has been used. Thus, we define

$$
\textbf{japanese-location}\,(t) \stackrel{\text{def}}{=} \tag{19.35}
$$
$$
\begin{cases}
\boxed{35.7^\circ \mid 139^\circ 46' \mid 24\text{ m} \mid 9\frac{143}{450}^{\mathrm{h}}} & \textbf{if } \textit{year} < 1888\\
\boxed{35^\circ \mid 135^\circ \mid 0\text{ m} \mid 9^{\mathrm{h}}} & \textbf{otherwise}
\end{cases}
$$

where

$$
\textit{year} = \textbf{gregorian-year-from-fixed}\,(\lfloor t \rfloor)
$$

As with the Chinese calendar, the sexagesimal cycles are not numbered. Rather, years are given according to the *nengō system*; this is a system of eras, the most recent of which are

[7] 筆者らは，必ずしも引用に同意というわけではない．

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Heisei (平成)	January 8, 1989–
Showa (昭和)	December 26, 1925–January 7, 1989
Taisho (大正)	July 31, 1912–December 25, 1925
Meiji (明治)	January 1, 1869–July 30, 1912
Keio (慶應)	April 7, 1865–December 31, 1868

The nengō changes when the emperor dies, even if that occurs in the middle of the year. Some tables (like [18]) give not only nengō years but also the *kigen*, a count of years since the mythological founding of the Japanese empire in 660 B.C.E. by Emperor Jimmu Tennō. Months are numbered as in Chinese; solar terms are given by the Chinese ideograms in Table 19.1, but they are pronounced using Japanese pronunciation of the Chinese characters.

To calculate the Japanese calendar, we just replace **chinese-location** with **japanese-location** throughout our functions for the Chinese calendar and change the epoch. The results match those in [20], which covers the period 1873–2050.[8] For earlier years, our results approximate those in [32] for 1844–1872 fairly well.[9] The Japanese dates given in [34] are untrustworthy.

The function **chinese-age** also conforms to the Japanese system of determining age in the "kazoe doshi" (literally, "counted-year") system.

19.10 The Korean Calendar[10]

This information is, of course, partially erroneous, since the Korean calendar conformed precisely with the Chinese.

George McAfee McCune: *Korean Relations with China and Japan, 1800–1864* (1941)

During the Chosun dynasty, 1392–1897, Korea used the Chinese calendar for reference but did their own independent calculations. In 1896 Korea adopted the Gregorian calendar, but a Korean form of the Chinese calendar is still used traditionally.[11] The geographic location currently used for computations of solar terms and lunar phases is the Seoul City Hall at latitude 37°34′ north and longitude 126°58′ east (9 hours after U.T.). Prior to April 1, 1908 local mean time was used;

[8] Except for 1947; Nishizawa [20] follows the published calendar for 1947, which erroneously had a leap month 3 instead of a leap month 2 as the rules would dictate (in fact, the correct time is given for Gŭyŭ in [20] but is inconsistent with the calendar there!). Nishizawa [21] suggests that the erroneous calendar occurred because of post-war confusion. Our algorithms give the "correct" calendar.

[9] Perfectly from 1860 onward but with occasional minor errors in 1844–1859, except for a major disagreement from the end of 1851 to the spring of 1852. Such disagreement is not surprising because, during 1844–1872, the Japanese calendar was based on *apparent time* whereas our functions use *local mean time*. Furthermore, as with the Chinese calendar before the twentieth century, the astronomical models used for the Japanese calendar in the nineteenth century are less accurate than our astronomical functions.

[10] Based on information provided by S. Sohn [27] of the Korea Astronomy & Space Science Institute.

[11] The most reliable tables of the Korean calendar for the modern era are found in [1]. These tables, however have two peculiarities. All calculations for years after 1911 were made using the time zone U.T.+9. For 1900–1911 the tables were taken from calendars of that period, but all times given for solar terms were computed using U.T.+9 (rather than either local mean time or U.T.+8.5), except for eight scattered dates in 1903–1911 in which U.T.+8 was used to give agreement with old records. Because of this situation, the calendar as computed by our Chinese calendar functions together with **korean-location** gives perfect agreement with [1] for all dates after 1911 until August 9, 1961 *except* March 21, 1954.

for some intervals since then, 8.5 hours after U.T. was used as the time zone (from April 1, 1908 to December 31, 1911 and from March 21, 1954 until August 9, 1961). Thus, to implement the Korean calendar we use

$$\textbf{korean-location}\,(t) \stackrel{\text{def}}{=} \boxed{37°34' \mid 126°58' \mid 0\text{ m} \mid z^{\text{h}}} \tag{19.36}$$

where

$$z = \begin{cases} \frac{3809}{450} & \textbf{if } t < \textbf{fixed-from-gregorian}\left(\boxed{1908 \mid \textbf{april} \mid 1}\right) \\ 8.5 & \textbf{if } t < \textbf{fixed-from-gregorian}\left(\boxed{1912 \mid \textbf{january} \mid 1}\right) \\ 9 & \textbf{if } t < \textbf{fixed-from-gregorian}\left(\boxed{1954 \mid \textbf{march} \mid 21}\right) \\ 8.5 & \textbf{if } t < \textbf{fixed-from-gregorian}\left(\boxed{1961 \mid \textbf{august} \mid 10}\right) \\ 9 & \textbf{otherwise} \end{cases}$$

Years on the Korean calendar are counted on the "Danki system," counting from 2333 B.C.E., the traditional year of the founding of Go-Chosun, the first Korean nation. In terms of the Chinese cycle and year numbers, the Danki year number is given by

$$\textbf{korean-year}\,(cycle, year) \stackrel{\text{def}}{=} 60 \times cycle + year - 364 \tag{19.37}$$

The solar terms are as follows in Korean (the translations are the same as those given in Table 19.1 on page 307):

1.	Ip-Chun (입춘)	315°	7.	Ip-Choo (입추)	135°
1.	**Woo-Soo** (우수)	**330°**	**7.**	**Chu-Suh** (처서)	**150°**
2.	Kyung-Chip (경칩)	345°	8.	Bak-Roo (백로)	165°
2.	**Chun-Bun** (춘분)	**0°**	**8.**	**Chu-Bun** (추분)	**180°**
3.	Chyng-Myung (청명)	15°	9.	Han-Roo (한로)	195°
3.	**Gok-Woo** (곡우)	**30°**	**9.**	**Sang-Kang** (상강)	**210°**
4.	Ip-Ha (입하)	45°	10.	Ip-Dong (입동)	225°
4.	**So-Man** (소만)	**60°**	**10.**	**So-Sul** (소설)	**240°**
5.	Mang-Jong (망종)	75°	11.	Dae-Sul (대설)	255°
5.	**Ha-Ji** (하지)	**90°**	**11.**	**Dong-Ji** (동지)	**270°**
6.	So-Suh (소서)	105°	12.	So-Han (소한)	285°
6.	**Dae-Suh** (대서)	**120°**	**12.**	**Dae-Han** (대한)	**300°**

The Korean calendar names years, months, and days according to the same sexagesimal system use in the Chinese calendar, with stems

(1) Kap (갑)	(6) Ki (기)
(2) El (을)	(7) Kyung (경)
(3) Byung (병)	(8) Shin (신)
(4) Jung (정)	(9) Im (임)
(5) Mu (무)	(10) Gye (계)

and branches

(1) Ja (자) (Rat)	(7) Oh (오) (Horse)
(2) Chuk (축) (Ox)	(8) Mi (미) (Sheep)
(3) In (인) (Tiger)	(9) Shin (신) (Monkey)
(4) Myo (묘) (Hare)	(10) Yoo (유) (Fowl)
(5) Jin (진) (Dragon)	(11) Sool (술) (Dog)
(6) Sa (사) (Snake)	(12) Hae (해) (Pig)

The main Korean holidays are Gregorian New Year (신정), Korean New Year (설날; computed like Chinese New Year), and Thanksgiving (한식 or 추석; day 15 of the eighth month). In addition, the dates of solar longitudes 297° (January 17–18), 27° (April 17–18), 117° (July 20–21), and 207° (October 20–21) are called *Toe-Wang-Yong-Sa* (토왕용사); on these days, the energy from the soil is thought to dominate, so traditionally no work related to the soil is done. Our function **chinese-solar-longitude-on-or-after** makes the determination of the toe-wang-yong-sa an easy matter.

19.11 The Vietnamese Calendar[12]

Minister Tranh gazed ahead at the far wall, as though divining some message from the mildewed wallpaper. "Are you familiar with the Vietnamese calendar, Miss Maitland?" he asked quietly. "Your calendar?" She frowned, puzzled by the new twist of conversation. "It—it's the same as the Chinese, isn't it?"

Tess Gerritsen: *Never Say Die* (1996)

The traditional Vietnamese calendar used today is the Chinese calendar computed for Hanoi (Vietnam Standard Time, U.T. + 8 before 1968, U.T. + 7 since 1968):[13]

$$\textbf{vietnamese-location}\,(t) \stackrel{\text{def}}{=} \boxed{21°2' \;|\; 105°51' \;|\; 12\text{ m} \;|\; z^{\text{h}}} \tag{19.38}$$

where

$$z = \begin{cases} 8 & \textbf{if } t < \textbf{gregorian-new-year}\,(1968) \\ 7 & \textbf{otherwise} \end{cases}$$

It was adopted in 1967 in North Vietnam and in 1976 in the whole country. Between 1813 and 1967 the Chinese calendar was used. Before 1813 the Vietnamese calendar was computed with slightly different formulas and tables, so it differs occasionally from the Chinese calendar, especially in the period 1645–1813.[14] See [12] and [13] for the full history of Vietnamese calendars.

[12] Based on information provided by Hồ Ngọc Đức [9] of the Institut für Informationssysteme, Universität zu Lübeck.

[13] Historical time-zone use in Vietnam is extremely complex, varying geographically (North versus South, before unification versus after), as well as historically (under the French, the Japanese, and after independence). What we use is simplistic but follows the TZ database and gives agreement with [29], as detailed in the following note.

[14] Our functions have complete agreement with [29] for 1999–2100. For 1901–1998 historical practice differed from our calculated values for six scattered months as given in Table 10 of [29, p. 69]

The years are not counted, but are named. The names of the stems and branches are translations of the Chinese names, but the animal totems are different from those of Chinese calendar in some cases: Water buffalo instead of Ox; Cat instead of Rabbit. In Vietnamese the names of the stems are:

(1) Giáp	(6) Kỷ
(2) Ất	(7) Canh
(3) Bính	(8) Tân
(4) Đinh	(9) Nhâm
(5) Mậu	(10) Quý

and the names of the branches are:

(1) Tý	(Rat)	(7) Ngọ	(Horse)
(2) Sửu	(Water buffalo)	(8) Mùi	(Goat)
(3) Dần	(Tiger)	(9) Thân	(Monkey)
(4) Mão	(Cat)	(10) Dậu	(Chicken)
(5) Thìn	(Dragon)	(11) Tuất	(Dog)
(6) Tỵ	(Snake)	(12) Hợi	(Pig)

Months are named in two ways, using the sexagesimal system as in the Chinese calendar or by the name of the month in the year only. The names are:

(1) Tháng Giêng	(7) Tháng Bảy
(2) Tháng Hai	(8) Tháng Tám
(3) Tháng Ba	(9) Tháng Chín
(4) Tháng Tư	(10) Tháng Mười
(5) Tháng Năm	(11) Tháng Một
(6) Tháng Sáu	(12) Tháng Chạp

Months 1, 11, and 12 have proper names; the other names are just numbers: "hai" is "second," . . . , "mười" is "tenth," and "tháng" is "month." Month 12 (Tháng Chạp) is sometimes called "Tháng Mười Hai" (the twelfth month), but Month 11 (Tháng Một) is almost never called "the eleventh month." The first month (Tháng Giêng) is never called "the first month." Leap months are indicated with "nhuận," for example "Tháng Tám nhuận."

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but, with those corrections to [29], our functions also agree for 1901–1998. For the years after 1890, except for those six months, our calculations agree with [12], on which [29] is based for 1901–2010. Our functions are also in complete agreement with the calculations of Hồ Ngọc Đức [9] for 1891–2100.

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Twelfth-century black stone slab from Andhra Pradesh, India, depicting the 12 signs of the zodiac surrounding a lotus in full bloom representing the sun. (Courtesy of the Prince of Wales Museum of Western India, Bombay.)

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