Errata and Notes for

Calendrical Calculations: The Millennium Edition

Edward M. Reingold and Nachum Dershowitz
Cambridge University Press, 2001

4:45pm, December 7, 2006

Do I contradict myself? Very well then I contradict myself.
(*I am large, I contain multitudes.*)

—Walt Whitman: *Song of Myself*

All those complaints that they mutter about... are on account of many places I have corrected. The Creator knows that in most cases I was misled by following... others whom I will spare the embarrassment of mention. But even were I at fault, I do not claim that I reached my ultimate perfection from the outset, nor that I never erred. Just the opposite, I always retract anything the contrary of which becomes clear to me, whether in my writings or my nature.

—Maimonides: *Letter to his student Joseph ben Yehuda* (circa 1190)*, Iggerot HaRambam, I. Shilat, Maaliyot, Maaleh Adumim, 1987, volume 1, page 295* [*in Judeo-Arabic*]

If you find errors not given below or can suggest improvements to the book, please send us the details (email to reingold@iit.edu or hard copy to Edward M. Reingold, Department of Computer Science, Illinois Institute of Technology, 10 West 31st Street, Suite 236, Chicago, IL 60616-3729 U.S.A.). If you have occasion to refer to errors below in corresponding with the authors, please refer to the item by page and line numbers in the book, *not* by item number.

Unless otherwise indicated, line counts used in describing the errata are positive counting down from the first line of text on the page, excluding the header, and negative counting up from the last line of text on the page *including footnote lines.*

A list of functions mentioned in the errata is given at the end of this document, as is a list of errata in order by date added or last modified.

Our thanks to all those who pointed out errors or suggested improvements to the text. An index of specific contributions is given at the end of this document.

The latest version of this document can be obtained from the Web site `http://www.calendarists.com`

SERIOUS ERRORS

The severity of an error is indicated by the red asterisks preceding the error number. No asterisk indicates a note or a trivial error, a single asterisk a more serious error, a double asterisk an even more serious error, and so on. The serious errors below are: 123, 158, 197, 201, 202, 205–207, 246, 247, 269, 293, 298, 300, 329, 337, 339, 370, 374, 375, 400, 409, 412, 415, 417–419, 421–423, 425, 427, 431–433.

CORRECTED ERRORS

An error that has been corrected in some printings is marked by a green circle containing the number of the printing in which the error was fixed. The corrected errors below are: 2, 23, 25, 30, 40–42, 50, 64, 74, 78, 79, 86, 92, 94, 96, 97, 117, 119, 123, 127, 130, 131, 141, 149, 155, 158, 166–168, 171, 173, 176, 180, 188, 189, 197, 199, 201, 202, 204–208, 218, 220, 221, 223, 233, 242, 246, 259, 269, 278, 292, 297–301, 314, 316, 317, 319, 321, 323, 328–333, 337–339, 341, 342, 347, 354, 357, 360–362, 364–367, 370, 371, 373–375, 377, 383, 387, 391–393, 396–401, 407, 408, 410, 411, 414, 419, 423, 424, 427, 428, 431–434, 445i, 445iii.

PRINTING HISTORY

Printing	Date	Notes
First	July, 2001	Paperback (2000) and hard-cover (400)
Second	November, 2002	Paperback (700); most serious (and many) minor errors corrected; CD revised
Third	November, 2004	Paperback (500); many minor errors corrected, including those introduced by C.U.P. in the second printing; index regenerated

The various printings can be identified by looking at page iv (the back of the title page, facing the Hebrew dedication): The first printing has a line saying "First published 2001"; the second printing says in addition "Second Printing 2002 (Corrected)"; the third printing says in addition "Third Printing 2004 (Corrected)".

The second printing was botched by C.U.P.; the following (now corrected) errata resulted: 247, 322, 409, 412, 415, 417, 418, 421, 422, 425.

FRONTMATTER & MISCELLANEOUS NOTES

1. Cover: The dials in Nathan ben Meir Hademer's *Sefer Ha-Evronot* shown on the cover are used as follows to determine the Julian season: Add up the numbers on each of the three circles (for metonic cycle number, year within cycle, season within year) to find how long after the molad of the month the Julian season begins. That is why each ordinary year (for example) contributes 10d 21h 204p, the excess of solar over lunar, using the Julian solar year length and 12 mean lunations. The manuscript has other dials for other calculations.

2. (2) Title page: Reingold's affiliation should read

   University of Illinois at Urbana-Champaign
   and
   Illinois Institute of Technology

3. Page xxi: Add the quote " La dernière chose qu'on trouve en faisant un ouvrage, est de savoir celle qu'il faut mettre la première." [The last thing one settles in writing a book is what one should put in first.] Blaise Pascal, *Pensée*, Section I (Pensées sur l'esprit et le style), paragraph 19 (1660). (Courtesy of Denis B. Roegel, October 3, 2006.)

4. Page xix: We should have included the gcd and lcm functions in the table. (Courtesy of Irv Bromberg, January 7, 2006.)

5. Page xix, bottom: We should have included the "box notation" introduced on page 23 in the table of notations and the representation of field selection by subscripting with the bold field name.

6. Good quote from Ralph Waldo Emerson (Journal, May, 1849): "I hate quotations. Tell me what you know."

7. Good quote from Samuel Johnson's preface to his *Dictionary*: "I have not always executed my own scheme, or satisfied my own expectations... [But] I look with pleasure on my book however defective and deliver it to the world with the spirit of a man that has endeavored well... When it shall be found that much is omitted, let it not be forgotten that much likewise has been performed."

8. Good quote from the Koran (Jonah, 10, 5): "It is He who gave the sun its radiance, the moon its luster, and appointed its stations so that you may compute years and numbers. God did not create them but with deliberation. He distinctly explains His signs for those can understand." (Translation by Ahmed Ali, *Al-Qur'an: A Contemporary Translation*, Princeton University Press, 1988.)

9. Good quote from *De Computo Dialogus*: "Quis enim potest intelligere dies et tempora et annos, nisi per numerum?" [Who can understand days and seasons and years, save by number?] See top of page xxv and footnote 20 in *Bede: The Reckoning of Time*, Faith Wallis, Liverpool University Press, Liverpool, 1999.

10. Good quote from I. B. Singer, *The Family Moskat* (page 39 in the Penguin edition): "He spent his days and half his nights writing a book on the history of calendars."

11. Good quote from Benjamin Franklin, *Poor Richard*, 1738:

    If you wou'd not be forgotten
    As soon as you are dead and rotten,
    Either write things worth reading,
    or do things worth the writing.

12. Good quote from Theodore Roosevelt's, annual address of the president of the American Historical Association, delivered at Boston, December 27, 1912. From the *American Historical Review* **18**, 3, pages 473–489: "Many learned people seem to feel that the quality of readableness in a book is one which warrants suspicion. Indeed, not a few learned people seem to feel that the fact that a book is interesting is proof that it is shallow. This is particularly apt to be the attitude of scientific men."

13. Here is an interesting calendrical occurrence as described by Arthur C. Clarke in "The Sea of Sinbad" (see *Greetings, Carbon-Based Bipeds!*, Harper Collins, 1999.

    > In 1966, the island of Ceylon cut itself adrift from the rest of the world. It abandoned the seven-day week and reverted to the traditionar Buddhist calendar, based on the phases of the Moon. Thus each lunar quarter became a holiday (Poya Day), and the day before it a halfholiday. The result was instant chaos. It was useless planning to meet anyone on, for example, Monday week, since Monday (or any other day) might be Poya, and all offices and shops would be closed. This was merely an inconvenience as far as the country's internal affairs were concerned, but it caused utter confusion in all dealings with the outside world. Once every six weeks or so, Poya Day fell on a Sunday and the Ceylonese were briefly in step with the rest of humanity. But most of the time, the tea brokers of Mincing Lane could

telephone their Colombo offices only three or four days out of every week, and they were never quite sure *which* day those would be...

This attempt to put the calendar back a couple of thousand years was a move by Prime Minister Senanayake's mildly left-of-center government to gain the approval of the priests, who have considerable influence in a country that is primarily Buddhist. But the opposition, the United Front party—led by Mrs. Bandaranaike—was just as keen on the idea.

Despite its cost to the country, and the grumblings of the businessmen, no politician dared to attack this exercise in nostalgia; yet before it had completed its fifth year, it was quietly abolished and Monday, Tuesday, Wednesday... reentered the Cylonese vocabulary. The sudden ending of the Poya calendar was a small but significant by-product of a national tragedy which proved that there is no way back into the past, and the real or imagined quaiities of one's ancestors have little relevance to the problems of modern life.

14. Page xxiv: The Y2K problem turned out to havce few serious consequences, perhaps because so much attention was paid to fixing the problems in time. Variations of the following (anonymous) humorous take on it can be found on thousands of web sites:

    I just received this status report from the Y-to-K project team:
    Our staff has completed the 18 months of work on time and on budget. We have gone through every line of code in every program in every system. We have analyzed all databases, all data files, including backups and historic archives, and modified all data to reflect the change.
    We are proud to report that we have completed the "Y-to-K" date change mission, and have now implemented all changes to all programs and all data to reflect your new standards: Januark, Februark, March, April, Mak, June, Julk, August, September, October, November, December As well as: Sundak, Mondak, Tuesdak, Wednesdak, Thursdak, Fridak, Saturdak
    I trust that this is satisfactory, because to be honest, none of this "Y to K" problem has made any sense to me. But I understand it is a global problem, and our team is glad to help in any way possible.
    And what does the year 2000 have to do with it?
    Speaking of which, what do you think we ought to do next year when the two digit year rolls over from 99 to 00?
    We'll await your direction.

    (Courtesy of Michael H. Deckers, August 7, 2006.)

15. Page xxv, lines 12–13: Microsoft has officially acknowledged the leap year problem in Excel; see `http://support.microsoft.com/default.aspx?scid=kb;en-us;214326`. (Courtesy of Irv Bromberg, January 30, 2005.)

16. Page xxv: More technical details on the Windows daylight saving time bug can be found in *PC World*, January 13, 1999 and on the web at `http://catless.ncl.ac.uk/Risks/21.34.html#subj9`.

17. Page xxv: Even the Astronomical Applications Department of the U.S. Naval Observatory is not immune to calendrical errors! As of March 9, 2004, they give incorrect dates for Passover for 2028 and 2029 on their web site `http://aa.usno.navy.mil/faq/docs/passover.html`. They give Sunday, April 9, 2028 and Thursday, March 29, 2029 instead of the correct dates Tuesday, April 11, 2028 and Saturday, March 31, 2029, respectively. The web site was corrected on March 10, 2004. (Courtesy of Jeff Sagarin, March 9, 2004.)

18. Page xxv: Another calendar error story—according to Reuters (Monday, March 22, 2004, 12:18pm EST):

> Due to a software glitch, the computer display in the 2004 model year Grand Prix shows the wrong day of the week, Pontiac spokesman Jim Hopson said on Monday. Engineers overlooked the fact that 2004 is a leap year, with an extra day,
>
> "Somehow or other, the fact that this was a leap year got missed," Hopson said. "We are working on a solution."
>
> GM may be able to fix the problem by resetting the software. A more costly solution could include replacing the display unit, he said.

19. Page xxv: Another calendar error story—on August 22, 2003, according to *The New York Times* of August 25, 2003, Evite, operator of an event-planning and invitation service, sent the following email to recipients of its monthly newsletter:

> Dear Evite Newsletter Subscriber,
>
> Yesterday we mailed a newsletter to our subscribers with incorrect dates for three important holidays. Please accept our sincerest apologies for these errors and note the following corrections:
> Labor Day, September 1st
> Rosh Hashana, September 27th
> Yom Kippur, October 6th
>
> In addition, we also wish to apologize for having listed Yom Kippur as one of our "Reasons To Party." We understand and respect that Yom Kippur is a Day of Atonement, a day to be taken seriously to reflect and fast, and as such, one of the most important Jewish holidays of the year.
>
> Again we deeply apologize for the error and thank you for allowing us to make this correction.
>
> Very Best,
> The Evite Team

20. Page xxv: Another calendar error story, this one silly. In *The New York Times* of Monday, March 27, 1967, the crossword puzzle (page 31), edited by Margaret Farrar, had the clue for number 21 down as "1800 or 1900", with the intended answer as "leap year". A lengthy correction (unsigned, but by Murray Illson—see his obituary in *The New York Times* of April 8, 2004) with an explanation of the history and the correct Gregorian leap year rule was published on March 30, 1967 (page 43).

21. Page xxv: Another calendar error story, by Irene Klotz for Reuters, dated Monday, November 6, 2006. "A computer problem could force NASA to postpone next month's launch of shuttle Discovery until 2007 to avoid having the spaceship in orbit when the clock strikes midnight on New Year's Eve. The shuttle is due to take off from the Kennedy Space Center in central Florida on December 7 on a 12-day mission to continue construction of the half-built International Space Station. But if the launch is delayed for any reason beyond December 17 or 18, the flight likely would be postponed until next year, officials at the U.S. space agency said on Monday. To build in added cushion, NASA may move up the take off to December 6. 'The shuttle computers were never envisioned to fly through a year-end changeover,' space shuttle program manager Wayne Hale told a briefing. After the 2003 accident involving space shuttle Columbia, NASA started developing procedures to work around the computer glitch. But NASA managers still do not want to launch Discovery knowing it would be in space when the calendar rolls over to January 1, 2007. The problem, according to Hale, is that the shuttle's computers do not reset to day one, as ground-based systems that support shuttle navigation do. Instead, after December 31, the 365th day of the year, shuttle computers figure January 1 is just day 366. NASA is under pressure to complete at least 14 more shuttle flights to finish the $100 billion International Space Station before the aging shuttle fleet is retired in 2010." (Courtesy of Nicolas Herran, November 10, 2006.)

22. Page xxix, line 1: Change “Michael Deckers” to “Michael H. Deckers”.

23. (2) Page xxix, line −16: Add a comma between “Goldberg” and “Shiho”. (Courtesy of Theodore M. Rolle, February 25, 2002.)

24. Page xxix: Good quote for the acknowledgments section: “The author has tried to indicate every known blemish in [2]; and he hopes that nobody will ever scrutinize any of his own writings as meticulously as he and others have examined the ALGOL report.” Donald E. Knuth, “The Remaining Trouble Spots in ALGOL 60,” *Communications of the ACM* **10** (1967), page 611. (Courtesy of Otto Stolz, November 7, 2001.)

25. (2) Page xxxii, line 6: Delete the phrase “and a Patent Pending on them.”

CHAPTER 1: INTRODUCTION

26. Chapter 1: Frontispiece possibility—the oil painting of Joseph Scaliger in the Senate Hall at Leiden.

27. Page 7, bottom 7 lines: The transliterations of the Armenian weekday names is poor. (Courtesy of Armond Avanes, December 19, 2003.) According to *The History of Armenian Astronomy*, B. E. Toumanyan, Yerevan State University Press, 1985: After accepting Christianity as a state religion, “Armenians began to make use of seven-day week. Like the Jewish calendar, the names of the weekdays designated their numerical order; miashabti, erkoushabti, erekshabti, chorekshabti, hingshabti, vetsshabti and shabat, where ‘shabat’ means-day of rest, while ‘miashabti’ meant the first day following the day of rest, erkushabti is the second day following the day of rest and so on.” The Armenian Christian church later renamed ‘vetsshabti’ as “ourbat,” meaning “to get ready for the rest day.” Subsequently, they declared the first day of the week as “kiraki” or “the Lord’s day” which became the day of rest. (I have not been able to locate a copy of Toumanyan’s book; the information here is from `http://www.usanogh.com/articles/article.php?story_id=212`.)

28. Page 8, line 2: Add “6-day weeks (Japan),”.

29. Page 8: The lunar cycle formed the basis for palaeolithic man’s marking of time—see Alexander Marshack’s *The Roots of Civilization*, McGraw-Hill, 1972; see also James Elkins’ “On the Impossibility of Close Reading,” *Current Anthropology*, **37**, 2 (April, 1996), 185–226 for criticism of Marshack’s methods. (Courtesy of Ananda Shankar Chakrabarty, September 22, 2004.)

30. (3) Page 8, line −12: Change “shadow” to “midday shadow”. (Courtesy of Robert H. Douglass, June 21, 2002.)

31. Page 9, last paragraph: See pages 677–678 of [2] for a discussion of the etymology of the term “leap”.

32. Page 10, Table 1.1: We should give the “vernal equinox year” length, currently 365.242374 days because of its importance to the astronomical Persian calendar. (Courtesy of Svante Janson, July 19, 2003.)

33. Page 11, line 1: Change “either according to” to “according to either”. (Courtesy of Nicholas J. Cox, January 16, 2006.)

34. Page 11, first complete paragraph: Except for 1039/84, all approximations in this paragraph derive from the continued fraction expansion of the ratio of solar years to lunar months. (Courtesy of Helmut Wildmann, August 1, 2005.).

35. Page 11, lines 17–18: The error when 334 solar years are approximated by 4131 lunar months is 7.27 seconds, not 3 minutes. (Courtesy of Helmut Wildmann, August 1, 2005.).

36. Page 11, introductory quotation for section 1.2: This is a loose translation of a famous Talmudic dictum from *Sanhedrin* 97b. The omitted words from Braude's translation (page 112 of his book) are "for the coming of the Messiah". The exact Talmudic wording is "Blasted be the bones of those who calculate the end". Braude is the first author's mother-in-law's uncle—his father, (the first author's wife's great-grandfather) was one of the first Orthodox Rabbis in Chicago around 1900. The book is dedicated to his children.

37. Page 11, line −2: Change "embarassingly" to "embarrassingly". (Courtesy of Nicholas J. Cox, January 16, 2006.)

38. Sections 1.2–1.8: The following could go in section 1.2, if we move the sentence in the middle of page 19 ('We use the term "moment"...') back there also:

$$\textbf{fixed-from-moment}\,(t) \stackrel{\text{def}}{=} \lfloor t \rfloor \qquad \text{(38-A)}$$

$$\textbf{time-of-day-from-moment}\,(t) \stackrel{\text{def}}{=} t \mod 1 \qquad \text{(38-B)}$$

Then the following would go in section 1.8:

$$\textbf{clock-from-moment}\,(t) \stackrel{\text{def}}{=} \qquad \text{(38-C)}$$

$$\mathit{hour} : \mathit{minute} : \mathit{second}$$

where

$$\begin{aligned} \mathit{tod} &= \textbf{time-of-day-from-moment}\,(t) \\ \mathit{hour} &= \lfloor \mathit{tod} \times 24 \rfloor \\ \mathit{minute} &= \lfloor \mathit{tod} \times 24 \times 60 \mod 60 \rfloor \\ \mathit{second} &= \mathit{tod} \times 24 \times 60 \times 60 \mod 60 \end{aligned}$$

$$\textbf{time-from-clock}\left(\boxed{\mathit{hour} \mid \mathit{minute} \mid \mathit{second}}\right) \stackrel{\text{def}}{=} \qquad \text{(38-D)}$$

$$\mathit{hour} + \tfrac{1}{60} \times \left(\mathit{minute} + \frac{\mathit{second}}{60}\right)^{\text{h}}$$

The function **clock-from-moment** would replace the current **time-from-moment** on page 24; to round to the nearest second, we would apply **clock-from-moment** to

$$\frac{\textbf{round}(t \times 24 \times 60 \times 60)}{24 \times 60 \times 60}$$

instead of t. In Lisp (for page 323) these functions are

```
(defun fixed-from-moment (tee)
  ;; TYPE moment -> fixed-date
  ;; Fixed-date from moment tee.
  (floor tee))
```

```
(defun time-of-day-from-moment (tee)
  ;; TYPE moment -> time-of-day
  ;; Time from moment tee.
  (mod tee 1))
```

```
(defun clock-from-moment (tee)
  ;; TYPE moment -> clock-time
  ;; Clock time (hour minute second) from moment tee.
  (let* ((tod (time-of-day-from-moment tee))
         (hour (floor (* tod 24)))
         (minute (floor (mod (* tod 24 60) 60)))
         (second (mod (* tod 24 60 6010) 60)))
    (time-of-day hour minute second)))
```

```
(defun time-from-clock (hms)
  ;; TYPE clock-time -> time-of-day
  ;; Time of day from hms = (hour minute second).
  (let* ((hour (first hms))
         (minute (second hms))
         (second (third hms)))
    (hr (+ hour (/ (+ minute (/ second 60)) 60)))))
```

39. Page 12, line 9: Insert a comma after "Section 1.5)". (Courtesy of Nicholas J. Cox, January 16, 2006.)

40. (3) Page 12, line −11: Change "Trê" to "Trē". (Courtesy of Svante Janson, January 31, 2003.)

41. (2) Page 12, line −14: The Julian day number is wrong; it should be 2,431,772. (Courtesy of Robert H. Douglass, April 23, 2002.)

42. (2) Page 13, line 1: Change "Pept" to "Pepet".

43. Page 13, lines 12–13: Delete "of the seventy-seventh sexagesimal cycle". (Courtesy of Helmer Aslaksen, November 13, 2001.)

44. Page 13, line 14: Change "Tula" to "Kārtika" (see Erratum 358).

45. Page 14: The Ecclesiatical Day starts at the previous sunset, not at sunrise as indicated; the ancient Egyptian day began at dawn (sunrise?). The corrected Figure 1.1 is given as Figure 45-A. (Courtesy of Robert H. Douglass, June 12, 2002.) Finally, until 1805 the "nautical day" ended at noon—when the astronomical day begins—the study of ship's logs must take this into account (see, for example, *New Scientist*, December 6, 2003, page 42).

46. Page 16, line 16: Change "For calendars like the Balinese Pawukon, in which cycles are unnumbered," to "For calendars like the Chinese or Balinese Pawukon, in which cycles are unnumbered,". (Courtesy of Helmer Aslaksen, November 13, 2001.)

47. Page 17, Table 1.2: Delete the entry for the Zoroastrian calendar. (Courtesy of Robert H. Douglass, June 19, 2002.)

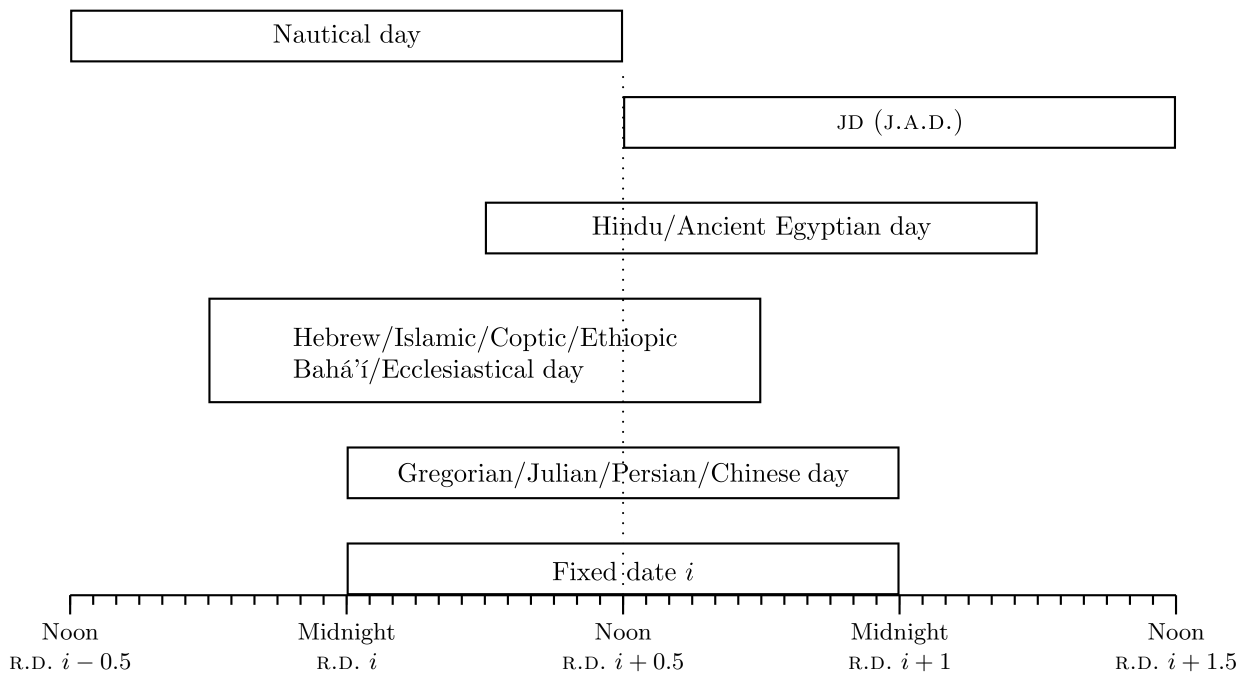

Figure 45-A: Replacement for page 14 (see Erratum 45).

48. Page 19, line 13: The julian day numbers as used by historians are defined as $jd + 0.5$ (see Neugebauer, 1975. vol. 3 p. 1064, for example). Thus our function **fixed-from-jd** gives the R.D. date intended by historians when they refer to julian dates. (Courtesy of Michael H. Deckers, August 7, 2006.)

49. Page 20, line 3: Add "We have $\lceil x \rceil = -\lfloor -x \rfloor$."

50. (3) Page 20, line -5: Change "for $y > 0$." to "for $y > 0$ and $x \not\equiv 0 \pmod{y}$." (Courtesy of Svante Janson, January 31, 2003.)

51. Page 20, last line: Change "multiple" to "integer multiple". (Courtesy of Michael H. Deckers, August 7, 2006.)

52. Page 20, bottom: With the mod function, we can define the greatest common divisor of two positive integers as

$$\gcd(u,v) \stackrel{\text{def}}{=} \begin{cases} u & \text{if } v = 0, \\ \gcd(v, u \bmod v) & \text{otherwise.} \end{cases} \tag{52-A}$$

and their least common multiple as

$$\mathrm{lcm}(u,v) \stackrel{\text{def}}{=} \frac{uv}{\gcd(u,v)}. \tag{52-B}$$

53. Page 21, (1.14) and (1.15): This fifth consequence of (1.11) is a generalization of the first (on page 20). (Courtesy of Arthur J. Roth, April 19, 2002.)

54. Pages 21–22, equations (1.19) and (1.20): We should give definitions of $\sum$, MIN and MAX (using tail recursion), the same way we do for the binary search operator MIN in equation (1.22). (Courtesy of Oscar van Vlijmen, May 8, 2002.)

55. Page 22, line 2: Add the sentence "MIN is undefined and does not terminate if the predicate $\psi(d)$ does not become true eventually." (Courtesy of Michael H. Deckers, August 7, 2006.)

56. Page 22, lines 2–6: This should be a separate paragraph. Add the following to the end of it: "MAX is undefined and does not terminate if the predicate $\psi(d)$ does not become false eventually." (Courtesy of Michael H. Deckers, August 7, 2006.)

57. Page 22, first complete paragraph on the page: We need to redo this so that the function inversion is explicit. The replacement text is something like the following.

To determine the time of astronomical events, such as an equinox or solstice, we need to invert astronomical functions, such as the celestial longitude of the sun in Section 12.4. In the absence of explicit methods for calculating the inverse of a function f, that is, for calculating a value x such that $f(x) = y$, we need to search an interval of time $[a : b]$ for the moment $a \le x \le b$ when $f(x) = y$. To express such a calculation, we write

$$f_\varepsilon^{-1}(y, [a:b]),$$

where $\varepsilon > 0$ is some small tolerance within which the result is acceptable. In other words, $f_\varepsilon^{-1}(y, [a:b])$ returns a value x_0 such that there is some $x \in [a : b]$ for which $f(x) = y$, precisely, and $|x - x_0| < \varepsilon$.

When the function f in question is *increasing*, bisection search [24] can be an efficient means of inverting f. We define

$$\boxed{y \approx \underset{\xi \in [\mu:\nu]}{\overset{\phi(l,u)}{\mathrm{MIN}}} \{\psi(\xi)\} \quad \text{means that} \quad \begin{array}{c} \mu \le l < y < u \le \nu, \\ \phi(l,u), \neg\psi(l), \text{ and } \psi(u) \end{array}} \tag{1.21}$$

That is, we search for a y satisfying the definiens under the assumption that the region $[\mu : \nu]$ can be split into two intervals $[\mu : x)$ and $[x : \nu]$, such that ψ is false throughout the former and true in the latter. Then y must be close enough to x so that it lies in an interval $(l : u)$, sandwiching x, small enough to satisfy the test $\phi(l, u)$.

We implement the definition using a straightforward bisection search of the interval $[\mu : \nu]$:

$$\text{MIN}\,(\mu, \nu, \phi, \psi) \stackrel{\text{def}}{=} \tag{57-A}$$

$$\begin{cases} x & \textbf{if } \phi\,(\mu, \nu) \\ \text{MIN}\,(\mu, x, \phi, \psi) & \\ \qquad \textbf{if} \text{ not } \phi\,(\mu, \nu) \text{ and } \psi\,(x) & \\ \text{MIN}\,(x, \nu, \phi, \psi) & \textbf{otherwise} \end{cases}$$

where

$$x = \frac{1}{2} \times (\nu + \mu)$$

If ψ is true of the midpoint x, then we "go left" and let the new upper bound ν be x. On the other hand, if ψ is false, we "go right" and let the new lower bound μ be x. This process continues until the interval $[\mu : \nu]$ is small enough that ϕ is true, at which point the midpoint is returned. At each stage of the search, $\psi(\mu)$ is false and $\psi(\nu)$ is true.

Using bisection search, we have

$$f_{\varepsilon}^{-1}(y, [a : b]) = \underset{x \in [a:b]}{\overset{u-l<\varepsilon}{\text{MIN}}} f(x) \geq y$$

Or, when there is a more complicated condition ϕ for ending the search, we write

$$f_{\phi}^{-1}(y, [a : b]) = \underset{x \in [a:b]}{\overset{\phi}{\text{MIN}}} f(x) \geq y$$

The astronomical functions we need to invert have range $[0, 360)$; this poses an additional complication, namely, the discontinuity at $360 = 0$. Since the interval $[a : b]$ will always be relatively small, and, therefore, $f(x) - y$ is small for all x in the interval, we can sidestep the discontinuity as follows:

$$f_{\varepsilon}^{-1}(y, [a : b]) = \underset{x \in [a:b]}{\overset{u-l<\varepsilon}{\text{MIN}}} (f(x) - y) \bmod 360 < 180$$

The functions affected by this change are **solar-longitude-after**, **lunar-phase-before**, **lunar-phase-after**, **hindu-new-moon-before**, **hindu-lunar-day-after** (the renamed **lunar-day-after**), and **hundu-solar-longitude-after**. (Courtesy of Michael H. Deckers, August 7, 2006.)

58. Page 23, top two paragraphs ("We represent. . . unchanged."): We should have been careful to distinguish fixed-length records (and field selection by field name which we never define!) used for dates and times from lists of varying length. Both are represented in the Lisp code by lists, but in the text we use box notation for records and angle brackets for lists. (Courtesy of Otto Stolz, November 7, 2001.)

59. Page 24, **time-from-moment**: As written, the function overflows 32-bit aritmetic around the year 4896. To avoid such overflow, apply the function to $t \bmod 1$ instead of t. See also Erratum 38. (Courtesy of Irv Bromberg, May 19, 2004.)

60. Page 24, lines 8–10: Change "To round to the nearest second, let... instead." to "To round to the nearest second, apply **time-from-moment** to

$$\frac{\textbf{round}(t \times 24 \times 60 \times 60)}{24 \times 60 \times 60}$$

instead of t." (Courtesy of Andrew Main, April 21, 2004.)

61. Page 24, **time-from-moment**: The inverse is

$$\textbf{moment-from-time}\left(\boxed{h \mid m \mid s}\right) \stackrel{\text{def}}{=} \frac{1}{24} \times \left(h + \frac{1}{60} \times \left(m + \frac{s}{60}\right)\right) \qquad \text{(61-A)}$$

62. Page 24, equation (1.25): The inverse, which takes an angle (in degrees) and converts it to a list of degrees, arcminutes, and arcseconds, is

$$\textbf{angle-from-degrees}\,(d) \stackrel{\text{def}}{=} \langle d, m, s\rangle \qquad \text{(62-A)}$$

where

$$\begin{aligned} d &= \lfloor \alpha \rfloor \\ m &= \lfloor 60 \times (\alpha \bmod 1) \rfloor \\ s &= \alpha \times 60 \times 60 \bmod 60 \end{aligned}$$

63. Section 1.9: The development of the ancient Egyptian calendar is discussed in *The Calendars of Ancient Egypt*, Richard A. Parker, University of Chicago Press, Chicago, 1950.

64. (3) Page 24, line −7: Change "noon" to "dawn". (Courtesy of Robert H. Douglass, June 18, 2002.)

65. Page 24: The months of the Egyptian calendar were:

(1) Thoth	30 days	(7) Phamenoth	30 days
(2) Phaophi	30 days	(8) Pharmuthi	30 days
(3) Athyr	30 days	(9) Pachon	30 days
(4) Choiak	30 days	(10) Payni	30 days
(5) Tybi	30 days	(11) Epiphi	30 days
(6) Mechir	30 days	(12) Mesori	30 days
		(13) (Unnamed)	5 days

Variants of these month names are still used in the Coptic calendar (see Erratum 127).

66. Page 26, lines 9–11: Change "The Zoroastrian... names." to "The Yazdegerd calendar has an identical structure to that of the ancient Egyptian calendar, but with a different epoch (see Table 1.2) and different month names."

67. Page 27, **day-of-week-from-fixed**: Rewriting this function as

$$\textbf{day-of-week-from-fixed}\,(\mathit{date}) \stackrel{\text{def}}{=} \quad (67\text{-A})$$

$$(\mathit{date} - \textbf{gregorian-epoch} + 1) \bmod 7$$

would make it more robust—right now, if the origin of the fixed dates changed to a non-Monday, the function would not work correctly. (Courtesy of Irv Bromberg, July 14, 2006.)

68. Pages 28–29: Equations (1.46)–(1.49) are specific instances of more general calculations that occur in cyclical calendars such as the Maya, Aztec, Bali, and so on. We can encapsulate (1.42) into

$$\textbf{k-day-of-cycle-on-or-before}\,(\mathit{date}, k, m, \Delta) \stackrel{\text{def}}{=} \quad (68\text{-A})$$

$$\mathit{date} - ((\mathit{date} + \Delta - k) \bmod m)$$

and then use it for similar functions:

$$\textbf{k-day-of-cycle-before}\,(\mathit{date}, k, m, \Delta) \stackrel{\text{def}}{=} \quad (68\text{-B})$$

$$\textbf{k-day-of-cycle-on-or-before}\,(\mathit{date} - 1, k, m, \Delta)$$

$$\textbf{k-day-of-cycle-on-or-after}\,(\mathit{date}, k, m, \Delta) \stackrel{\text{def}}{=} \quad (68\text{-C})$$

$$\textbf{k-day-of-cycle-on-or-before}\,(\mathit{date} + m - 1, k, m, \Delta)$$

$$\textbf{nth-k-day-of-cycle-on-or-after} \quad (68\text{-D})$$

$$(\mathit{date}, n, k, m, \Delta) \stackrel{\text{def}}{=}$$

$$\textbf{k-day-of-cycle-on-or-after}\,(\mathit{date} + (n-1) \times m, k, m, \Delta)$$

$$\textbf{k-day-of-cycle-after}\,(\mathit{date}, k, m, \Delta) \stackrel{\text{def}}{=} \quad (68\text{-E})$$

$$\textbf{k-day-of-cycle-on-or-before}\,(\mathit{date} + m, k, m, \Delta)$$

$$\textbf{k-day-of-cycle-nearest}\,(\mathit{date}, k, m, \Delta) \stackrel{\text{def}}{=} \quad (68\text{-F})$$

$$\textbf{k-day-of-cycle-on-or-before}\left(\mathit{date} + \left\lfloor \frac{m}{2} \right\rfloor, k, m, \Delta\right)$$

In Lisp:

```
(defun k-day-of-cycle-on-or-before (date k m cap-Delta)
  ;; TYPE (fixed-date nonnegative-integer
  ;; TYPE positive-integer nonnegative-integer)
  ;; TYPE -> fixed-date
  ;; Fixed date of k-day in the cycle of m days offset
  ;; by cap-Delta that occurs on or before date.
  (- date
     (mod (+ date cap-Delta (- k)) m)))
```

```
(defun k-day-of-cycle-before (date k m cap-Delta)
  ;; TYPE (fixed-date nonnegative-integer
  ;; TYPE positive-integer nonnegative-integer)
  ;; TYPE -> fixed-date
  ;; Fixed date of k-day in the cycle of m days offset
  ;; by cap-Delta that occurs before date.
  (k-day-of-cycle-on-or-before (1- date) k m cap-Delta))
```

```
(defun k-day-of-cycle-on-or-after (date k m cap-Delta)
  ;; TYPE (fixed-date nonnegative-integer
  ;; TYPE positive-integer nonnegative-integer)
  ;; TYPE -> fixed-date
  ;; Fixed date of k-day in the cycle of m days offset
  ;; by cap-Delta that occurs on or after date.
  (k-day-of-cycle-on-or-before (+ date (1- m)) k m cap-Delta))
```

```
(defun nth-k-day-of-cycle-on-or-after (date n k m cap-Delta)
  ;; TYPE (fixed-date nonnegative-integer nonnegative-integer
  ;; TYPE positive-integer nonnegative-integer)
  ;; TYPE -> fixed-date
  ;; Fixed date of n kth-day in the cycle of m days
  ;; offset by cap-Delta that occurs on or after date.
  (k-day-of-cycle-on-or-after (+ date (* (1- n) m)) k m cap-Delta))
```

```
(defun k-day-of-cycle-after (date k m cap-Delta)
  ;; TYPE (fixed-date nonnegative-integer
  ;; TYPE positive-integer nonnegative-integer)
  ;; TYPE -> fixed-date
  ;; Fixed date of k-day in the cycle of m days offset
  ;; by cap-Delta that occurs after date.
  (k-day-of-cycle-on-or-before (+ date m) k m cap-Delta))
```

```
(defun k-day-of-cycle-nearest (date k m cap-Delta)
  ;; TYPE (fixed-date nonnegative-integer
  ;; TYPE positive-integer nonnegative-integer)
  ;; TYPE -> fixed-date
  ;; Fixed date of k-day in the cycle of m days offset
  ;; by cap-Delta that occurs nearest date.
  (k-day-of-cycle-on-or-before
   (+ date (floor (/ m 2))) k m cap-Delta))
```

69. Page 29, lines 9–13: This paragraph and equation (1.45) are wrong. Change the text "Note that if... in the Chinese calendar (Chapter 16)." to read "Note that formula (1.42) for the last k-label day on or before day number d remains correct even if the cycle of labels is $a, a+1, \ldots, a+m-1$ (that is, based at a instead of 0). We use this in the Chinese calendar (Chapter 16) for $a = 1$, that is, for 1-based cycles of labels." (Courtesy of Arthur J. Roth, December 23, 2001.)

70. Page 29, line −12: Add new paragraphs as follows.

    Despite appearances, there is no assumption that d, m, k, Δ, or a are integers. Labels can be continuous, as long as they repeat every m days; in the continuous case, moments are labeled rather than days.

    A similar derivation gives the first k-labeled moment at or after moment d:

    $$x \geq (d - k + \Delta)/m > x + 1,$$

    and thus

    $$x = \lceil (d - k + \Delta)/m \rceil,$$

    from which it follows that the desired moment is

    $$\begin{aligned} D &= d - (d - k + \Delta - \lceil (d - k + \Delta)/m \rceil \times m) \\ &= k - \Delta - \lfloor (k - d - \Delta)/m \rfloor \times m \\ &= d + [(k - d - \Delta) \bmod m]. \end{aligned} \qquad \text{(70-A)}$$

    Formula (70-A) is used for Balinese holidays (Chapter 11).

71. Page 29, Equations (1.46)–(1.49): These k-day functions would be a bit nicer if k were the first parameter. (Courtesy of Irv Bromberg, May 11, 2006.)

72. Page 31, line 14: Change that line from "$(ck) \bmod d = g$" to "$k\frac{c}{g} \bmod \frac{d}{g} = 1$". (Courtesy of Arthur J. Roth, December 23, 2001.)

73. Page 33, lines 3–4: Change "the time of day (as a fraction of a day)" to "the time of day or month (as a fraction of the day or month)". (Courtesy of Arthur J. Roth, December 23, 2001.)

74. (2) Page 33, line −6: Change the section from "2.2" to "2.1". (Courtesy of Arthur J. Roth, April 19, 2002.)

75. Page 33, line −1: Change the phrase "Islamic months" to "Islamic months (leap year)". Add a line just before the last line of the table for "Islamic months (ordinary year)" with $c = 12$, $l = 6$, $\Delta = 1$, $L = 29$, $\overline{L} = 59/2$, $\delta = 1/2$. (See Erratum 145.)

76. Page 34, line before (1.57): Delete the comma. (Courtesy of Nicholas J. Cox, January 16, 2006.)

77. Page 35, lines 1–3: Change "These three short gaps and... $\Delta = 8$)." to "If we associate each leap year with the gap preceding it and number the gaps 0, 1, ... 10, these three short gaps are numbers 2, 6, and 9, to which formula (1.57) could also be applied (with $c = 11$, $l = 3$, and $\Delta = 2$)." (Courtesy of Arthur J. Roth, December 23, 2001.)

78. (2) Page 36, line 8: Change "(1.59)" to "(1.58)". (Courtesy of Arthur J. Roth, December 23, 2001.)

79. (2) Page 39, line 12: Subtract one from the righthand side; that is, change the equation to read

$$y = \left\lceil \frac{m + 1 - \frac{2{,}093{,}611}{2{,}160{,}000}}{\frac{2{,}226{,}389}{180{,}000}} \right\rceil - 1.$$

(Courtesy of Arthur J. Roth, April 17, 2002.)

80. Page 39, after line 1: Add the paragraph "When $\tilde{L}$ is rational, and $\tilde{L} = l/c$ for relatively prime l and c, then one *can* use (1.57) through (1.64), with Δ such that $l\Delta \equiv \lfloor c\delta \rfloor \pmod{c}$. For example, for the old Hindu calendar we can use $c = 180000$, $l = 66389$, $\lfloor c\delta \rfloor = 174467$ and $\Delta = 147703$. However, the δ formula is more general in that it applies even if average year length is not rational. (Courtesy of Svante Janson, February 17, 2003.)

81. Page 39: Add the following discussion to the end of Section 1.12: A number of calendars can be cast into a simple single-cycle framework, using the formulas of this section. Suppose we are given the calendar epoch, **single-cycle-epoch**, an integer; the offset of the first critical event, **delta-year**, a number in the range $[0, 1)$; the average year length, **average-year-length**, of at least 1 day; the average month length, **average-month-length**, at least 1 day long, but no longer than an average year; and the offset for the first month, **delta-month**, also in the range $[0, 1)$. The critical yearly event for the epochal year occurred **delta-year** days after the earliest possible moment, which is $1 -$ **delta-year** days before the critical time; the critical monthly event for the first month of the calendar occurred **delta-month** days after its earliest possible time. For example, for the Coptic calendar of Section 4.1, we would have the constants

$$\textbf{single-cycle-epoch} \stackrel{\text{def}}{=} \textbf{coptic-epoch} \tag{81-A}$$

$$\textbf{delta-year} \stackrel{\text{def}}{=} \frac{1}{4} \tag{81-B}$$

$$\textbf{avg-year-length} \stackrel{\text{def}}{=} 365\frac{1}{4} \tag{81-C}$$

$$\textbf{avg-month-length} \stackrel{\text{def}}{=} 30 \tag{81-D}$$

$$\textbf{delta-month} \stackrel{\text{def}}{=} 0 \tag{81-E}$$

To convert a single-cycle 1-based date to an R.D. date, we add to the epoch the days before the *year*, the days before *month* in *year*, and the days before *day* in *month*, taking the initial offsets into account:

$$\textbf{fixed-from-single-cycle}\left(\boxed{\textit{year} \mid \textit{month} \mid \textit{day}}\right) \stackrel{\text{def}}{=} \tag{81-F}$$

$$\textbf{single-cycle-epoch} +$$
$$\lfloor (\textit{year} - 1) \times \textbf{avg-year-length} + \textbf{delta-year} \rfloor +$$
$$\lfloor (\textit{month} - 1) \times \textbf{avg-month-length} + \textbf{delta-month} \rfloor + \textit{day} - 1$$

In the other direction, we compute the single-cycle date from an R.D. date by determining the year from the start of the mean year using (1.68), the month from (1.68) applied to the month parameters, and the day by taking the remainder:

$$\textbf{single-cycle-from-fixed}\,(date) \stackrel{\text{def}}{=} \quad (81\text{-G})$$

$$\boxed{\;year\;|\;month\;|\;day\;}$$

where

$$days = date - \textbf{single-cycle-epoch}$$

$$year = \left\lceil \frac{days + 1 - \textbf{delta-year}}{\textbf{avg-year-length}} \right\rceil$$

$$n = days - \lfloor \textbf{delta-year} + (year - 1) \times \textbf{avg-year-length} \rfloor$$

$$month = \left\lceil \frac{n + 1 - \textbf{delta-month}}{\textbf{avg-month-length}} \right\rceil$$

$$day = n + 1 - \lfloor \textbf{delta-month} + (month - 1) \times \textbf{avg-month-length} \rfloor$$

We could also have a variable-month version in which instead of the fixed-month structure given by **average-month-length** we simply specify the number of months in the year, **months-per-year** and the offset **delta-month**:

$$\textbf{months-per-year} \stackrel{\text{def}}{=} 12 \quad (81\text{-H})$$

As before, we have the epoch of the calendar **single-cycle-epoch**, the average year length **average-year-length**, and the initial offset, **delta-year**. To convert between R.D. dates and dates on this single-cycle mean calendar, we again apply formulas (1.65) and (1.68) from Section 1.12, but with minor variations. To convert a single-cycle date to an R.D. date, we add the days before the mean *month* in *year*, and the days before *day* in *month*:

$$\textbf{var-fixed-from-single-cycle} \left(\boxed{\;year\;|\;month\;|\;day\;} \right) \stackrel{\text{def}}{=} \quad (81\text{-I})$$

$$\textbf{single-cycle-epoch} + \lfloor (year - 1) \times \textbf{avg-year-length} + \textbf{delta-year} + (month - 1) \times \textbf{avg-month-length} \rfloor + day - 1$$

where

$$\textit{average-month-length} = \frac{\textbf{avg-year-length}}{\textbf{months-per-year}}$$

In the other direction, we compute the single-cycle date from an R.D. date by determining the year from the start of the mean year using (1.68), the month from (1.68) applied to the month parameters, and the day by subtraction:

$$\textbf{var-single-cycle-from-fixed}\,(\textit{date}) \stackrel{\text{def}}{=} \qquad \text{(81-J)}$$

year	*month*	*day*

where

$$\textit{days} = \textit{date} - \textbf{single-cycle-epoch}$$

$$\textit{offset} = \textit{days} + 1 - \textbf{delta-year}$$

$$\textit{year} = \left\lceil \frac{\textit{offset}}{\textbf{avg-year-length}} \right\rceil$$

$$\textit{average-month-length} = \frac{\textbf{avg-year-length}}{\textbf{months-per-year}}$$

$$\textit{month} = 1 + \left(\left(\left\lceil \frac{\textit{offset}}{\textit{average-month-length}} \right\rceil - 1 \right) \bmod \textbf{months-per-year} \right)$$

$$\textit{day} = \textit{days} + 1 - \left\lfloor \textbf{delta-year} + \left(\left\lceil \frac{\textit{offset}}{\textit{average-month-length}} \right\rceil - 1 \right) \times \textit{average-month-length} \right\rfloor$$

All of the above functions require precise arithmetic to work properly. Here they are in Lisp:

```
(defun fixed-from-single-cycle (s-date)
  ;; TYPE single-cycle-date -> fixed-date
  (let* ((year (standard-year s-date))
         (month (standard-month s-date))
         (day (standard-day s-date)))
    (+ single-cycle-epoch
       (floor (+ (* (1- year) avg-year-length)
                 delta-year))
       (floor (+ (* (1- month) avg-month-length)
                 delta-month))
       day -1)))
```

```
(defun single-cycle-from-fixed (date)
  ;; TYPE fixed-date -> single-cycle-date
  (let* ((days (- date single-cycle-epoch))
         (year (ceiling (- days -1 delta-year)
                        avg-year-length))
         (n (- days (floor (+ delta-year
                              (* (1- year) avg-year-length)))))
         (month (ceiling (- n -1 delta-month) avg-month-length))
         (day (- n -1 (floor (+ delta-month
                                (* (1- month)
                                   avg-month-length))))))
    (standard-date year month day)))
```

```
(defun var-fixed-from-single-cycle (s-date)
  ;; TYPE single-cycle-date -> fixed-date
  (let* ((year (standard-year s-date))
         (month (standard-month s-date))
         (day (standard-day s-date))
         (average-month-length (/ avg-year-length
                                  months-per-year)))
    (+ single-cycle-epoch
       (floor (+ (* (1- year) avg-year-length)
                 delta-year
                 (* (1- month) avg-month-length)))
       day -1)))
```

```
(defun var-single-cycle-from-fixed (date)
  ;; TYPE fixed-date -> single-cycle-date
  (let* ((days (- date single-cycle-epoch))
         (offset (- days -1 delta-year))
         (year (ceiling offset avg-year-length))
         (average-month-length (/ avg-year-length
                                  months-per-year))
         (month (+ 1 (mod (1- (ceiling offset average-month-length))
                          months-per-year)))
         (day (- days -1
                 (floor (+ delta-year
                           (* (1- (ceiling offset average-month-length))
                              average-month-length))))))
    (standard-date year month day)))
```

82. Page 39: We could add a new section after Section 1.12 describing how to determine the exact year number of fixed *date* for arithmetic calendars even when that calendar does not follow the paradigm of Section 1.12. Let **epoch** be the calendar's fixed epoch (start of year 1), Y its mean year length, **new-year**(i) the fixed starting day of year i, and $\delta = \max_i\{\textbf{new-year}(i) - \textbf{epoch} + i \times Y\}$, the maximum length of time a real year can begin before the mean year does. We first estimate the year of *date* to be the mean value $y = \lfloor(\textit{date} - \textbf{epoch})/Y\rfloor + 1$. Then, we check if $(\textit{date} - \textbf{epoch}) \bmod Y > Y - \delta$ (*date* falls in the "twilight zone") and $\textit{date} \geq \textbf{new-year}(y+1)$ (the estimate is actually wrong), in which case the estimate is off by one and the correct year is $y + 1$. We use this in **alt-iso-from-fixed** in Erratum 136.

83. Page 40, line 14: Change the comma to a colon. (Courtesy of Nicholas J. Cox, January 16, 2006.)

84. Page 40, line −10: Perhaps the code should include such predicate functions for each calendar.

85. Page 41, after line 8: Add the paragraph "Care must be taken with indices of arrays and cycles. Our arrays are 0-based, while some programming languages begin with index 1. However, when we speak of elements of a sequence as "first," "second," and so on, we intend standard English usage with no zeroth element. Most calendars number their days, months, and years starting with 1, but there are exceptions (Hindu years and Mayan days, for example). Some of the cycle formulæ in this chapter work for arbitrary starting points; others require adjustment when the first element of a cycle is not 0."

86. (3) Page 42, reference [9]: Change "manuscript, 1999" to "*ACM Computing Surveys*, volume 36, pp. 68–80, 2004". The title has been changed to "Line Drawing, Leap Years, and Euclid".

87. Page 42, reference [9]: Delete the comma after "Harris". (Courtesy of Nicholas J. Cox, January 16, 2006.)

88. Page 43, Good quote for the end of this long list of references: "If you steal from one book, you are condemned as a plagiarist, but if you steal from ten books, you are considered a scholar, and if you steal from thirty or forty books, a distinguished scholar." Amos Oz quotes his father as saying this (see *A Tale of Love and Darkness*, Harcourt, 2003, bottom of page 129). However, Bartlett's attributes to Wilson Mizner (1876–1933) the saying "If you steal from one author it's plagiarism. If you steal from many, it's research." Oz's father's version is sharper.

CHAPTER 2: THE GREGORIAN CALENDAR

89. Pages 46–49: Pope Gregory XIII was not only responsible for the institution of the revised calendar, but he was also responsible for a bull *Vices eius nos* (September 1, 1577) organizing regular missionizing sermons by apostate Jews that the Jewish community of Rome was forced to attend and subsidize. His bull *Sancta mater ecclesia* (September 1, 1584) specified more precise conditions: beadles armed with rods made sure the Jews paid attention and checked that they had not put wax in their ears. These sermons took place throughout the Papal States and much of the Roman Catholic world, as well in the church nearest the Jewish quarter in Rome, San Gregorio della Divina Pietà (the front of which has an inscription in Hebrew and Latin, beside an image of the crucified Jesus, quoting from *Isaiah* 65:2–3, "I have spread out My hands all the day unto a rebellious people, that walk in a way that is not good, after their own thoughts; a people that provoke me to my face continually.")

90. Page 48, line 8: The values $c = 12$ and $L = 30$ are obvious: There are 12 months and the ordinary length is 30 days. The value $l = 7$ comes from the 7 long months of 31 days; the value $\Delta = 11$ forces January to be month number 1 (rather than 0), necessary for the applicability of formulas (1.60) and (1.64). (Courtesy of Arthur J. Roth, February 5, 2002.)

91. Page 48, equation (2.2): Change the period after the equation to a comma and add the phrase "where, as in the derivation of (1.64), the first day of the year is $n = 0$; that is, n is the number of prior days in the year rather than the day number in the usual sense." (Courtesy of Arthur J. Roth, December 31, 2001.)

92. (3) Page 48, lines 1–2 of the footnote: Change "Varro gives the year of the founding of Rome as 753 B.C.E." to "Varro's statements imply the year of the founding of Rome to be 753 B.C.E." (Courtesy of Svante Janson, February 17, 2003.)

93. Page 48, line −4 (of the footnote): Bede's work *De Temporum Ratione* has been translated by Faith Wallis, *Bede: The Reckoning of Time*, Liverpool University Press, Liverpool, 1999 (also University of Pennsylvania Press, Philadelphia, 2000). (Courtesy of Svante Janson, January 31, 2003.)

94. (3) Page 49, line 10: Change "still" to "then". (Courtesy of Robert H. Douglass, May 10, 2002.)

95. Page 49, lines 18–19: There is a 1712 Swedish almanac showing February having 30 days: It is *Allmanach, på åhret effter Christi födelse 1712* (system number 0672155 in the National Library of Sweden).

96. (3) Page 50, line 6: Change "in England" to "in England under the Julian calendar". (Courtesy of Svante Janson, February 17, 2003.)

97. (3) Page 50, line 8: Delete the comma after "1660".

98. Page 50, first paragraph: Here is an oddity relating to when the year starts. At the Salisbury cathedral in England, one of the hundreds of tombstones making up the floor of the cathedral is a 16 inch by 37 inch stone with an inscription reading

    H S E
    THE BODY OF THO
    THE SONN OF THO
    LAMBERT GENT.
    WHO WAS BORNE
    MAY Y 13 AN DO
    1683 & DYED FEB
    19 the same year

    A modern English translation reads: "Here lies the body of Thomas Lambert the son of Thomas Lambert, Gentleman. Who was born May the 13th Anno Domini 1683 and died February 19th the same year." From the middle of the 11th century the English calendar began on March 25 each year. This continued until 1752 when the English Parliament passed an act adopting the Gregorian Calendar with January 1 as the start of the year. See *Copies of the Epitaphs in Salisbury Cathedral, Cloisters and Cemetry*, James Harris, Brodie and Dowding, Salisbury, 1825. (Courtesy of Svante Janson, February 17, 2003.)

99. Page 51, lines −7 to −1: Change "We add together... since the epoch is determined by" to "We start at the R.D. number of the last day before the epoch (**gregorian-epoch** $-1 = 0$, but we do it explicitly so that the dependence on our arbitrary starting date is clear); to this, we add the number of nonleap days (positive for positive years, negative otherwise) between R.D. 0 and the last day of the year preceding the given year, the corresponding (positive or negative) number of leap days, the number of days in prior months of the given year, and the number of days in the given month up to and including the given day. The number of leap days between R.D. 0 and the last day of the year preceding the given year is determined by" (Courtesy of Arthur J. Roth, December 31, 2001.)

100. Page 53, line 13: Change "is also correct" to "is correct even". (Courtesy of Arthur J. Roth, December 31, 2001.)

101. Page 55, line 2: Change "has 30 days," to "has 30 days and we count months starting from December,". (Courtesy of Arthur J. Roth, February 5, 2002.)

102. Page 55, line 11: Change "work" to "works". (Courtesy of Arthur J. Roth, December 31, 2001.)

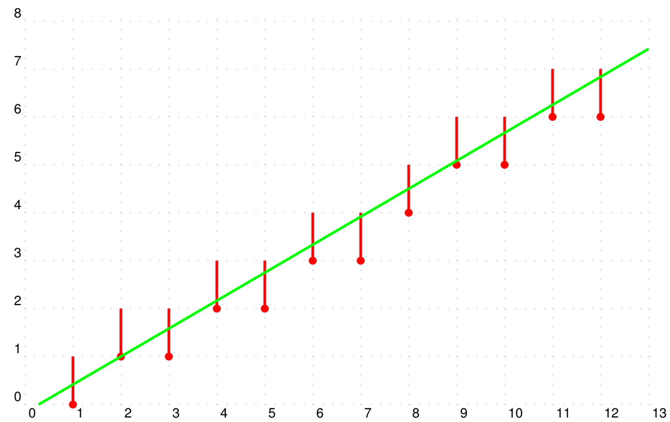

Figure 103-A: The twelve half open line segments giving the ranges that the corrective line must transect, along with the correction of equation (2.1) on page 48, $C(m) = (7m - 2)/12$; see Erratum 103.

103. Pages 55, lines 8–9: The parenthetical remark that "these lower and upper bounds come from considering each of the twelve month numbers" is too obscure—the detailed analysis is as follows. The sum on the left side of equation (2.1) on page 48 has a corrective term, the floor of

$$C(m) = \frac{7m - 2}{12}$$

which is

m	1	2	3	4	5	6	7	8	9	10	11	12
$\lfloor C(m) \rfloor$	0	1	1	2	2	3	3	4	5	5	6	6

which we show as a set of points $(m, \lfloor C(m) \rfloor)$ in Figure 103-A. Each of these points can be moved upward by any amount less than 1 without changing the value of $\lfloor C(m) \rfloor$); each of these ranges is represented as a half open line segment in Figure 103-A. The problem is to determine lines $L(m) = am + b$ so that $\lfloor L(m) \rfloor = \lfloor C(m) \rfloor$ for the twelve integer values, $1 \le m \le 12$. In other words, we want to determine lines that transect each of the twelve half open line segments in Figure 103-A. The line we know about, $C(m) = (7m - 2)/12$, is shown in Figure 103-A also.

To cut both the half open line segments $[(7, 3), (7, 4))$ and $[(9, 5), (9, 6))$, a line $L(m) = am + b$ must have slope $a > 1/2$; to cut both the half open line segments $[(2, 1), (2, 2))$ and $[(7, 3), (7, 4))$, a line $L(m) = am + b$ must have slope $a < 3/5$. To see that any slope $1/2 < a < 3/5$ is possible, we give an explicit line for each slope in that range: $a = 1/2 + \epsilon$, $b = 1/2 - 8\epsilon$ works for $0 < \epsilon \le 1/12$, and $a = 3/5 - \epsilon$, $b = -1/5 + 2\epsilon$ works for $0 < \epsilon \le 1/35$. Because $1/2 + 1/12 > 3/5 - 1/35$, there exists a b for each value of a, $1/2 < a < 3/5$. (Courtesy of Michael H. Deckers, January 16, 2002.)

104. Pages 55, line −10: Delete "[16] or" since Ore's book does not seem to mention Zeller's congruence.

105. Page 55, line −8: Give and explain the Zeller congruence.

106. Page 56: We could (should?) simplify **alt-fixed-from-gregorian** to:

alt-fixed-from-gregorian (2.25)

$$\left(\boxed{\textit{year} \mid \textit{month} \mid \textit{day}} \right) \stackrel{\text{def}}{=}$$

$$\textbf{gregorian-epoch} - 307 + 365 \times y + \left\lfloor \frac{y}{4} \right\rfloor - \left\lfloor \frac{y}{100} \right\rfloor + \left\lfloor \frac{y}{400} \right\rfloor + \left\lfloor \frac{2 + 3 \times m}{5} \right\rfloor + 30 \times m + \mathit{day}$$

where

$$m = (\mathit{month} - 3) \bmod 12$$

$$y = \mathit{year} - \left\lfloor \frac{m}{10} \right\rfloor$$

Or, in Lisp (page 327):

```
(defun alt-fixed-from-gregorian (g-date)
  ;; TYPE gregorian-date -> fixed-date
  ;; Alternative calculation of fixed date equivalent to the
  ;; Gregorian date.
  (let* ((month (standard-month g-date))
         (day (standard-day g-date))
         (year (standard-year g-date))
         (m (mod (- month 3) 12))
         (y (- year (quotient m 10))))
      (+ gregorian-epoch
         -307          ; Days in March...December.
         (* 365 y)     ; Ordinary days since epoch.
         (quotient y 4); Julian leap days since epoch...
         (-            ; ...minus century years since epoch...
          (quotient y 100))
         (quotient     ; ...plus years since epoch divisible...
          y 400)       ; ...by 400.
         (quotient     ; Days in prior months this year.
          (+ 2 (* 3 m)) 5)
         (* 30 m)
         day)))        ; Days so far this month.
```

107. Page 56, line −2: Change “3” to “**march**”; in the Lisp code, this is on page 328, line 11 of `alt-gregorian-from-fixed`. (Courtesy of Arthur J. Roth, December 31, 2001.)

108. Page 57, lines 15 and −3: The “2” is needed because the number of days in years 1 through n of the 400-year cycle can fall short of $365.2425 \times n$ by as much as 1.4775 days (for $n = 303$). Thus 2 is the smallest integer we can add that guarantees that for the first day of any year n, $\mathit{approx} \geq n - 1$. (Courtesy of Arthur J. Roth, December 31, 2001.)

109. Page 58, last line: Change “of the k-day” to “of the last k-day”. (Courtesy of Arthur J. Roth, December 31, 2001.)

110. Page 59, line 7: Add “or” at the beginning of the line. (Courtesy of Arthur J. Roth, December 31, 2001.)

111. Page 59: Consider having **daylight-saving-start** return a moment rather than a fixed date, since D.S.T. typically starts at 2 a.m. Also, consider renaming **daylight-saving-end** to **standard-time-start** because it will return the moment immediately after D.S.T. ends (as given, **daylight-saving-end** returns a fixed date which, being an integer, corresponds to midnight, at which time D.S.T. would still be in effect in most locales). Also, perhaps we should mention the E.U. D.S.T. rules. (Courtesy of Irv Bromberg, October 1, 2002.)

112. Page 60. We can add a discussion of finding sequences of days with specific properties, such as all Friday the Thirteenths within a given range:

$$\textbf{unlucky-fridays}\,(\mathit{start}, \mathit{end}) \stackrel{\text{def}}{=} \tag{112-A}$$

$$\begin{cases} \langle\,\rangle & \textbf{if } \mathit{start} > \mathit{end} \\ \begin{Bmatrix} \langle \mathit{fri} \rangle & \textbf{if } \mathit{date}_{\textbf{day}} = 13 \\ \langle\,\rangle & \textbf{otherwise} \end{Bmatrix} \\ \parallel \textbf{unlucky-fridays}\,(\mathit{fri}+1, \mathit{end}) & \\ & \textbf{otherwise} \end{cases}$$

where

$$\mathit{fri} = \textbf{kday-on-or-after}\,(\mathit{start}, \textbf{friday})$$

$$\mathit{date} = \textbf{gregorian-from-fixed}\,(\mathit{fri})$$

or, in Lisp:

```
(defun unlucky-fridays (start end)
  ;; TYPE (fixed-date fixed-date) -> list-of-fixed-dates
  ;; List of Fridays between fixed dates start and
  ;; end (inclusive) that are day 13 of Gregorian months.
  (if (> start end)
      nil
    (let* ((fri (kday-on-or-after start friday))
           (date (gregorian-from-fixed fri)))
      (append
       (if (= (standard-day date) 13)
           (list fri)
         nil)
       (unlucky-fridays (1+ fri) end)))))
```

This provides a Gregorian calendar example that should be cited when giving the function **sacred-wednesdays**. Mention Solomn W. Golomb's problem E3292 [*American Mathematical Monthly* **95** (1988), page 873; solution **98** (1991), pages 646–649] to determine the longest interval between successive Friday the Thirteenths (answer: 426 days); there are further references there. John H. Conway remarked (in 1996 on a mathematics history email list) that every year must contain a Friday the Thirteenth because the seven months from May through November each start on a different weekday.

113. Pages 60, 72, and 124: Reference [1] should be

"The Calendar," *The Nautical Almanac and Astronomical Ephemeris*, His Majesty's Stationery Office, London, 1931–1934; revised 1935–1938; abridged 1939–1941. (Written by J. K. Fotheringham.)

Fotheringham wrote the article, but is credited with authorship only in the preface (in the 1933 edition at least); hence our mysterious index entries to him when his name does not appear on those pages.

114. Pages 61: Delete Ore's book [16] as a reference (see Erratum 104).

CHAPTER 3: THE JULIAN CALENDAR

115. Chapter 2 or 3: Good quote attributed to Voltaire (= François Marie Arouet): "The English mob preferred their calendar to disagree with the Sun than to agree with the Pope and they refused to accept a reform for which one should have been grateful to the Grand Turk if he had proposed it" (see page 71 of George Sarton's *Six Wings*: *Men of Science in the Renaissance*, Indiana University Press, 1957). Pierre Gordon's *Les fêtes à travers les âges* (Editions Arma Artis, 1983) gives the quote "n'être pas d'accord avec le soleil plutôt que de l'être avec Rome." Nothing like this appears in the writings of Voltaire available on line.

116. Chapter 3: Give the conversion to/from a year on the Julian calendar and years A.U.C. (see footnote on page 48). (Courtesy of Andrew Main, April 21, 2004.) Because there is some uncertainty about the year of the founding of Rome, we make it a symbolic value:

$$\textbf{year-rome-founded} \stackrel{\text{def}}{=} 753 \text{ B.C.E.} \tag{116-A}$$

Years were not counted from zero on the Julian calendar, so we assume that they should not be counted from zero A.U.C.; recalling that B.C.E. years are represented internally as negative integers we write:

$$\textbf{julian-year-from-auc-year}\,(\mathit{year}) \stackrel{\text{def}}{=} \tag{116-B}$$

$$\begin{cases} \mathit{year} + \textbf{year-rome-founded} - 1 \\ \qquad \textbf{if } 1 \le \mathit{year} \le -\textbf{year-rome-founded} \\ \mathit{year} + \textbf{year-rome-founded} \quad \textbf{otherwise} \end{cases}$$

and

$$\textbf{auc-year-from-julian-year}\,(\mathit{year}) \stackrel{\text{def}}{=} \tag{116-C}$$

$$\begin{cases} \mathit{year} - \textbf{year-rome-founded} + 1 \\ \qquad \textbf{if year-rome-founded} \le \mathit{year} \le -1 \\ \mathit{year} - \textbf{year-rome-founded} \quad \textbf{otherwise} \end{cases}$$

Or, in Lisp:

```
(defconstant year-rome-founded
  ;; TYPE julian-year
  ;; Year on the Julian calendar of the founding of Rome.
  (bce 753))
```

```
(defun julian-year-from-auc-year (year)
  ;; TYPE nonzero-integer -> julian-year
  ;; Julian year equivalent to AUC year
  (if (<= 1 year (- year-rome-founded))
      (+ year year-rome-founded -1)
    (+ year year-rome-founded)))
```

```
(defun auc-year-from-julian-year (year)
  ;; TYPE julian-year -> nonzero-integer
  ;; Year AUC equivalent to Julian year
  (if (<= year-rome-founded year -1)
      (- year year-rome-founded -1)
    (- year year-rome-founded)))
```

(Courtesy of Irv Bromberg, July 29, 2004.)

117. (2) Page 64, last line: There is a missing y before the equal sign. This error was introduced somehow by the compositor. (Courtesy of Otto Stolz, November 7, 2001.)

118. Page 65, lines 1 to 5: Change "We add together…including the given date." to "We start at **julian-epoch** − 1, the R.D. number of the last day before the epoch; to this, we add the number of nonleap days (positive for positive years, negative otherwise) between the last day before the epoch and the last day of the year preceding the given year, the corresponding (positive or negative) number of leap days, the number of days in prior months of the given year, and the number of days in the given month up to and including the given day." (Courtesy of Arthur J. Roth, December 31, 2001.)

119. (2) Page 67, line 5: Change "July 4" to "July 6". (Courtesy of Arthur J. Roth, December 31, 2001.)

120. Page 67, second paragraph: See pages 92–94 and 678–680 of [2] for a discussion of the placement of the leap day on the Julian calendar. We should mention that despite the official Roman calendar, unofficial and medieval usage made the day after February 23 the leap day; the resulting changes to **fixed-from-roman** and **roman-from-fixed** are simple.

121. Page 67, fourth paragraph: Add the following sentence at the end of the paragraph. "Determining the Roman name for a Gregorian date is easily done by making the appropriate substitutions of **gregorian-from-fixed** and **gregorian-leap-year?** for the corresponding Julian functions. (Courtesy of Svante Janson, July 1, 2003.)

122. Page 68, equation (3.11): This is the first example of how the translation of the Lisp `cond` was handled differently from that of Lisp's nested `if` construction. For example, the function

```
(defun u (a)
  (if (< a 0)
      (value1)
    (if (< a 1)
        (value2)
      (value3))))
```

is translated as

$$\mathbf{u}\,(a) \stackrel{\text{def}}{=} \begin{cases} \mathbf{value}_1 & \textbf{if } a < 0 \\ \mathbf{value}_2 & \textbf{if } a \geq 0 \text{ and } a < 1 \\ \mathbf{value}_3 & \textbf{otherwise} \end{cases} \tag{122-A}$$

but

```
(defun v (a)
  (cond ((< a 0) (value1))
        ((< a 1) (value2))
        (t (value3))))
```

is translated as

$$\mathbf{v}\,(a) \stackrel{\text{def}}{=} \begin{cases} \mathbf{value}_1 & \textbf{if } a < 0 \\ \mathbf{value}_2 & \textbf{if } a < 1 \\ \mathbf{value}_3 & \textbf{otherwise} \end{cases} \tag{122-B}$$

The intention in both cases is clear and in Lisp the nested `if` and the `cond` are algorithmically identical (each condition is checked only if all the previous conditions have failed). However, the translation of the nested `if` explicitly displays the failure of all the previous conditions, while the translation of `cond` does not. The translation of the `if` form is more mathematically precise, but the translation of the `cond` form is more concise. (Courtesy of Arthur J. Roth, December 31, 2001.)

*123. (3) Pages 68–70, equation (3.11): The variable *year′* is *year* + 1 if the coming month is January, which is wrong for *year* = −1 (that is, 1 B.C.E.); the corrected function is:

$$\textbf{roman-from-fixed}\,(date) \stackrel{\text{def}}{=} \tag{3.11}$$

$$\begin{cases} \boxed{\textit{year}} \boxed{\textit{month}} \boxed{\textbf{kalends}} \boxed{1} \boxed{\text{false}} & \textbf{if } day = 1 \\ \boxed{\textit{year}} \boxed{\textit{month}} \boxed{\textbf{nones}} \boxed{\textbf{nones-of-month}\,(month) - day + 1} \boxed{\text{false}} & \textbf{if } day \leq \textbf{nones-of-month}\,(month) \\ \boxed{\textit{year}} \boxed{\textit{month}} \boxed{\textbf{ides}} \boxed{\textbf{ides-of-month}\,(month) - day + 1} \boxed{\text{false}} & \textbf{if } day \leq \textbf{ides-of-month}\,(month) \\ \boxed{\textit{year}'} \boxed{\textit{month}'} \boxed{\textbf{kalends}} \boxed{kalends_1 - date + 1} \boxed{\text{false}} & \textbf{if } month \neq \textbf{february} \text{ or not } \textbf{julian-leap-year?}\,(year) \\ \boxed{\textit{year}} \boxed{\textbf{march}} \boxed{\textbf{kalends}} \boxed{30 - day} \boxed{\text{false}} & \textbf{if } day < 25 \\ \boxed{\textit{year}} \boxed{\textbf{march}} \boxed{\textbf{kalends}} \boxed{31 - day} \boxed{day = 25} & \textbf{otherwise} \end{cases}$$

where

$$j = \textbf{julian-from-fixed}\,(date)$$

$$month = j_{\textbf{month}}$$

$$day = j_{\textbf{day}}$$

$$year = j_{\textbf{year}}$$

$$month' = (month + 1) \quad \text{amod} \quad 12$$

$$year' = \begin{cases} year & \textbf{if } month' \neq 1 \\ year + 1 & \textbf{if } month' = 1 \text{ and } year \neq -1 \\ 1 & \textbf{otherwise} \end{cases}$$

$$kalends_1 = \textbf{fixed-from-roman}\left(\boxed{year' \mid month' \mid \textbf{kalends} \mid 1 \mid \text{false}}\right)$$

Or, in Lisp (pages 332–333):

```
(defun roman-from-fixed (date)
  ;; TYPE fixed-date -> roman-date
  ;; Roman name for fixed date.
  (let* ((j (julian-from-fixed date))
         (month (standard-month j))
         (day (standard-day j))
         (year (standard-year j))
         (month-prime (adjusted-mod (1+ month) 12))
         (year-prime (if (/= month-prime 1)
                         year
                       (if (/= year -1)
                           (1+ year)
                         1)))
         (kalends1 (fixed-from-roman
                    (roman-date year-prime month-prime
                                kalends 1 false))))
    (cond
     ((= day 1) (roman-date year month kalends 1 false))
     ((<= day (nones-of-month month))
      (roman-date year month nones
                  (1+ (- (nones-of-month month) day)) false))
     ((<= day (ides-of-month month))
      (roman-date year month ides
                  (1+ (- (ides-of-month month) day)) false))
     ((or (/= month february)
          (not (julian-leap-year? year)))
      ; After the Ides, in a month that is not February of a
      ; leap year
```

```
     (roman-date year-prime month-prime kalends
                 (1+ (- kalends1 date)) false))
    ((< day 25)
     ; February of a leap year, before leap day
     (roman-date year march kalends (- 30 day) false))
    (true
     ; February of a leap year, on or after leap day
     (roman-date year march kalends
                 (- 31 day) (= day 25))))))
```

(Courtesy of Irv Bromberg, February 19, 2004.)

124. Page 70, line −8: Change "Because the Julian year is always at least as long... at all." to read "With the current alignment of the Julian and Gregorian calendars, and because the Julian year is always at least as long as the corresponding Gregorian year, Eastern Orthodox Christmas occurs at most once in a given Gregorian year—in modern times it occurs near the beginning. However, far in the past or the future, there are Gregorian years in which it does not occur at all (1100, for example); as the two calendars get further out of alignment (it will take some 50,000 years for them to be a full year out of alignment), Eastern Orthodox Christmas will migrate throughout the Gregorian year." The next sentence, "We write..." should begin a new paragraph. (Courtesy of Arthur J. Roth, February 5, 2002.)

125. Page 71, line −10: Add the following sentence at the end of the line "Recall that...": "Tens of thousands of years from the present, the alignment of the Gregorian and Julian calendars is such that some Julian dates occur twice in a Gregorian year—the first example of this is Julian date February 28 occurring twice in Gregorian year 41104; the function **julian-in-gregorian** correctly returns a list of two R.D. dates in such cases." (Courtesy of Arthur J. Roth, February 5, 2002.)

126. Page 71, line −9: Delete the words "zero or one". (Courtesy of Arthur J. Roth, February 5, 2002.)

CHAPTER 4: THE COPTIC AND ETHIOPIC CALENDARS

127. (2) Page 75, line −14: Change "The months are called by Arabic names in Coptic (Sahidic):" to "The months are called by coptized forms of their ancient Egyptian names; in Coptic (Sahidic) they are:". (See Erratum 65.)

128. Page 76, lines −8 to −6: Change "Add together... in *month*:" to "Start at **coptic-epoch** − 1, the R.D. number of the last day before the epoch; to this add the number of nonleap days (positive for positive years, negative otherwise) between this date and the last day of the year preceding *year*, the corresponding (positive or negative) number of leap days, the number of days in prior months in *year*, and the number of days in *month* up to and including *day*:" (Courtesy of Arthur J. Roth, February 5, 2002.)

129. Page 78, lines −3 and −2: Delete "which spans two Gregorian years,". (Courtesy of Arthur J. Roth, February 5, 2002.)

130. (2) Page 79, line −15: Change "Kiyahk" to "Koiak". (Courtesy of Arthur J. Roth, February 5, 2002.)

131. (2) Page 79, lines −8 and −7: Change "Mary's Announcement (Parmoute 29)" to "Mary's Announcement (Paremotep 29)". (Courtesy of Robert H. Douglass, May 10, 2002.)

CHAPTER 5: THE ISO CALENDAR

132. Chapter 5: Microsoft Access 2000 and Excel 2000 have a week numbering function `WEEKNUM` that can be set to number weeks starting on either Sunday or Monday. However, these week numbers are not always the same as the ISO week because Microsoft defines the first week in the year as the week containing January 1. Lotus Notes uses the rule "An ISO calendar year is long (53-week) if and only if the corresponding Gregorian year begins on a Thursday when it is a common year or begins on a Wednesday when it is a leap year." This rule fails 13 times in the 400-year Grgeorian cycle—it fails in 2004, for example. The rule needs to be amended to "An ISO calendar year is long if and only if the corresponding Gregorian year begins on a Thursday when it is a common year or begins either on a Wednesday or a Thursday when it is a leap year" which is equivalent to "An ISO calendar year is long if and only if the corresponding Gregorian year either begins or ends (or both) on a Thursday." (Courtesy of Robert H. van Gent, October 25, 2004.)

133. Pages 83, lines -7 and -8: Robert H. van Gent has observed that the "short" (52-week) ISO years occur $329/400 = 82.25\%$ of the time and "long" (53-week) ISO years occur $71/400 = 17.75\%$ of the time: The Gregorian cycle of 400 years contains $146097 = 7 \times 20871$ days which is exactly 20871 weeks. Thus the ISO cycle of short/long years repeats after 400 years. Let s be number of short years and l be the number of long years in the cycle; we have

$$s + l = 400$$
$$52s + 53l = 20871$$

whose solution is $s = 329$, $l = 71$. Simon Cassidy has observed that an ISO year y is short if and only if $F(y-1) \not\equiv 3$ and $F(y) \not\equiv 4$ modulo 7, where

$$F(y) = y + \left\lfloor \frac{y}{4} \right\rfloor - \left\lfloor \frac{y}{100} \right\rfloor + \left\lfloor \frac{y}{400} \right\rfloor$$

Note that the $F(y)$ is concealed in the simplified **alt-fixed-from-gregorian** of Erratum 106 because $365 \equiv 1 \pmod 7$; it gives the day of the week of December 31 in Gregorian year y. Thus Cassidy's rule says that the ISO year is short if and only if neither January 1 nor December 31 is a Thursday.

134. Chapter 5: The ISO calendar is reminiscent of a tenth century Icelandic calendar in which ordinary years had 52 weeks and every seventh year was a leap year with 53 weeks [Ari The Learned, *Libellum Islandorum* (*The Book of Icelanders*), c. 1130, in J. Benediktsson, ed., 1968, *Íslenzk fornrit I*: *Ískebdubgabók, Landnámabók fyrri hluti* (*The Book of Icelanders and the Book of Settlements*), Reykjavík: Hiðíslenzka fornritafélag]. See Þorsteinn Vilhjálmsson, "Time-reckoning in Iceland before literacy," pp. 69–76 in *Archaeoastronomy in the 1990s*, Clive L. N. Ruggles, ed., Loughborough, UK Group D Publications, 1991.

135. Page 83, line 2 of the first paragraph: Change "specifies a date by giving the ordinal..." to "specifies a 'week-date' by giving the ordinal...". In the newest version of the ISO standard (2004) the reference is section 2.2.10 and the quoted part defines a "calendar week number" as the

> ordinal number which identifies a calendar week within its calendar year according to the rule that the first calendar week of a year is that one which includes the first Thursday of that year and that the last calendar week of a calendar year is the week immediately preceding the first calendar week of the next calendar year

(Courtesy of Michael H. Deckers, August 7, 2006.)

136. Page 84: An alternative for **iso-from-fixed** (see Erratum 82) is:

$$\textbf{alt-iso-from-fixed}\,(date) \stackrel{\text{def}}{=} \boxed{\begin{array}{c|c|c} year & week & day \end{array}} \tag{5.3}$$

where

$$approx = \left\lfloor \frac{date - 4}{\frac{146097}{400}} \right\rfloor + 1$$

$$year = \begin{cases} approx + 1 & \textbf{if } date \geq \textbf{fixed-from-iso}\left(\boxed{\begin{array}{c|c|c} approx+1 & 1 & 1 \end{array}}\right) \\ approx & \textbf{otherwise} \end{cases}$$

$$week = \left\lfloor \frac{date - \textbf{fixed-from-iso}\left(\boxed{\begin{array}{c|c|c} year & 1 & 1 \end{array}}\right)}{7} \right\rfloor + 1$$

$$day = (date - \textbf{gregorian-epoch} + 1) \ \text{amod}\ 7$$

or in Lisp (page 335):

```
(defun alt-iso-from-fixed (date)
  ;; TYPE fixed-date -> iso-date
  ;; ISO (year week day) corresponding to the fixed date.
  (let* ((approx ; Approx may be one year off.
          (1+ (quotient (- date 4) 146097/400)))
         (year (if (>= date
                       (fixed-from-iso
                        (iso-date (1+ approx) 1 1)))
                    (1+ approx)
                  approx))
         (week (1+ (quotient
                    (- date
                       (fixed-from-iso (iso-date year 1 1)))
                    7)))
         (day (adjusted-mod (- date (1- gregorian-epoch))
                            7)))
    (iso-date year week day)))
```

137. Page 84, line −9: Change “the start of the approximate ISO year.” to “the start of the year after the approximate ISO year.” (Courtesy of Arthur J. Roth, February 5, 2002.)

138. Page 84, reference: ISO 8601 was revised in 2004.

CHAPTER 6: THE ISLAMIC CALENDAR

139. Chapter 6: In the Ottoman Empire, the fiscal year was a complicated issue because although the Islamic calendar was followed as the official calendar, and was thus used for expenditures, revenue collecting generally followed the solar year because seasons affected income producing activities such as agriculture, shipping, and mining. The result was that there were lunar years that had no revenue because for every 32 solar years there are 33 Islamic (lunar) years; thus every 33 Islamic years had a "skip" year, called a *sıvış* year in Turkish. Such years precipitated crises, such as in 1448 C.E. (852 A.H.) in which the troops' pay was six months in arrears, resulting in a lack of resistance on their part when Hungarian and Serbian forces entered the Ottoman Empire. Halil Sahillioğlu's article, "*Sıvış* Year Crises in the Ottoman Empire," *Studies in the Economic History of the Middle East*, M. A. Cook, ed., Oxford Univeristy Press, London, 1970, pages 230–252, gives a detailed analyis of the phenomenon. (Courtesy of Fariba Zarinebaf, October 3, 2006.)

140. Chapter 6: Robert H. van Gent notes that a number of Microsoft-related web pages such as `http://support.microsoft.com/default.aspx?scid=kb;EN-ME;884701` and `http://www.microsoft.com/globaldev/DrIntl/columns/002/default.mspx` discuss the so-called "Kuwaiti Algorithm" for the Hijri calendar used by Microsoft in its recent software. Microsoft says

> The Hijri calendar is very important to Saudi Arabia and other countries such as Kuwait, and thus this seemingly unsolveable problem must be solved.
>
> In an effort to solve this challenging problem, several years ago some of the top developers in Microsoft's Middle East Products Divison (MEPD) did extensive research into it. They had the longest timeline of information on the Hijri calendar as is used in Kuwait, and they took this information and did statistical analysis on it, finally arriving at the most accurate algorithm they could devise. This algorithm is used in many Microsoft products, including all operating systems that support Arabic locales, Microsoft Office, COM, Visual Basic, VBA, and SQL Server 2000.

Microsoft gives no details on the workings of the "Kuwaiti algorithm" but van Gent discovered that it nothing more than the standard arithmetic approximation. van Gent says, "Naming this the 'Kuwaiti Algorithm' is thus erroneous (as well as deceitful) as it suggests that it is based on a new analysis of new data and more accurate than previous algorithms." (Courtesy of Robert H. van Gent, July 22, 2005.)

141. (3) Page 87, line −8: There is a spurious *ya* in the Arabic for Monday; it should be يَوْم الاثنين. (Courtesy of Daher Kaiss, November 29, 2001.)

142. Page 89, lines 4–6: The variant structure is also used in the tables of Bar Hebraeus (Gregory Abu'l-Faraj), James Greaves (1650; based on those of Ulugh Beg), and in the "Kuwaiti Algorithm" (Erratum 140). (Courtesy of Robert H. van Gent, September 16, 2005.)

143. Page 89, line 8: Add at the end of the paragraph that the Bohras (an Ismailite Moslem sect of about 1 million in India) follow a book called *Sahifa* giving leap years 2, 5, 8, 10, 13, 16, 19, 21, 24, 27, and 29; this corresponds to $\Delta = 1$. Their epoch is Thursday, July 15, 622 C.E. (Julian). (Courtesy of Svante Janson, February 16, 2003.)

144. Page 89: More details are given by Helmer Aslaksen on his web site `http://www.math.nus.edu.sg/aslaksen/calendar/islamic.html` where he says:

Some sources describe an arithmetical (tabular) Islamic calendar. It is sometimes used for approximate conversions for civil purposes, but is not used for religious purposes by Sunnis or Twelver (Ithna Asharia) Shi‘ites. However, it is common among Sevener (Isma‘ili) Shi‘ites, including the Bohras (Musta’lis) and Nizaris (Isma‘ili Khojas, Aga Khanis). It seems to have been designed to be closer to new Moon than to the first visibility of the lunar crescent, so it often runs a day or two ahead of the regular Islamic calendars. There are currently about one million Bohras and about 15 millions Nizaris, compared to over a billion Sunnis and close to a hundred million Twelver Shi‘ites. Both of these groups are today primarily Indian Muslim groups, but they trace their history from the Fatimid Caliphate that ruled Egypt from about 970 to 1171. The calendar was put into practice by Imam al-Hakim (985–1021) and is therefore sometimes referred to as the Fatimid or misr (Egyptian) calendar. The calendar is sometimes attributed to the famous astronomer Al-Battani (850–929) and an alternative version to Ulugh Beg (1393–1449). It is also sometimes referred to as hisabi. It is possibly also used by the Qadianis (Ahmadiyyas), but they are not considered Muslims by other Muslims.

The average lunar year is about $354\frac{11}{30}$ days, so you get a reasonable lunar calendar by using a cycle of 11 leap years (kasibah) with 355 days in a 30 year cycle. The odd numbered months have 30 days and the even numbered months have 29 days, except in a leap year when the 12th and final month has 30 days. There are several versions for how to space out the 11 leap years. One rule is to use years 2, 5, 7, 10, 13, 16, 18, 21, 24, 26, 29. This seems to be the rule followed by the Nizaris Isma‘ili, but some replace 16 by 15 and others replace 7 by 8, 18 by 19 and 26 by 27. According to Imran Hussain the Bohra have leap year in years 2, 5, 8, 10, 13, 16, 19, 21, 24, 27, 29. He has both a Bohra and a Sunni version of his Islamic Diary.

(Courtesy of Helmer Aslaksen, November 22, 2005.)

145. Page 89, line 9 to the beginning of (6.4): Replace the (6.3) and the text before and after it by the following version:

“To convert an Islamic date to its R.D. equivalent, start at **islamic-epoch** − 1, the R.D. number of the last day before the epoch; to this add the number of days between that date and the last day of the year preceding the given year [using formula (1.60)], the number of days in prior months in the given year, and the number of days in the given month, up to and including the given day. The number of days in months prior to the given month is also computed by (1.60) because the pattern of Islamic month lengths in an ordinary year satisfies the cycle formulas of Section 1.12 with $c = 12$, $l = 6$, $\Delta = 1$ (to count months from 1 instead of 0), and $L = 29$; because the leap day is day 30 of month 12, this works for leap years also:

$$\textbf{fixed-from-islamic}\left(\boxed{\textit{year} \mid \textit{month} \mid \textit{day}}\right) \stackrel{\text{def}}{=} \qquad (6.3)$$

$$\textbf{islamic-epoch} - 1 + (\textit{year} - 1) \times 354 + \left\lfloor \frac{3 + 11 \times \textit{year}}{30} \right\rfloor + 29 \times (\textit{month} - 1) + \left\lfloor \frac{\textit{month}}{2} \right\rfloor + \textit{day}$$

Computing the Islamic date equivalent to a given R.D. date is slightly more complicated (though it is more straightforward than the computations for the Gregorian calendar or the Julian). We can calculate the exact value of the year using formula (1.64). We want to determine the month number in the same way, and then determine the day of the month by subtraction. Determining the month cannot be done directly from (1.64) using the values $c = 12$, $l = 6$, $\Delta = 1$, and $L = 29$, which describe the common year month lengths, not the leap year. Indeed, no set of values with $c = 12$ can work properly in the cycle length formulas for the leap year because there are three 30s in a row (months 11, 12, and 1). However, the values $c = 11$, $l = 6$, $\Delta = 10$, $L = 29$ do work—not completely, but over the range $0 \le n \le 354$ in (1.64), which is all we care about; thus (6.3) remains correct if $\lfloor \mathit{month}/2 \rfloor$ is replaced with $\lfloor (6 \times \mathit{month} - 1)/11 \rfloor$. Hence the month can be determined using (1.64) and we obtain:"

The Lisp code for **fixed-from-islamic** (page 336) should be replaced by

```
(defun fixed-from-islamic (i-date)
  ;; TYPE islamic-date -> fixed-date
  ;; Fixed date equivalent to Islamic date.
  (let* ((month (standard-month i-date))
         (day (standard-day i-date))
         (year (standard-year i-date)))
    (+ (1- islamic-epoch)    ; Days before start of calendar
       (* (1- year) 354)     ; Ordinary days since epoch.
       (quotient             ; Leap days since epoch.
        (+ 3 (* 11 year)) 30)
       (* 29 (1- month))     ; Days in prior months this year
       (quotient month 2)
       day)))                ; Days so far this month.
```

(Courtesy of Arthur J. Roth, February 5, 2002.)

CHAPTER 7: THE HEBREW CALENDAR

146. Page 95, line −7: Change "the days Sunday–Friday" to "the days, for the most part,". (Courtesy of Arthur J. Roth, April 17, 2002.)

147. Page 95, footnote: Sacha Stern, argues, in chapter 4 of *Calendar and Community: A History of the Jewish Calendar, 2nd Century BCE to 10th Century CE*, Oxford University Press, Oxford, 2001, that the Hebrew calendar calculations were not standardized or fixed until at least the ninth century.

148. Pages 96–97: Add symbolic names for the other Hebrew months to make the functions that refer to them on pages 109–113 cleaner. (Courtesy of Irv Bromberg, June 24, 2004.)

149. 2 Page 98, line 1: Change "sunset" to "sunset (6 p.m.)". (Courtesy of Arthur J. Roth, April 17, 2002.)

150. Page 99, line 8: Delete "for a common year". (Courtesy of Arthur J. Roth, April 17, 2002.)

151. Page 99, line −16: Add the sentence "The current year cannot become too short because of this delay; it is shortened from 355 days to 354, with the following Rosh ha-Shanah being delayed until Saturday." (Courtesy of Arthur J. Roth, April 17, 2002.)

152. Page 99, line −11: Add "(noon plus 624 parts)" after "12:35:40 p.m.". (Courtesy of Irv Bromberg, January 20, 2006.)

153. Page 99, last paragraph: The best source in English for details of the controversy is pages 264–275 of Stern's book (see Erratum 147).

154. Page 100, line −9 in the first printing, line −10 in the second and third printings: There is too much space after the comma in "$69, 715$".

155. (3) Page 100, lines −7 to −4: Change the displayed equations to read:

$$\begin{aligned}\frac{\text{lcm}(69715,\ 181440)\text{ parts}}{69715\text{ parts/cycle}} &= \frac{2{,}529{,}817{,}920\text{ parts}}{69{,}715\text{ parts/cycle}}\\ &= 36{,}288\text{ cycles}\\ &= 689{,}472\text{ years}\end{aligned}$$

Change the sentence fragment on the lines following the displayed equations to read "for the excess parts to accumulate into an even number of weeks, and for the calendar to return to the same pattern of delays." (Courtesy of Arthur J. Roth, April 17, 2002.)

156. Page 100, line −8, second printing: Change to read

$$\text{lcm}(69715, 181440)/69715 = (2{,}529{,}817{,}920\text{ parts}) \ /\ (69{,}715\text{ parts/cycle})$$

Thus Erratum 155 should say "(2,529,817,920 parts) / (69,715 parts/cycle) in the first line, not "2,529,817,920 / 69,715 parts". Moreover, the last two lines of the equation are more logical in reverse order. (Courtesy of Svante Janson, May 3, 2003.)

157. Page 100, line −5, second and third printings (line −4 in the first printing): Change "even" to "integer". (Courtesy of Irv Bromberg, January 7, 2006.)

**158. (2) Page 101: Molad determination is wrong (the CD is correct). It should be:

$$\textbf{molad}\,(\textit{h-month}, \textit{h-year}) \stackrel{\text{def}}{=} \qquad (7.7)$$

$$\textbf{hebrew-epoch} - \tfrac{876}{25920} + \textit{months-elapsed} \times \left(29 + 12^{\text{h}} + \tfrac{793}{25920}\right)$$

where

$$y = \begin{cases} \textit{h-year} + 1 & \textbf{if } \textit{h-month} < \textbf{tishri} \\ \textit{h-year} & \textbf{otherwise} \end{cases}$$

$$\textit{months-elapsed} = \textit{h-month} - \textbf{tishri} + \left\lfloor \frac{235 \times y - 234}{19} \right\rfloor$$

Or, in Lisp (page 338):

```
(defun molad (h-month h-year)
  ;; TYPE (hebrew-month hebrew-year) -> moment
  ;; Moment of mean conjunction of h-month in Hebrew
  ;; h-year.
  (let* ((y ;; Treat Nisan as start of year.
          (if (< h-month tishri)
              (1+ h-year)
            h-year))
         (months-elapsed
          (+ (- h-month tishri)  ;; Months this year.
```

```
            (quotient ;; Months until New Year.
              (- (* 235 y) 234)
              19))))
      (+ hebrew-epoch
         -876/25920
         (* months-elapsed (+ 29 (hr 12) 793/25920)))))
```

159. Page 101, **molad**: For consistency with other functions, the order of the parameters should be reversed.

160. Page 101: The degree to which **molad** approximates the astronomical new moon can be seen in Figure 160-A which shows a scatter plot of the error (in hours) for Nisan for 2000–8000 A.H. (Courtesy of Irv Bromberg, August 18, 2004.)

161. Page 102, **hebrew-calendar-elapsed-days**: Change the variable *day* to *days*. (Courtesy of Arthur J. Roth, April 17, 2002.)

162. Page 102, just after equation (7.8), **hebrew-calendar-elapsed-days**: Change "So that... separately.[11]" to "Because the count of elapsed days begins with Sunday evening (which is already the second day of the week from the point of view of the Hebrew calendar), we use $day + 1$ for the number of days since the Sunday before the first molad. Whole days and fractional days (parts) are computed separately, so that 32 bits suffice for dates in the foreseeable future.[11]"

163. Pages 102–103, **hebrew-new-year-delay**: The name is a misnomer because that name implies that it returns the total number of days that the Hebrew New Year Day is delayed relative to the molad, whereas the delay value only represents the two least common delays. A better name would be **hebrew-year-length-correction**. (**hebrew-calendar-elapsed-days** is also a misnomer because it does not include the third and fourth delays.) We were deliberately careless about small performance issues because we wanted to highlight the novel way of computing the last 2 delays; but perhaps incorporating this into **hebrew-new-year** is advisable so that the value is calculated only once for the given *h-year*. (Courtesy of Irv Bromberg, July 31, 2005.)

164. Page 103, **last-day-of-hebrew-month**: For consistency with other functions, the order of the parameters should be reversed.

165. Page 105, last line of equation (7.16): the "+1" is in the wrong place, separating the function name, **fixed-from-hebrew**, from its argument, $\boxed{\textit{year} \mid \textit{month} \mid 1}$. This error is caused by our automatic translation. (Courtesy of Irv Bromberg, September 23, 2002.)

166. 3 Page 105, line −14: Change "begins after *date*" to "ends on or after *date*". (Courtesy of Arthur J. Roth, April 17, 2002.)

167. 2 Page 106, line 2: Change "(7.2)" to "(7.8)". This error is caused by our automatic translation; that translation needs to put the label definition in the TEX file for each function instead of it being placed manually after the command that inputs that file. (Courtesy of Arthur J. Roth, April 17, 2002.)

168. 2 Page 106, line 20: Change "Elul 30" to "Elul 29". (Courtesy of Arthur J. Roth, April 17, 2002.)

169. Page 107, line 1: Change "on the average" to "within thousands of years of the present". (Courtesy of Andrew Main, April 21, 2004.)

170. Page 107, equation (7.17): the "+1" is in the wrong place, separating the function name, **gregorian-year-from-fixed**, from its argument, **hebrew-epoch**. This error is caused by our automatic translation. (Courtesy of Irv Bromberg, September 22, 2002.)

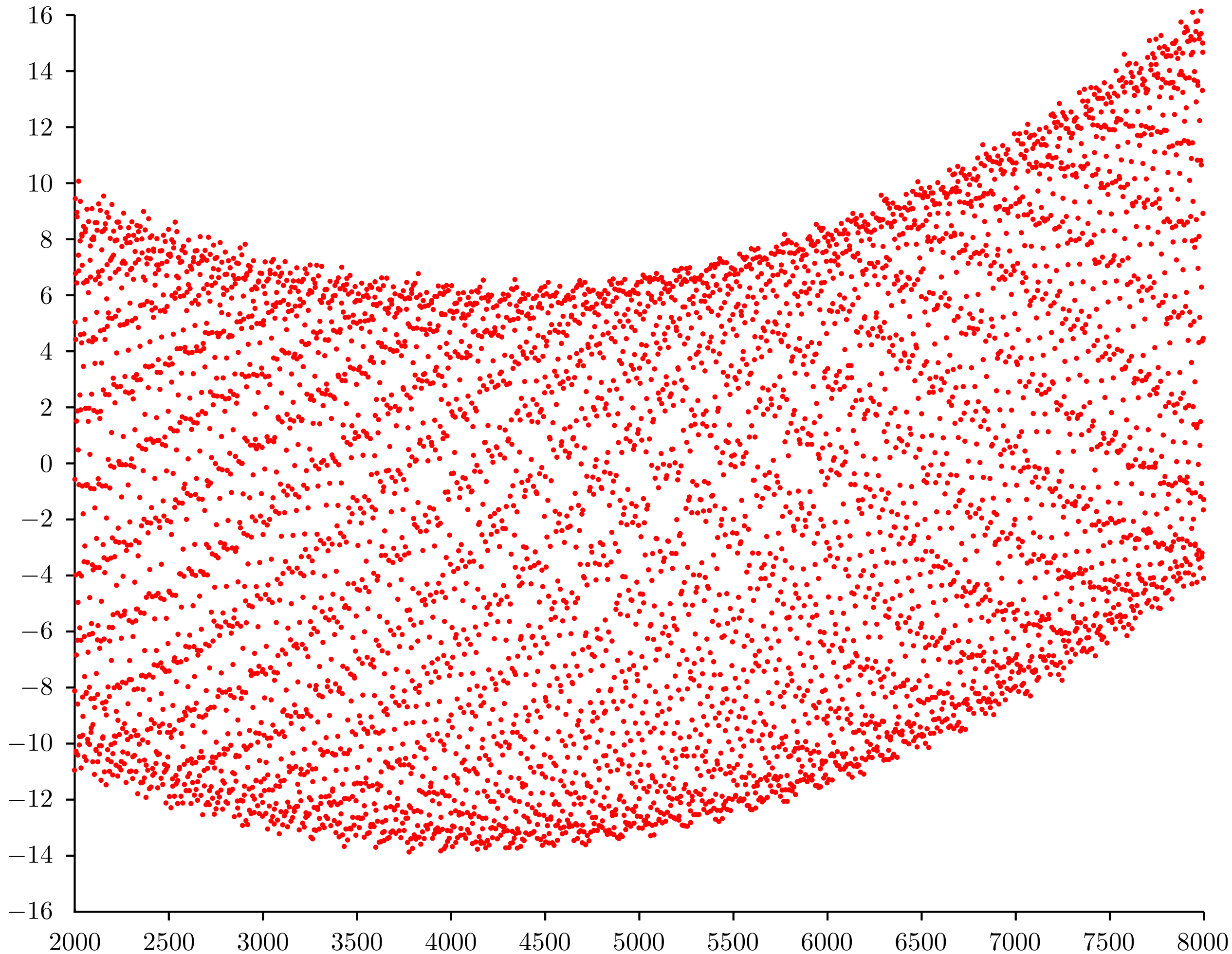

Figure 160-A: Molad of Nisan minus the actual moment of the new moon Jerusalem local time, in hours, for 2000–8000 A.H. (courtesy of Irv Bromberg).

171. (2) Page 107, line −9: Delete the spurious characters "The mi" after the word "these". (Courtesy of Michael R. Stein, August 7, 2001.)

172. Page 110, lines 5–6 and footnote: In Israel in 2001, Yom ha-Shoah was pushed forward from Friday to Thursday, but it was on Friday outside of Israel. It remains to be seen what will happen in future years.

173. (2) Page 110, line −5: Change "Hātūr" to "Athôr".

174. Page 110, last paragraph: We should mention that in Israel, *sh'ela* begins on Marḥeshvan 7.

175. Page 110, line 8: Add a footnote after "if it falls on Thursday or Friday." stating that in 2004, the Israeli government decided to postpone Yom ha-Zikkaron (as well as Israel Independence Day) by one day whenever Iyyar 4 falls on Sunday [*Ha'Aretz*, February 2, 2004].

176. (2) Page 111, line 5: Change "at 6 p.m. Wednesday evening, Baramhāt 30, 1641," to "at 6 p.m. on the eve of Wednesday, Paremotep 30, 1641,". (Courtesy of Robert H. Douglass, May 7, 2002.)

177. Page 111, **birkath-ha-hama**, equation (7.25): This function would be more consistent with other code (say, **omer**) if it returned either the date, when applicable, or **bogus** when not. Returning a list is peculiar since the event either occurs in a given year or does not. (Courtesy of Arthur J. Roth, April 17, 2002.)

178. Page 111, line −3: At the beginning of this line, add the sentence, "The birthday in an ordinary year of someone born during the first 29 days of Adar I in a leap year is on the corresponding day of Adar; in a leap year, the birthday occurs in Adar I, as expected." (Courtesy of Arthur J. Roth, April 17, 2002.)

179. Page 113, line 13: Change "normal anniversary" to "normal (that is, same month number) anniversary". (Courtesy of Arthur J. Roth, April 17, 2002.)

180. (3) Page 114, line 3: Change "anniversary in Adar I" to "anniversary of a common-year date in Adar I".

181. Page 115, reference [18]: The more complete reference is A. Spier, *The Comprehensive Hebrew Calendar: Its Structure, History, and One Hundred Years of Corresponding Dates: 5660–5760, 1900–2000*, Behrman House, New York, 1952. Revised 2nd edition published with the new subtitle *Up to the Twenty-Second Century 5703–5860, 1943–2100*, Feldheim Publishers, New York, 1981. Revised 3rd edition published with the new subtitle *Twentieth to Twenty-Second Centuries, 5660–5860, 1900–2100*, Feldheim Publishers, New York, 1986.

CHAPTER 8: THE ECCLESIASTICAL CALENDARS

182. Page 116, line 1 of the caption: Change "according the" to "according to the".

183. Chapter 8, opening quotation: It is from "The Synodal Letter" and can be found in Gelasius, *Historia Concilii Nicæni*, book II, chapter xxxiii. Our translation is from Fotheringham (our reference [1]), page 746 (see Erratum 113).

184. Chapter 8: Good discussions of the history of the setting of the date of Easter are given in *The Sun in the Church: Cathedrals as Solar Observatories*, J. L. Heilbron, Harvard University Press, Cambridge, MA, 1999 and in *Anno Domini*: *The Origins of the Christian Era*, Georges Declercq, Brepols Publishers, Turnhout, Belgium, 2000.

Our statement (on page 117) that the Council of Nicæa set the date of Easter as "The first Sunday after the first full moon occurring on or after the vernal equinox" is unjustified. The Council was concerned with uniformity across various Christian groups, as the opening chapter quote on page 117 suggests. Declercq puts it this way (page 52):

> The agreement reached at Nicaea did not solve the Paschal controversy. The Nicene fathers who were united in their rejection of Jewish practices, could not gain the same unanimity with regard to a definite and unequivocal method of calculating Easter... At the time of Nicaea, almost everyone in the official Church agreed to the definition that Easter was the first Sunday following the first full moon of spring.

In fact, the Julian rule for Easter was promulgated by Dionysius Exiguus and the Venerable Bede, who attributed it to the Council of Nicæa. (Courtesy of Michael H. Deckers, August 7, 2006.)

185. Chapter 8: Many historical details and references about Easter algorithms can be found in "Gauß and Beyond: The Making of Easter Algorithms," Reinhold Bien, *Archive for History of Exact Sciences*, **58**, 5 (July, 2004), 439–452.

186. Page 117, footnote: Change "Gauss's original paper contained an error" to "Gauss's original paper contained an error (which he later corrected)". (Courtesy of John Cross, February 6, 2002.)

187. Page 119, lines 2–3: The limiting dates for Orthodox Easter, March 22 and April 25, are Julian, not Gregorian. This is implicit in the use of **fixed-from-julian** in (8.1) at the bottom of the previous page, but we should have indicated it explicitly in the text. (Courtesy of Donald W. Fausett, March 21, 2002.)

188. (3) Page 119, lines 3–4: Change "never coincided... C.E." to "have not coincided since 783 C.E." (Courtesy of Robert H. Douglass, June 14, 2002.)

189. (2) Page 119, line 5: Change "and 4 days." to "and 5 days." (Courtesy of Winfried Görke, January 28, 2002.)

190. Page 119, line 6: Change "calender" to "calendar". (Courtesy of Nicholas J. Cox, January 16, 2006.)

191. Page 120, second bullet: We mention that the 1-day bias is said to have been deliberately introduced to minimize the coincidence of Easter with Passover. The concern that date of Passover would influence the date of Easter goes back to the earliest days of Christianity. For example, Eusebius (*Vita Constantini*, book iii, 18–20) gives a letter of the Emperor sent to those not present at the Council of Nicæa. Here are some extracts:

> When the question relative to the sacred festival of Easter arose... [i]t was declared to be particularly unworthy for this, the holiest of all festivals, to follow the custom of the Jews... We ought not, therefore, to have anything in common with the Jews... we desire, dearest brethren, to separate ourselves from the detestable company of the Jews, for it is truly shameful for us to hear them boast that without their direction we could not keep this feast. How can they be in the right, they who, after the death of the Saviour, have no longer been led by reason but by wild violence, as their delusion may urge them? They do not possess the truth in this Easter question... it would still be your duty not to tarnish your soul by communications with such wicked people.

(Courtesy of Tom Peters, September 14, 2005.)

Avoiding Passover was evident in the Gregorian reform of the Easter calculation. Canon 6 of the Gregorian calendar (`http://hermes.ulaval.ca/~sitrau/calgreg/canon6.html`) published in 1582 and probably written by Clavius, says so twice: in the last sentence of the first paragraph

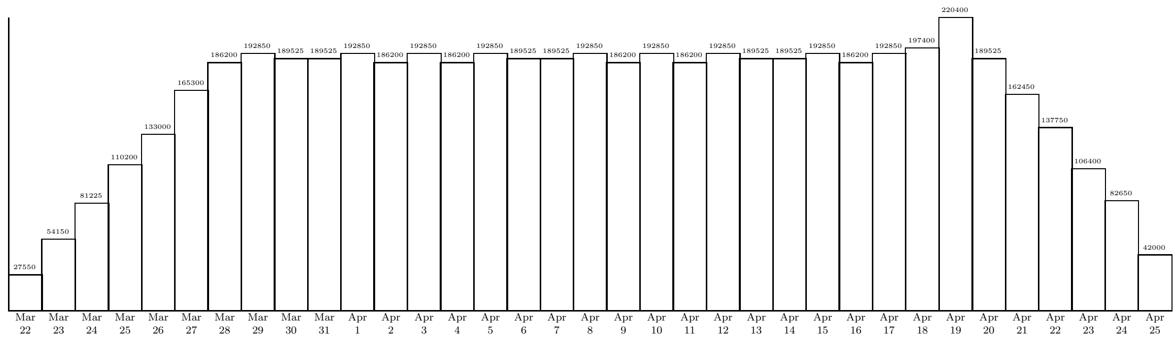

Figure 194-A: Distribution of Easter dates over the full 5,700,000-year cycle.

ne cum Iudaeis conveniamus, si forte dies XIV lunae caderet in diem dominicum

[so that we would not come together with the Jews if by chance day 14 of the moon may fall on a Sunday] and in the middle of the second paragraph

Ne igitur cum Iudaeis conveniamus, qui Pascha celebrant die XIV lunae,. . .

[Hence so that we would not come together with the Jews who celebrate Passover on day 14 of the moon,. . .] (Courtesy of Rodolphe Audette, September 13, 2005.) Thanks to Michael H. Deckers for the translations.

192. Page 120, line −1: Change "in the second half" to "in the second half (after year 10)". (Courtesy of Arthur J. Roth, April 17, 2002.)

193. Page 120, lines −14 to −17: O'Beirne [11, page 174] says that the originators of the Gregorian calendar "had chosen [their Easter calculation] to be wrong with the moon rather than be right with the Jews." (Courtesy of John Cross, February 6, 2002.)

194. Page 120, lines −1 to −10: We should have stated explicitly that April 19 is the most frequent date for Easter when the entire 5,700,000-year cycle is considered. The relative frequencies of the individual dates in the allowable range (March 22 through April 25) are given in Figure 194-A. (Courtesy of Irv Bromberg, August 31, 2004.) If we restrict ourselves to the years 1583–2099, the least frequent date of Easter is March 24 (only in 1799 and 1940), while the most frequent dates are April 11 and April 16 (22 times each). (Courtesy of Helmut Wildmann, August 1, 2005.).

195. Page 122, lines 4–5. The source of the Kepler quote "Easter is a feast, not a planet" (in German, "Ostern ist ein Fest vnd khein Stern") is an unpublished paper *Ein Gespräch von der Reformation des alten Kalenders worauff die Correctio Gregoriana gegründet*, written in German by Kepler in 1613; a Latin translation of this paper was published by M. G. Hansch as *Liber singularis de Calendario Gregoriano sive de reformatione Calendarii Juliani necessaria et de fundamentis atque ratione correctionis Gregorianae*, (Leipzig, 1726). The German text of this paper has only been published as the *Dialogus de Calendario Gregoriano* in the Frisch edition (1858–1871) of Kepler's collected works, *Joannis Kepleri Opera Omnia*, vol. 4 (1863), page 37. Kepler's paper is a dialogue between a "Mathematicus" (Kepler), two Catholics ("Confessarius" and "Cancellarius") and two Protestants ("Ecclesiastes" and "Syndicus") who argue the desirability of the Gregorian reform. Kepler, the imperial mathematician of Emperor Matthias, wrote this dialogue for the Emperor who wanted to be informed about this subject. Kepler was a proponent of the Gregorian calendar but he didn't care much about theological disputes and argued that the date of Easter, like other days of observance, should not depend on long and arduous

calculations such as are necessary for predicting the positions of the planets. (Courtesy of Robert H. van Gent, December 23, 2001.)

196. Page 122, line −10: Delete the comma after "Gras". (Courtesy of Nicholas J. Cox, January 16, 2006.)

*197. (2) Page 123: All the dates of "classical" Passover in Table 8.1 are off by at least one day (see Erratum 300). The replacement table is shown in Table 197-A.

198. Pages 123–124: The Beckwith reference should be put in place in the caption of Table 8.1. Also, the title of that reference omits the series in which it is published (*Arbeiten zur Geschichte des antiken Judentums und des Urchristentums*).

199. (2) Page 124, line 6: Change "Gregorian" to "Julian". (Courtesy of John Cross, April 15, 2002.)

CHAPTER 9: THE OLD HINDU CALENDARS

200. Chapter 9: Interesting quote from Dr. Murli Manohar Joshi, Indian Human Resources and Development Minister (in *The Irish Times*, Dublin, August 4, 2003; reproduced in *New Scientist*, August 9, 2003, page 8): "Scientists with advanced computers have sometimes failed to predict major earthquakes, but ancient Indian astrology does have the tools to roughly foretell the time and sometimes even the exact date and time of an earthquake."

201. (2) Page 131, **fixed-from-old-hindu-solar: The functions **fixed-from-old-hindu-solar** and **old-hindu-solar-from-fixed** are inconsistent when the mean sun enters a zodiacal sign exactly at sunrise (which happens on New Year every 576 years). To correct this, replace the floor operator in **fixed-from-old-hindu-solar** with ceiling and subtract 1 from its argument:

$$\textbf{fixed-from-old-hindu-solar}\left(\boxed{\mathit{year} \mid \mathit{month} \mid \mathit{day}}\right) \stackrel{\text{def}}{=} \left\lceil \textbf{hindu-epoch} + \mathit{year} \times \textbf{arya-solar-year} + (\mathit{month}-1) \times \textbf{arya-solar-month} + \mathit{day} - \tfrac{5}{4} \right\rceil \tag{9.7}$$

or in Lisp (page 345):

```
(defun fixed-from-old-hindu-solar (s-date)
  ;; TYPE hindu-solar-date -> fixed-date
  ;; Fixed date corresponding to Old Hindu solar date.
  (let* ((month (standard-month s-date))
         (day (standard-day s-date))
         (year (standard-year s-date)))
    (ceiling
     (+ hindu-epoch ; Since start of era.
        (* year arya-solar-year) ; Days in elapsed years
        (* (1- month) arya-solar-month) ; ...in months.
        day -5/4)))) ; Midnight of day.
```

(Courtesy of John Cross, March 18, 2002.)

Julian Year	Passover Eve		Easter Full Moon		
	Classical	Arithmetic	Orthodox	Gregorian	Proposed
9 C.E.	Saturday, March 30	Friday, March 29	Wednesday, March 27	Friday, March 29	Friday, March 29
10 C.E.	Friday, April 18	Wednesday, April 16	Tuesday, April 15	Thursday, April 17	Thursday, April 17
11 C.E.	Tuesday, April 7	Monday, April 6	Saturday, April 4	Monday, April 6	Monday, April 6
12 C.E.	Saturday, March 26	Friday, March 25	Thursday, March 24	Saturday, March 26	Saturday, March 26
13 C.E.	Friday, April 14	Friday, April 14	Wednesday, April 12	Friday, April 14	Friday, April 14
14 C.E.	Tuesday, April 3	Monday, April 2	Sunday, April 1	Tuesday, April 3	Wednesday, April 4
15 C.E.	Sunday, March 24	Friday, March 22	Thursday, March 21	Saturday, March 23	Sunday, March 24
16 C.E.	Saturday, April 11	Friday, April 10	Thursday, April 9	Saturday, April 11	Saturday, April 11
17 C.E.	Wednesday, March 31	Wednesday, March 31	Monday, March 29	Wednesday, March 31	Wednesday, March 31
18 C.E.	Tuesday, April 19	Saturday, March 19	Sunday, April 17	Tuesday, April 19	Monday, April 18
19 C.E.	Sunday, April 9	Friday, April 7	Wednesday, April 5	Friday, April 7	Saturday, April 8
20 C.E.	Thursday, March 28	Wednesday, March 27	Monday, March 25	Wednesday, March 27	Wednesday, March 27
21 C.E.	Wednesday, April 16	Monday, April 14	Sunday, April 13	Tuesday, April 15	Tuesday, April 15
22 C.E.	Sunday, April 5	Saturday, April 4	Thursday, April 2	Saturday, April 4	Sunday, April 5
23 C.E.	Thursday, March 25	Wednesday, March 24	Monday, March 22	Wednesday, March 24	Friday, March 26
24 C.E.	Wednesday, April 12	Wednesday, April 12	Monday, April 10	Wednesday, April 12	Wednesday, April 12
25 C.E.	Monday, April 2	Monday, April 2	Friday, March 30	Sunday, April 1	Sunday, April 1
26 C.E.	Friday, March 22	Friday, March 22	Thursday, April 18	Saturday, April 20	Saturday, April 20
27 C.E.	Thursday, April 10	Wednesday, April 9	Monday, April 7	Wednesday, April 9	Wednesday, April 9
28 C.E.	Tuesday, March 30	Monday, March 29	Saturday, March 27	Monday, March 29	Monday, March 29
29 C.E.	Sunday, April 17	Saturday, April 16	Friday, April 15	Sunday, April 17	Sunday, April 17
30 C.E.	Thursday, April 6	Wednesday, April 5	Tuesday, April 4	Thursday, April 6	Thursday, April 6
31 C.E.	Tuesday, March 27	Monday, March 26	Saturday, March 24	Monday, March 26	Tuesday, March 27
32 C.E.	Sunday, April 13	Monday, April 14	Saturday, April 12	Monday, April 14	Monday, April 14
33 C.E.	Friday, April 3	Friday, April 3	Wednesday, April 1	Friday, April 3	Friday, April 3
34 C.E.	Wednesday, March 24	Monday, March 22	Sunday, March 21	Tuesday, March 23	Tuesday, March 23
35 C.E.	Tuesday, April 12	Monday, April 11	Saturday, April 9	Monday, April 11	Monday, April 11
36 C.E.	Saturday, March 31	Friday, March 30	Thursday, March 29	Saturday, March 31	Friday, March 30
37 C.E.	Thursday, March 21	Wednesday, March 20	Wednesday, April 17	Friday, April 19	Thursday, April 18
38 C.E.	Tuesday, April 8	Monday, April 7	Saturday, April 5	Monday, April 7	Tuesday, April 8
39 C.E.	Saturday, March 28	Friday, March 27	Wednesday, March 25	Friday, March 27	Saturday, March 28
40 C.E.	Friday, April 15	Friday, April 15	Wednesday, April 13	Friday, April 15	Friday, April 15

Table 197-A: Replacement for Table 8.1 on page 123 (see Erratum 197).

**202. 2 Page 132, lines 5–6: Change "Subtracting 1/4 of a day from the resultant moment and taking the floor has this effect." to "Subtracting 5/4 of a day from the resultant moment and taking the ceiling has this effect."

203. Page 134, line −10: Change "about 0.98435 days or is somewhat shorter than a day." to read "about 0.98435 days, somewhat shorter than a full day."

204. 3 Page 136, line 2: Clarify by replacing "since the first" with "since the start of the first". (Courtesy of Svante Janson, July 2, 2003.)

*205. 3 Page 138–139, **fixed-from-old-hindu-lunar**: The functions **fixed-from-old-hindu-lunar** and **old-hindu-lunar-from-fixed** are inconsistent when a lunar day begins exactly at sunrise (which happens in 13,000 years). To correct this, replace the floor operator in **fixed-from-old-hindu-solar** [equation (9.14)] with ceiling and replace "+3/4" with "−1/4":

$$\textbf{fixed-from-old-hindu-lunar}\left(\boxed{\,year \mid month \mid leap \mid day\,}\right) \stackrel{\text{def}}{=} \left\lceil \textbf{hindu-epoch} + \mathit{lunar\text{-}new\text{-}year} + \textbf{arya-lunar-month} \times \begin{cases} month & \textbf{if } \text{not } leap \text{ and } \left\lceil \dfrac{\mathit{lunar\text{-}new\text{-}year} - mina}{\textbf{arya-solar-month} - \textbf{arya-lunar-month}} \right\rceil \le month \\ month - 1 & \textbf{otherwise} \end{cases} + (day - 1) \times \textbf{arya-lunar-day} - \frac{1}{4} \right\rceil \tag{9.14}$$

where

$$mina = (12 \times year - 1) \times \textbf{arya-solar-month}$$

$$\mathit{lunar\text{-}new\text{-}year} = \textbf{arya-lunar-month} \times \left(\left\lfloor \frac{mina}{\textbf{arya-lunar-month}} \right\rfloor + 1 \right)$$

or in Lisp (page 346):

```
(defun fixed-from-old-hindu-lunar (l-date)
   ;; TYPE old-hindu-lunar-date -> fixed-date
   ;; Fixed date corresponding to Old Hindu lunar date.
   (let* ((year (old-hindu-lunar-year l-date))
          (month (old-hindu-lunar-month l-date))
          (leap (old-hindu-lunar-leap l-date))
          (day (old-hindu-lunar-day l-date))
```

```
            (mina ; One solar month before solar new year.
             (* (1- (* 12 year)) arya-solar-month))
            (lunar-new-year ; New moon after mina.
             (* arya-lunar-month
                (1+ (quotient mina arya-lunar-month)))))
       (ceiling
        (+ hindu-epoch
           lunar-new-year
           (* arya-lunar-month
              (if ; If there was a leap month this year.
                  (and (not leap)
                       (<= (ceiling (/ (- lunar-new-year mina)
                                       (- arya-solar-month
                                          arya-lunar-month)))
                           month))
                  month
                (1- month)))
           (* (1- day) arya-lunar-day) ; Lunar days.
           -1/4)))) ; Subtract 1 if phase begins before sunrise.
```

(Courtesy of Svante Janson, July 2, 2003.)

*206. (3) Page 139, line 5: Change "We add 3/4 before taking the floor because..." to "We subtract 1/4 before taking the ceiling because...". (Courtesy of Svante Janson, July 2, 2003.)

*207. (2) Page 138, line 2 of **fixed-from-old-hindu-lunar**: The boxed date should read [*year* | *month* | *leap* | *day*]. This is an error in the automatic translation. (Courtesy of Peter Zilahy Ingerman, February 16, 2002.)

CHAPTER 10: THE MAYAN CALENDARS

208. (3) Page 140, line 1 of the caption: Capitalize "new year".

209. Pages 141–143: Floyd G. Lounsbury's paper "A Derivation of the Mayan-to-Julian Calendar Correlation from the Dresden Codex Venus Chronology," pp. 184–206 in *The Sky in Mayan Literature,* A. F. Aveni, ed., Oxford University Press, Oxford, 1992 is a fine example of the "astroarcheological" method of determining the correspondence between the Mayan calendars and Western calendars. It discusses the sources of the the two main contenders, JD 584,283 and JD 584,285. (Courtesy of Michael H. Deckers, August 7, 2006.)

210. Page 142, top: The book *The Book of the Year*: *Middle American Calendrical Systems* by Munro S. Edmundson (University of Utah Press, Salt Lake City, Utah, 1988) contains extensive discussions of the regional variations of the calendars of Mesoamerica. However, its correlations are considered speculative, not authoritative. Another good source is Linton Satterthwaite's article "Calendarics of the Maya Lowlands," chapter 24 (pages 603–631) of *Handbook of Middle American Indians* (Robert Wauchope, general editor), volume 3, part 2 (Gordon R. Willey, volume editor), University of Texas Press, Austin, Texas, 1965. Susan Milbrath's *Star Gods of the Maya*: *Astronomy in Art, Folklore, and Calendars*, University of Texas Press, Austin, Texas, 1999, is yet another good source.

211. Page 142, last line before the footnote: Change "Wednesday" to "Monday".

212. Page 143, footnote 3: Give as a reference F. G. Lounsbury, "A Derivation of the Mayan-to-Julian Calendar Correlation from the Dresden Codex Venus Chronology," in *The Sky in Mayan Literature*, edited by Anthony F. Aveni, pp. 184–206, Oxford University Press, New York (1992). (Courtesy of Michael H. Deckers, August 7, 2006.)

213. Page 144, bottom: The translation of the haab "month" names as given by Edmundson (page 248) are:

(1) Pop (Mat)	(7) Yaxkin (Green time)	(13) Mac (Cover)
(2) Uo (Frog)	(8) Mol (Gather)	(14) Kankin (Yellow time)
(3) Zip (Stag)	(9) Chen (Well)	(15) Muan (Owl)
(4) Zotz (Bat)	(10) Yax (Green)	(16) Pax (Drum)
(5) Tzec (Skull)	(11) Zac (white)	(17) Kayab (Turtle)
(6) Xul (End)	(12) Ceh (Deer)	(18) Cumku (Dark god)
		(19) Uayeb

214. Page 146, bottom: According to Milbrath's *Star Gods of the Maya* (page 2), "The 260-day [tzolkin] calendar was used to prognosticate human destiny according to the day of birth and to predict the appropriate days for the planting cycle. This ritual calendar survives today among the Quiché of Guatemala... [who] explain that the calendar corresponds to the human gestation period... [and] approximates the length of the agricultural calendar. ... Indeed, it is possible that the 260-day agricultural cycle and the cycle of human gestation were linked together at an earlier time, and that the two cycles were used to develop the unique 260-day calendar."

215. Page 146, bottom: The translation of the tzolkin day names as given by Edmundson (page 247) are:

(1) Imix (Alligator)	(6) Cimi (Death)	(11) Chuen(Monkey)	(16) Cib (Owl)
(2) Ik (Wind)	(7) Manik (Deer)	(12) Eb (Tooth)	(17) Caban (Quake)
(3) Akbal (Night)	(8) Lamat (Rabbit)	(13) Ben (Cane)	(18) Etznab (Flint)
(4) Kan (Iguana)	(9) Muluc (Rain)	(14) Ix (Jaguar)	(19) Cauac (Storm)
(5) Chicchan (Serpent)	(10) Oc (Foot)	(15) Men (Eagle)	(20) Ahau (Lord)

216. Page 149, after first paragraph: The Mayans referred to haab years by their "yearbearer," a name similar to the Aztec xiuhmolpilli (see Erratum217). The yearbearer of a haab year is the tzolkin day name of the first day of that haab year, 0 Pop (this is the Tikal custom; some scholars aver and some data is consistent rather with the tzolkin name of the last day of the previous year). Because the haab year is 365 days and the tzolkin is 260, only tzolkin day names Ik, Manik, Eb, and Caban can occur as yearbears in this scheme. The yearbearer for a given R.D. date is computed by

$$\textbf{mayan-yearbearer-from-fixed}\,(date) \stackrel{\text{def}}{=} \qquad \text{(216-A)}$$

$$\begin{cases} \textbf{bogus} & \textbf{if mayan-haab-from-fixed}\,(date)_{\textbf{month}} = 19 \\ \textbf{mayan-tzolkin-from-fixed}\,(x)_{\textbf{name}} & \textbf{otherwise} \end{cases}$$

where

$$x = \textbf{mayan-haab-on-or-before}\left(\boxed{1 \mid 0}, date + 364\right)$$

or, in Lisp,

```
(defun mayan-yearbearer-from-fixed (date)
  ;; TYPE fixed-date -> mayan-tzolkin-name
  ;; Year bearer of year containing fixed date.
  (let* ((x (mayan-haab-on-or-before
             (mayan-haab-date 1 0)
             (+ date 364))))
    (if (= (mayan-haab-month (mayan-haab-from-fixed date))
           19)
        bogus
      (mayan-tzolkin-name (mayan-tzolkin-from-fixed x)))))
```

217. Page 150: Add the following discussion of the Aztec calendar which is based on Alfonso Caso's article "Calendrical Systems of Central Mexico," chapter 13 (pages 333–348) of *Handbook of Middle American Indians* (Robert Wauchope, general editor), volume 10, part 1 (Gordon F. Ekholm and Ignacio Bernal, volume editors), University of Texas Press, Austin, Texas, 1971 and Kay Read's *Time and Sacrifice in the Aztec Cosmos*, Indiana University Press, Bloomington Indiana, 1998. Thanks to Anthony Aveni, Gordon Brotherson, Susan Milbrath, and Kay A. Read for their help.

A good quote for this material is "The import of calendrics for Mesoamerican culture cannot be overstated." This is from Read's book (top of page 11).

The Aztecs (more properly called Mexica-Tenochca) used two calendars, the *xihuitl* which is nearly identical in to the Mayan haab and the *tonalpohualli* which is akin to the Mayan tzolkin; in both cases the names are in Nahuatl, however. There are many idiosyncrasies in the Aztec calendar (associating dates, days, or years with colors, directions, patrons, auspiciousness, and so on), but these are computationally trivial and we ignore them.

The precise correlation between Aztec dates and our R.D. dates is based on the recorded Aztec dates of the fall of (what later became) Mexico City to Hernán Cortés, August 13, 1521 (Julian). Thus we define

$$\textbf{aztec-correlation} \stackrel{\text{def}}{=} \qquad \text{(217-A)}$$

$$\textbf{fixed-from-julian}\left(\boxed{1521 \mid \textbf{august} \mid 13}\right)$$

which was R.D. 555,403.

The xihuitl calendar approximated the solar year; like the Mayan haab, it was 365 days long, broken down into 18 "months" of 20 days each, followed by 5 unnamed worthless days called *nemontemi*. Scholars believe that the Aztecs used intercalation on the xihuitl calendar to keep it synchronized with the solar seasons, but the details of how they added days is a matter of speculation. The Aztec names of the months are:

(1) Izcalli (Resurrection)
(2) Atlcahualo (They leave the water)
(3) Tlacaxipehualiztli (Flaying of men)
(4) Tozoztontli (Short watch)
(5) Hueytozoztli (Long watch)
(6) Toxcatl (Dry thing)
(7) Etzalcualiztli (Meal of maize and beans)
(8) Tecuilhuitontli (Small feast of the Lords)
(9) Hueytecuilhuitl (Great feast of the Lords)
(10) Tlaxochimaco (Flowers are given)
(11) Xocotlhuetzi (The fruit falls)
(12) Ochpaniztli (Sweeping)
(13) Teotleco (Arrival of the gods)
(14) Tepeilhuitl (Feast of the mountains)
(15) Quecholli (Flamingo)
(16) Panquetzaliztli (Raising of the flags)
(17) Atemoztli (The water falls)
(18) Tititl (Shrunken)
(19) Nemontemi

But, while in the Mayan haab the day count is of elapsed days (that is, goes from 0 to 19), the xihuitl day count goes from 1 to 20. Thus we represent a xihuitl date as a pair

$$\boxed{\textit{month} \mid \textit{day}},$$

where *month* and *day* are integers in the ranges 1 to 19 and 1 to 20, respectively, and we treat the nemontemi as a defective nineteenth month. We can count the number of elapsed days into cycle of Aztec xihuitl date as follows:

$$\textbf{aztec-xihuitl-ordinal}\,(\textit{x-date}) \stackrel{\text{def}}{=} \tag{217-B}$$

$$(\textit{month} - 1) \times 20 + \textit{day} - 1$$

where

$$\textit{day} = \textbf{aztec-xihuitl-day}\,(\textit{x-date})$$

$$\textit{month} = \textbf{aztec-xihuitl-month}\,(\textit{x-date})$$

The only difference from the haab computation is the subtraction of 1 from the day to compensate for the shift in range.

According to Table 3 in Caso, the xihuitl date at the correlation point is 2 Xocotlhuetzi, so we define

$$\textbf{aztec-xihuitl-epoch} \stackrel{\text{def}}{=} \tag{217-C}$$

$$\textbf{aztec-correlation} - \textbf{aztec-xihuitl-ordinal}\,(\textbf{aztec-xihuitl-date}\,(11, 2))$$

Then we can compute the xihuitl date of an R.D. by

$$\textbf{aztec-xihuitl-from-fixed}\,(\textit{date}) \stackrel{\text{def}}{=} \tag{217-D}$$

$$\textbf{aztec-xihuitl-date}\,(\textit{month}, \textit{day})$$

where

$$\textit{count} = (\textit{date} - \textbf{aztec-xihuitl-epoch}) \bmod 365$$

$$\textit{day} = (\textit{count} \bmod 20) + 1$$

$$\textit{month} = \left\lfloor \frac{\textit{count}}{20} \right\rfloor + 1$$

Again, the only difference from the haab computation is the addition of 1 to the day to compensate for the shift in range.

As with the Mayan haab, because there is no count of the cycles we cannot invert this function and find the R.D. of a xihuitl date, but we can use (1.42) to find the R.D. of the xihuitl date on or before a given R.D.:

$$\textbf{aztec-xihuitl-on-or-before}\,(\mathit{xihuitl}, \mathit{date}) \stackrel{\text{def}}{=} \tag{217-E}$$

$$\mathit{date} - \big(\,\big(\,\mathit{date} - \textbf{aztec-xihuitl-epoch} - \textbf{aztec-xihuitl-ordinal}\,(\mathit{xihuitl})\,\big) \bmod 365\,\big)$$

The Aztec tonalpohualli (divinatory) calendar is, except for the names in the cycle of days, identical to that of the Mayan tzolkin: two simultaneous cycles run, a 13-day count and a cycle of 20 names:

(1) Cipachtli (Alligator)	(6) Miquizitli (Death)	(11) Ozomatli (Monkey)	(16) Cozcacuauhtli(Buzzard)
(2) Ehecatl (Wind)	(7) Mazatl (Deer)	(12) Malinalli (Grass)	(17) Olin (Movement)
(3) Calli (House)	(8) Tochtli (Rabbit)	(13) Acatl (Reed)	(18) Tecpatl (Flint)
(4) Cuetzpalin (Lizard)	(9) Atl (Water)	(14) Ocelotl (Jaguar)	(19) Quiahuitl (Rain)
(5) Coatl (Snake)	(10) Itzcuintli (Dog)	(15) Cuauhtli (Eagle)	(20) Xochitl (Flower)

The implementation is identical to the Mayan tzolkin; we represent tonalpohualli dates as

number	*name*

,

where *number* and *name* are integers in the ranges 1 to 13 and 1 to 20, respectively, and we compute the ordinal number in the cycle of a given tonalpohualli date by:

$$\textbf{aztec-tonalpohualli-ordinal}\,(\mathit{t\text{-}date}) \stackrel{\text{def}}{=} \tag{217-F}$$

$$(\mathit{number} - 1 + 39 \times (\mathit{number} - \mathit{name})) \bmod 260$$

where

$$\mathit{number} = \textbf{aztec-tonalpohualli-number}\,(\mathit{t\text{-}date})$$

$$\mathit{name} = \textbf{aztec-tonalpohualli-name}\,(\mathit{t\text{-}date})$$

The date at the correlation is 1 Coatl, according to Table 3 of Caso:

$$\textbf{aztec-tonalpohualli-epoch} \stackrel{\text{def}}{=} \tag{217-G}$$

$$\textbf{aztec-correlation} - \textbf{aztec-tonalpohualli-ordinal}\,(\textbf{aztec-tonalpohualli-date}\,(1, 5))$$

Mimicking our tzolkin conversions we have:

$$\textbf{aztec-tonalpohualli-from-fixed}\,(\mathit{date}) \stackrel{\text{def}}{=} \tag{217-H}$$

$$\textbf{aztec-tonalpohualli-date}\,(\mathit{number}, \mathit{name})$$

where

$$\begin{aligned}
\mathit{count} &= \mathit{date} - \textbf{aztec-tonalpohualli-epoch} + 1 \\
\mathit{number} &= \mathit{count} \ \text{amod}\ 13 \\
\mathit{name} &= \mathit{count} \ \text{amod}\ 20
\end{aligned}$$

$$\textbf{aztec-tonalpohualli-on-or-before}\,(\mathit{tonalpohualli}, \mathit{date}) \stackrel{\text{def}}{=} \tag{217-I}$$

$$\mathit{date} - \Big(\big(\mathit{date} - \textbf{aztec-tonalpohualli-epoch} - \textbf{aztec-tonalpohualli-ordinal}\,(\mathit{tonalpohualli})\big) \bmod 260\Big)$$

According to Caso and Read, the Aztec, like the Maya, used "calendar rounds" or "centuries" of 52 xihuitl years—the time it takes for the xihuitl and tonalpohualli to realign; these were called *xiuhmolpilli*. The 52 xihuitl years of a calendar round were designated by names and numbers using four of the twenty tonalpohualli day signs, Acatl, Tecpatl, Calli, and Tochtli (similar to the "yearbearer" of the Mayan calendar) and numbers 1 through 13. Thus we represent xiuhmolpilli designations as

number	*name*

,

where *number* is an integer in the range 1 to 13 and *name* is an integer 3, 8, 13, or 18. The xihuitl year designation was taken from the tonalpohualli date of the last day of that xihuitl year (excluding the nemontemi, of course). The name of the xihuitl year containing a given R.D. is thus given by

$$\textbf{aztec-xiuhmolpilli-from-fixed}\,(\mathit{date}) \stackrel{\text{def}}{=} \tag{217-J}$$

$$\begin{cases} \textbf{bogus} & \textbf{if aztec-xihuitl-month}\,(\textbf{aztec-xihuitl-from-fixed}\,(\mathit{date})) = 19 \\ \textbf{aztec-tonalpohualli-from-fixed}\,(x) & \textbf{otherwise} \end{cases}$$

where

$$x = \textbf{aztec-xihuitl-on-or-before}\,(\textbf{aztec-xihuitl-date}\,(18, 20), \mathit{date} + 364)$$

This returns **bogus** for the nemontemi.

We can determine the combination of xihuitl and tonalpohualli dates on or before an R.D. by using (1.52):

$$\textbf{aztec-xihuitl-tonalpohualli-on-or-before}\,(\mathit{xihuitl}, \mathit{tonalpohualli}, \mathit{date}) \stackrel{\text{def}}{=} \tag{217-K}$$

$$\begin{cases} date - ((date - \textit{xihuitl-count} - 365 \times \textit{diff}) \bmod 18980) & \textbf{if } (\textit{diff} \bmod 5) = 0 \\ \textbf{bogus} & \textbf{otherwise} \end{cases}$$

where

$$\textit{xihuitl-count} = \textbf{aztec-xihuitl-ordinal}(\textit{xihuitl}) + \textbf{aztec-xihuitl-epoch}$$

$$\textit{tonalpohualli-count} = \textbf{aztec-tonalpohualli-ordinal}(\textit{tonalpohualli}) + \textbf{aztec-tonalpohualli-epoch}$$

$$\textit{diff} = \textit{tonalpohualli-count} - \textit{xihuitl-count}$$

The Lisp code for the Aztec calendar is thus

```
(defun aztec-xihuitl-date (month day)
  ;; TYPE (aztec-xihuitl-month aztec-xihuitl-day) ->
  ;; TYPE aztec-xihuitl-date
  (list month day))
```

```
(defun aztec-xihuitl-month (date)
  ;; TYPE aztec-xihuitl-date -> aztec-xihuitl-month
  (first date))
```

```
(defun aztec-xihuitl-day (date)
  ;; TYPE aztec-xihuitl-date -> aztec-xihuitl-day
  (second date))
```

```
(defun aztec-xihuitl-ordinal (x-date)
  ;; TYPE aztec-xihuitl-date -> nonnegative-integer
  ;; Number of elapsed days into cycle of Aztec xihuitl x-date.
  (let* ((day (aztec-xihuitl-day x-date))
         (month (aztec-xihuitl-month x-date)))
    (+ (* (1- month) 20) (1- day))))
```

```
(defun aztec-xihuitl-from-fixed (date)
  ;; TYPE fixed-date -> aztec-xihuitl-date
  ;; Aztec xihuitl date of fixed date.
  (let* ((count (mod (- date aztec-xihuitl-epoch) 365))
         (day (1+ (mod count 20)))
         (month (1+ (quotient count 20))))
    (aztec-xihuitl-date month day)))
```

```
(defun aztec-xihuitl-on-or-before (xihuitl date)
  ;; TYPE (aztec-xihuitl-date fixed-date) -> fixed-date
  ;; Fixed date of latest date on or before fixed date
  ;; that is Aztec xihuitl date xihuitl.
  (- date
     (mod (- date aztec-xihuitl-epoch
             (aztec-xihuitl-ordinal xihuitl))
          365)))
```

```
(defun aztec-tonalpohualli-date (number name)
  ;; TYPE (aztec-tonalpohualli-number aztec-tonalpohualli-name)
  ;; TYPE -> aztec-tonalpohualli-date
  (list number name))
```

```
(defun aztec-tonalpohualli-number (date)
  ;; TYPE aztec-tonalpohualli-date -> aztec-tonalpohualli-number
  (first date))
```

```
(defun aztec-tonalpohualli-name (date)
  ;; TYPE aztec-tonalpohualli-date -> aztec-tonalpohualli-name
  (second date))
```

```
(defun aztec-tonalpohualli-ordinal (t-date)
  ;; TYPE aztec-tonalpohualli-date -> nonnegative-integer
  ;; Number of days into Aztec tonalpohualli cycle of t-date.
  (let* ((number (aztec-tonalpohualli-number t-date))
         (name (aztec-tonalpohualli-name t-date)))
    (mod (+ number -1
            (* 39 (- number name)))
         260)))
```

```
(defun aztec-tonalpohualli-from-fixed (date)
  ;; TYPE fixed-date -> aztec-tonalpohualli-date
  ;; Aztec tonalpohualli date of fixed date.
  (let* ((count (- date aztec-tonalpohualli-epoch -1))
         (number (adjusted-mod count 13))
         (name (adjusted-mod count 20)))
    (aztec-tonalpohualli-date number name)))
```

```
(defun aztec-tonalpohualli-on-or-before (tonalpohualli date)
  ;; TYPE (aztec-tonalpohualli-date fixed-date) -> fixed-date
  ;; Fixed date of latest date on or before fixed date
  ;; that is Aztec tonalpohualli date tonalpohualli.
  (- date
     (mod (- date
             aztec-tonalpohualli-epoch
             (aztec-tonalpohualli-ordinal tonalpohualli))
          260)))
```

```
(defun aztec-xiuhmolpilli-designation (number name)
  ;; TYPE (aztec-xiuhmolpilli-number aztec-xiuhmolpilli-name)
  ;; TYPE -> aztec-xiuhmolpilli-designation
  (list number name))
```

```
(defun aztec-xiuhmolpilli-number (date)
  ;; TYPE aztec-xiuhmolpilli-designation
  ;; TYPE -> aztec-xiuhmolpilli-number
  (first date))
```

```
(defun aztec-xiuhmolpilli-name (date)
  ;; TYPE aztec-xiuhmolpilli-designation
  ;; TYPE -> aztec-xiuhmolpilli-name
  (second date))
```

```
(defun aztec-xiuhmolpilli-from-fixed (date)
  ;; TYPE fixed-date -> aztec-xiuhmolpilli-designation
  ;; Designation of year containing fixed date.
  (let* ((x (aztec-xihuitl-on-or-before
             (aztec-xihuitl-date 18 20)
             (+ date 364))))
    (if (= (aztec-xihuitl-month (aztec-xihuitl-from-fixed date))
           19)
        bogus
      (aztec-tonalpohualli-from-fixed x))))
```

```
(defun aztec-xihuitl-tonalpohualli-on-or-before
  (xihuitl tonalpohualli date)
  ;; TYPE (aztec-xihuitl-date aztec-tonalpohualli-date
  ;; TYPE fixed-date) -> fixed-date
  ;; Fixed date of latest xihuitl-tonalpohualli combination
  ;; on or before date.  That is the date on or before
  ;; date that is Aztec xihuitl date xihuitl and
  ;; tonalpohualli date tonalpohualli.
  (let* ((xihuitl-count
          (+ (aztec-xihuitl-ordinal xihuitl) aztec-xihuitl-epoch))
         (tonalpohualli-count
          (+ (aztec-tonalpohualli-ordinal tonalpohualli)
             aztec-tonalpohualli-epoch))
         (diff (- tonalpohualli-count xihuitl-count)))
    (if (= (mod diff 5) 0)
        (- date
           (mod (- date xihuitl-count (* 365 diff))
                18980))
      bogus)));  xihuitl-tonalpohualli combination is impossible.
```

218. (3) Page 150, line 2 of reference [5]: Change "*Bibliography*" to "*Biography*". (Courtesy of Helmer Aslaksen, February 14, 2002.)

CHAPTER 11: THE BALINESE PAWUKON CALENDAR

219. Page 152, lines 3–5 of the caption: Put "Reproduced. . . 1991." in parentheses.

220. 2 Page 155, bottom line of column 2: Change "Pept" to "Pepet".

221. 2 Page 156: There is a spurious "5" above the word "Redite" at the top of the first column. (Courtesy of John Cross, January 25, 2002.)

222. Page 158: The calculation of **bali-pancawara-from-fixed** can be slightly simplified:

$$\textbf{bali-pancawara-from-fixed}\,(\mathit{date}) \stackrel{\text{def}}{=} \tag{11.7}$$

$$(\textbf{bali-day-from-fixed}\,(\mathit{date}) + 2) \quad \text{amod} \quad 5$$

or in Lisp (page 351):

```
(defun bali-pancawara-from-fixed (date)
  ;; TYPE fixed-date -> 1-5
  ;; Position of date in 5-day Balinese cycle.
  (adjusted-mod (+ (bali-day-from-fixed date) 2) 5))
```

223. 2 Page 158, line −2 above the footnote: Change "(*ekiwara*)" to "(*ekawara*)". (Courtesy of Jonathan Leffler, April 8, 2002.)

224. Page 161, line 1: After "cycle" add "($1 \le n \le c$)".

225. Page 161, line 2: The "analogue of formula (1.42)" is formula (70-A) in Erratum 70. (Courtesy of Svante Janson, May 16, 2003.)

226. Page 161, line 9: Replace line with "Here $\Delta + 1$ is congruent modulo c to the position of R.D. 0 in a cycle $1, 2, \ldots, c$."

CHAPTER 12: TIME AND ASTRONOMY

227. Good quote:

> For of Meridians, and Parallels,
> Man hath weav'd out a net, and this net throwne
> Upon the Heavens, and now they are his owne.

John Donne, *Poetical Works*, page 215.

228. Good quote:

> Esa trama de tiempos que se aproximan, se bifurcan, se cortan o que secularmente se ignoran, abarca *todas* la posibilidades. No existimos en la mayoría de esos tiempos. . .
>
> [This web of time—the strands of which approach one another, bifurcate, intersect or ignore each other through the centuries—embraces every possibility. We do not exist in most of them. . .]

Jorge Luis Borges, in the essay “El jardín de senderos que se bifurcan”, 1941.

229. Page 166, **urbana**: Here and elsewhere the “m” indicating meters should be roman, not italic. This is an error in the automatic translation. (Courtesy of Nicholas J. Cox, January 16, 2006.)

230. Page 166, last line: The correct page in [13] is 93; it was page 89 in the first edition of [13]. (Courtesy of Helmer Aslaksen, November 13, 2001.)

231. Page 167, line 2: Add Greenwich as a second example:

greenwich $\stackrel{\text{def}}{=}$ (231-A)

$51.477783°$	$0°$	$46.9m$	0

(Courtesy of Irv Bromberg, January 3, 2004.)

232. Page 167: Another interesting location is the Canadian Forces Station (CFS) Alert, Nunavut:

cfs-alert $\stackrel{\text{def}}{=}$ (232-A)

$82°30'$	$62°19'$	$0m$	-5

This location, the northernmost settled point in the western hemisphere, is useful for checking that functions return **bogus** appropriately instead of generating run-time errors. By longitude it ought to be time zone -4, but they use the Eastern Time, zone-5, because they are the eastern tip of Ellesmere Island and want to be in the same time zone as the bulk of the Territory of Nunavut; because they are commanded from Ottawa, they want to be in the same time zone as Ottawa. (Courtesy of Irv Bromberg, June 16, 2004.)

233. (3) Page 167, formula (12.2): Change this definition to

mecca $\stackrel{\text{def}}{=}$ (12.2)

$21°25'24''$	$39°49'24''$	$298m$	3

See also Errata 399 and 414. (Courtesy of Robert A. Saunders, April 8, 2003.)

234. Page 167, formula (12.4): The “mod 360” in **direction** is superfluous. The Lisp function `direction`, page 354, lines 18–22, should also have the `mod` function removed.

235. Page 167, formula (12.4): Note that imperfect arithmetic accuracy can result in meaningless values of **direction** when *locale* and *focus* are nearly coincident or antipodal. To preclude illegal division by zero, we first check the value of the denominator. (Courtesy of Irv Bromberg, January 3, 2004.)

236. Page 167, formulas (12.4), first line: The “0” should have a degree symbol. This change requires addition of a call to `deg` to **direction** on page 354. There are numerous similar missing degree symbols! (Courtesy of John Cross, February 12, 2002.)

237. Page 167, formula (12.5): We should replace the two-argument function **arctan-degrees** to give the arctangent of the angle made by the x-axis and the line connecting $(0, 0)$ to (a, b):

$$\textbf{arctan}_2\,(a, b) \stackrel{\text{def}}{=} \left\{ \begin{array}{ll} \alpha & \textbf{if } b \geq 0 \\ \alpha + 180^\circ & \textbf{otherwise} \end{array} \right\} \bmod 360 \qquad \text{(237-A)}$$

where

$$x = \frac{a}{b}$$

$$\alpha = \arctan x$$

or in Lisp,

```
(defun arctan2 (A B)
   (let* ((x (/ A B))
          (alpha (radians-to-degrees (atan x))))
     (mod (if (>= B 0)
              alpha
            (+ alpha (deg 180l0)))
          360)))
```

This would simplify the three places where the arctangent function is used, **direction** (page 167), **lunar-altitude** (page 196), and **asr** (page 203).

238. Section 12.2: Include the map of world time zones from H. M. Nautical Almanac Office (as in *Calendrical Tabulations: 1900–2200*). Perhaps mention `http://www.twinsun.com/tz/tz-link.htm` as a resource for time zones and the use of daylight saving time.

239. Page 169, lines 10–11: Clarify by changing the parenthetical comment "(except…mid-year)" to read "(except that we insert all leap seconds at the end of the year)".

240. Page 169: The history of time measurement and time zones in the United States is discussed at length in *Keeping Watch*: *A History of American Time*, Michael O'Malley, Viking, New York, 1990.

241. Page 170, middle: Add a function to compute the local mean time zone from the longitude:

$$\textbf{zone-from-longitude}\,(l) \stackrel{\text{def}}{=} l \times \frac{24}{360} \qquad \text{(241-A)}$$

or in Lisp:

```
(defun zone-from-longitude (l)
  ;; TYPE angle -> interval
  ;; Difference between UT and local mean time at longitude l.
  (* l 24/360))
```

242. (2) Page 170, line −16: Change "is added" to "is subtracted". (Courtesy of John Cross, February 8, 2002.)

243. Page 170, line −16: Delete the comma. (Courtesy of Nicholas J. Cox, January 16, 2006.)

244. Page 170, line −10: Change "(that is, steadily changing)" to "(that is, non-periodic)". (Courtesy of Michael H. Deckers, August 7, 2006.)

245. Page 170, line −3: Clarify the parenthetical comment "(usually. . . January 1)" to read "(leap seconds have been added either between June 30 and July 1 or between December 31 and January 1)". (Courtesy of Richard M. Koolish, November 27, 2001.)

*246. (2) Page 171, **ephemeris-correction**: This function is not right for the range of years 1700–1799. It's unclear where this approximation came from, but it is nonsense. John Cross suggests

$$\textbf{ephemeris-correction}(t) \stackrel{\text{def}}{=} \tag{12.12}$$

$$\begin{cases} \dfrac{\mathit{year} - 1933}{24 \times 60 \times 60} & \textbf{if } 1988 \le \mathit{year} \le 2019 \\ -0.00002 + 0.000297 \times c + 0.025184 \times c^2 - \\ 0.181133 \times c^3 + 0.553040 \times c^4 - 0.861938 \times c^5 + \\ 0.677066 \times c^6 - 0.212591 \times c^7 & \textbf{if } 1900 \le \mathit{year} \le 1987 \\ -0.000009 + 0.003844 \times c + 0.083563 \times c^2 + \\ 0.865736 \times c^3 + 4.867575 \times c^4 + 15.845535 \times c^5 + \\ 31.332267 \times c^6 + 38.291999 \times c^7 + 28.316289 \times c^8 \\ + 11.636204 \times c^9 + 2.043794 \times c^{10} & \textbf{if } 1800 \le \mathit{year} \le 1899 \\ \dfrac{\begin{array}{l} 8.118780842 - \\ 0.005092142 \times (\mathit{year} - 1700) + \\ 0.003336121 \times (\mathit{year} - 1700)^2 - \\ .0000266484 \times (\mathit{year} - 1700)^3 \end{array}}{24 \times 60 \times 60} & \textbf{if } 1700 \le \mathit{year} \le 1799 \\ \dfrac{\begin{array}{l} 196.58333 - 4.0675 \times (\mathit{year} - 1600) + \\ 0.0219167 \times (\mathit{year} - 1600)^2 \end{array}}{24 \times 60 \times 60} & \textbf{if } 1620 \le \mathit{year} \le 1699 \\ \dfrac{\dfrac{x^2}{41048480} - 15}{24 \times 60 \times 60} & \textbf{otherwise} \end{cases}$$

where

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

$$c = \frac{1}{36525} \times \textbf{gregorian-date-difference}\left(\boxed{1900 \mid \textbf{january} \mid 1}, \boxed{\textit{year} \mid \textbf{july} \mid 1}\right)$$

$$x = 12^{\text{h}} + \textbf{gregorian-date-difference}\left(\boxed{1810 \mid \textbf{january} \mid 1}, \boxed{\textit{year} \mid \textbf{january} \mid 1}\right)$$

or in Lisp (pages 356–357):

```
(defun ephemeris-correction (tee)
  ;; TYPE moment -> fraction-of-day
  ;; Dynamical Time minus Universal Time (in days) for
  ;; fixed time tee.  Adapted from "Astronomical Algorithms"
  ;; by Jean Meeus, Willmann-Bell, Inc., 1991.
  (let* ((year (gregorian-year-from-fixed (floor tee)))
         (c (/ (gregorian-date-difference
                (gregorian-date 1900 january 1)
                (gregorian-date year july 1))
               36525l0)))
    (cond ((<= 1988 year 2019)
           (/ (- year 1933) 24l0 60l0 60l0))
          ((<= 1900 year 1987)
           (poly c
                 (list -0.00002l0 0.000297l0 0.025184l0
                       -0.181133l0 0.553040l0 -0.861938l0
                       0.677066l0 -0.212591l0)))
          ((<= 1800 year 1899)
           (poly c
                 (list -0.000009l0 0.003844l0 0.083563l0
                       0.865736l0 4.867575l0 15.845535l0
                       31.332267l0 38.291999l0 28.316289l0
                       11.636204l0 2.043794l0)))
          ((<= 1700 year 1799)
           (/ (poly (- year 1700)
                    (list 8.118780842l0 -0.005092142l0 0.003336121l0
                          -.0000266484l0))
              24l0 60l0 60l0))
          ((<= 1620 year 1699)
           (/ (poly (- year 1600)
                    (list 196.58333l0 -4.0675l0 0.0219167l0))
              24l0 60l0 60l0))
          (t (let* ((x (+ (hr 12l0)
                          (gregorian-date-difference
                           (gregorian-date 1810 january 1)
                           (gregorian-date year january 1)))))
               (/ (- (/ (* x x) 41048480l0) 15)
                  24l0 60l0 60l0))))))
```

This change causes the sample data to be wrong in some cases; see Errata 432 and 433. We should replace

Figures 12.1 and 12.2 with plots of the actual values versus those produced by **ephemeris-correction** as shown in Figures 246-A and 246-B, respectively. (Courtesy of John Cross, February 8, 2002.)

*247. Page 171 of the second printing only, **ephemeris-correction**: C.U.P botched fixing Erratum 246 in the second printing, omitting the definition of c and x as given in that erratum. The Lisp code in Appendix B and on the revised CD is correct. (Courtesy of Anoop Chaturvedi, February 26, 2004.)

248. Page 176, line 5: Change "corrective factor" to "additive corrective factor". (Courtesy of Michael H. Deckers, August 7, 2006.)

249. Pages 176–177 and page 208: Discuss the change in shape of the analemma and add the reference "The Shape of the Analemma" by B. M. Oliver, *Sky and Telescope*, July, 1972, pages 20–22.

250. Page 177, lines 13–14: Delete the degree symbols in the components of *eccentricity* which is a dimensionless quantity. This change requires deletion of the call to `deg` on lines 17–18 of **equation-of-time** on page 355. There are numerous similar extraneous degree symbols! (Courtesy of John Cross, February 8, 2002.)

251. Page 178, **midnight** and **midday**, equations (12.20) and (12.21): The following are very slightly more accurate versions of **midday** and **midnight**, taking the slight changes in the equation of time in different locations over the course of a day into account:

$$\textbf{midnight}\,(\textit{date}, \textit{locale}) \stackrel{\text{def}}{=} \tag{12.20}$$

$$\begin{array}{l}\textbf{standard-from-universal}\\ \quad (\ \textbf{local-from-apparent}\\ \qquad (\textbf{universal-from-local}\,(\textit{date}, \textit{locale}))\,,\\ \quad\ \textit{locale}\ )\end{array}$$

$$\textbf{midday}\,(\textit{date}, \textit{locale}) \stackrel{\text{def}}{=} \tag{12.21}$$

$$\begin{array}{l}\textbf{standard-from-universal}\\ \quad \Big(\ \textbf{local-from-apparent}\\ \qquad \big(\textbf{universal-from-local}\,\big(\textit{date} + 12^{\text{h}}, \textit{locale}\big)\big)\,,\\ \quad\ \textit{locale}\ \Big)\end{array}$$

or in Lisp (page 356):

```
(defun midnight (date locale)
  ;; TYPE (fixed-date location) -> moment
  ;; Standard time on fixed date of true (apparent)
  ;; midnight at locale.
  (standard-from-universal
   (local-from-apparent
    (universal-from-local date locale))
   locale))
```

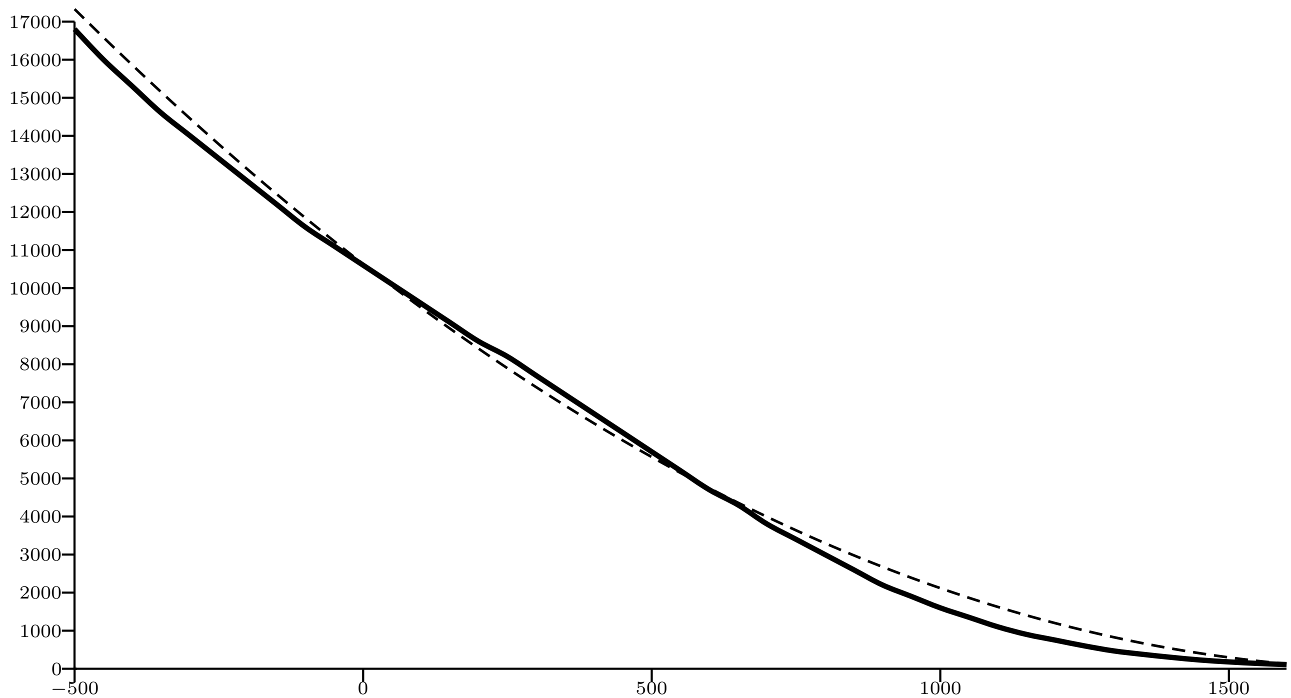

Figure 246-A: Replacement for Figure 12.1 on page 173. Difference between Dynamical (terrestrial) Time and Universal Time in atomic seconds plotted by Gregorian year. The dashed line shows the values of **ephemeris-correction**. Suggested by R. H. van Gent and based on [23, Chapter 14].

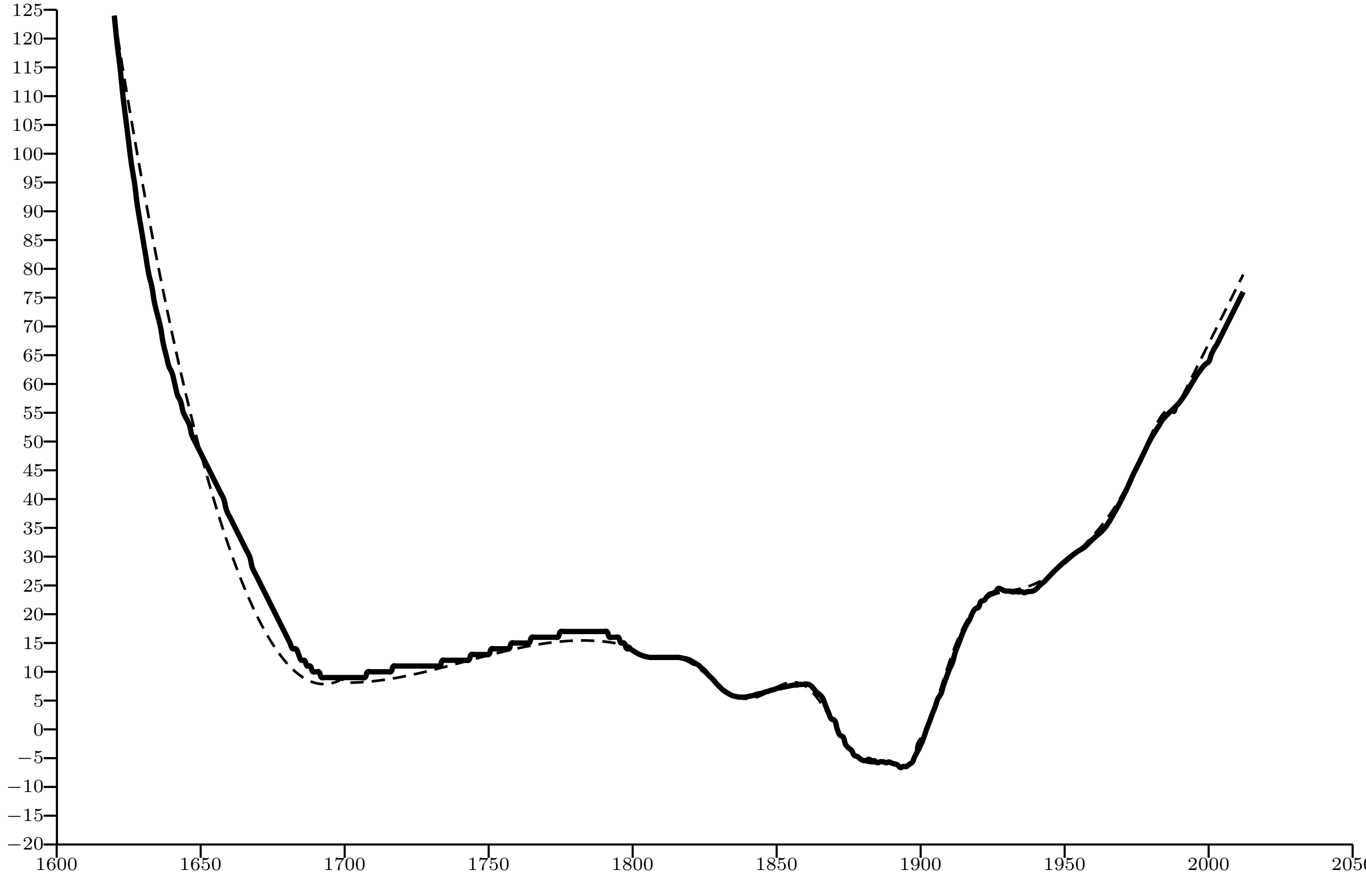

Figure 246-B: Replacement for Figure 12.2 on page 174. Difference between Dynamical (terrestrial) Time and Universal Time in atomic seconds plotted by Gregorian year. The dashed line shows the values of **ephemeris-correction**. Data supplied by R. H. van Gent [personal communication] based on *Astronomical Almanac for the Year 2000*, Nautical Almanac Office, United States Naval Observatory, Washington, D.C., pp. K8–K9; the extrapolated values to 2012 were obtained from the National Earth Orientation Service.

```
(defun midday (date locale)
   ;; TYPE (fixed-date location) -> moment
   ;; Standard time on fixed date of midday at locale.
   (standard-from-universal
    (local-from-apparent
     (universal-from-local (+ date (hr 12l0)) locale))
    locale))
```

252. Page 178: Good quote—"How could David have known exactly when [true] midnight occurs? Even Moses didn't know!" *Babylonian Talmud* (Beraḥot, 3a)

253. Page 179, lines −11: Change the first sentence of the paragraph to read "The Earth's *rotation period* with respect to the fixed celestial sphere is approximately $23^h56^m4^s.09890^s$. This is marginally more than the length of a (*mean*) *sidereal* (or *tropical*) *day*, namely, $23^h56^m4^s.09054^s$, which is the time of rotation relative to the First Point of Aries." (Courtesy of Michael H. Deckers, August 7, 2006.)

254. Page 180, line 3: Change "23.441884°" to "23.439291°". (Courtesy of Robert H. Douglass, April 30, 2002.)

255. Page 182, line 10: Change "an astronomical" to "a U.T.".

256. Page 182, line −8: Change "10 minutes of arc" to "2 seconds of arc". (Courtesy of Oscar van Vlijmen, August 20, 2003.)

257. Page 183, Table 12.1: This table, as well as Tables 12.3–12.6 are generated automatically from the Lisp code and they are all oddly arranged. It would be more sensible to have the columns in decreasing order by the first value; instead, one has to read across the rows to see the entries in decreasing order. (Courtesy of Irv Bromberg, March 5, 2003.)

258. Page 184, **solar-longitude-after**: Change the variables u and l to a and b, respectively. (Courtesy of Michael H. Deckers, August 7, 2006.)

259. (2) Page 185, line 10: Change "R.D. 729,014.34235" to "R.D. 730,475.31751". (Courtesy of Robert H. Douglass, April 25, 2002.)

260. Section 12.5: Good introductory quote from Bede's *De Temporum Ratione*: "Should someone rather less skilled in calculation nonetheless be curious about the course of the moon, we have also for his sake devised a formula adapted to the capacity of his intelligence, so that he might find what he seeks." Faith Wallis, *Bede: The Reckoning of Time*, Liverpool University Press, Liverpool, 1999 (also University of Pennsylvania Press, Philadelphia, 2000), page 63.

261. Section 12.5: The times of moonrise/set can be determined from **lunar-altitude** by sequentially scanning each hour of a given day for a rise/set event and then performing a bisection search within the hour for the minute. (Courtesy of Richard P. Kelly, March 28, 2002.)

262. Section 12.5. Good quote from the Balcony Scene in Shakespeare's *Romeo and Juliet*, Act II, scene ii (1591):

    O, swear not by the moon, th' inconstant moon,
    That monthly changes in her circle orb. . .

263. Page 185, line −14: Clarify by changing "have the same longitude" to "have the same (celestial) longitude". (Courtesy of Richard M. Koolish, November 27, 2001.)

264. Page 185, lines −6 to −4: Clarify by changing "Approximations of this value... determinations." to "Approximations of this value are used in many lunar and lunisolar calendars." (Courtesy of Helmer Aslaksen, November 13, 2001.)

265. Page 185: Add to the end of Section 12.5: To calculate sidereal longitude, we use the algorithm for precession in Meeus's 2nd edition (pages 136–137):

$$\textbf{precession}\,(t) \stackrel{\text{def}}{=} (p + P - \mathit{arg}) \bmod 360 \qquad \text{(265-A)}$$

where

$$c = \textbf{julian-centuries}\,(t)$$

$$\eta = \Big((47.0029)'' \times c + ((-0.03302))'' \times c^2 + (0.000060)'' \times c^3 \Big) \bmod 360$$

$$P = \Big(174.876384^\circ + ((-869.8089))'' \times c + (0.03536)'' \times c^2 \Big) \bmod 360$$

$$p = \Big((5029.0966)'' \times c + (1.11113)'' \times c^2 + (0.000006)'' \times c^3 \Big) \bmod 360$$

$$A = \cos\eta \times \sin P$$

$$B = \cos P$$

$$\mathit{arg} = \textbf{arctan}_2\,(A, B)$$

To use it, we need to choose a date at which sidereal and ecliptic longitude coincide, such as:

$$\textbf{sidereal-start} \stackrel{\text{def}}{=} \textbf{precession}\,\big(\textbf{universal-from-local}\,(\textbf{mesha-samkranti}\,(285 \text{ C.E.}), \textbf{hindu-locale})\big) \qquad \text{(265-B)}$$

Then we have:

$$\textbf{sidereal-solar-longitude}\,(t) \stackrel{\text{def}}{=} \big(\textbf{solar-longitude}\,(t) - \textbf{precession}\,(t) + \textbf{sidereal-start}\big) \bmod 360 \qquad \text{(265-C)}$$

266. Page 187, lines −8 and −7: Change "the first new moon after R.D. 0, which was on January 11, 1 (Gregorian):" to "the new moon of January 11, 1 (Gregorian), which was the first new moon after R.D. 0:" (Courtesy of Andrew Main, April 21, 2004.)

267. Page 188, **nth-new-moon**, top line: For compatibility with alternative fixed day numbering epochs, change *approx* to

$$approx = gregorian\text{-}epoch + 730124.59765$$

(Courtesy of Irv Bromberg, September 19, 2006.)

268. Pages 189 (captions of Tables 12.3 and 12.4) and 192 (caption of Table 12.5): The page references in the tables of coefficients are wrong. It is not clear why LaTeX got this wrong! (Courtesy of Oscar van Vlijmen, May 8, 2002.)

269. (2) Page 190: Slight differences between the approximations used by the functions **nth-new-moon and **lunar-phase** (which in turn uses **solar-longitude** and **lunar-longitude**) lead to rare occasions when t is very close to the time of a new moon and the code for **new-moon-before** and **new-moon-after** returns inconsistent values. To force consistency (not accuracy), we should use:

$$\textbf{new-moon-before}\,(t) \stackrel{\text{def}}{=} \qquad (12.36)$$

$$\textbf{nth-new-moon}\left(\underset{k\geq n-1}{\text{MAX}}\left\{\textbf{nth-new-moon}\,(k) < t\right\}\right)$$

where

$$t_0 = \textbf{nth-new-moon}\,(0)$$

$$\phi = \textbf{lunar-phase}\,(t)$$

$$n = \text{round}\left(\frac{t - t_0}{\textbf{mean-synodic-month}} - \frac{\phi}{360^\circ}\right)$$

$$\textbf{new-moon-after}\,(t) \stackrel{\text{def}}{=} \qquad (12.37)$$

$$\textbf{nth-new-moon}\left(\underset{k\geq n}{\text{MIN}}\left\{\textbf{nth-new-moon}\,(k) \geq t\right\}\right)$$

where

$$t_0 = \textbf{nth-new-moon}\,(0)$$

$$\phi = \textbf{lunar-phase}\,(t)$$

$$n = \text{round}\left(\frac{t - t_0}{\textbf{mean-synodic-month}} - \frac{\phi}{360^\circ}\right)$$

For robustness (independence of the phase at the R.D. epoch), we also subtract from t the moment t_0 of the first new moon after R.D. 0. In Lisp (pages 362–363):

```
(defun new-moon-before (tee)
   ;; TYPE moment -> moment
   ;; Moment UT of last new moon before tee.
   (let* ((t0 (nth-new-moon 0))
          (phi (lunar-phase tee))
          (n (round (- (/ (- tee t0) mean-synodic-month)
                       (/ phi (deg 360))))))
     (nth-new-moon (final k (1- n) (< (nth-new-moon k) tee)))))
```

```
(defun new-moon-after (tee)
   ;; TYPE moment -> moment
   ;; Moment UT of first new moon at or after tee.
   (let* ((t0 (nth-new-moon 0))
          (phi (lunar-phase tee))
          (n (round (- (/ (- tee t0) mean-synodic-month)
                       (/ phi (deg 360))))))
     (nth-new-moon (next k n (>= (nth-new-moon k) tee)))))
```

270. Pages 190–1: For **lunar-longitude** we should use the updated mean arguments (*solar-anomaly*, *moon-node*, etc.) given in the second edition of Meeus (page 338, based on Chapront, et al. [1998]), which can make a difference in arcseconds. (Courtesy of Oscar van Vlijmen, May 27, 2002.) Here is an updated version of **lunar-longitude**:

$$\textbf{lunar-longitude}\,(t) \stackrel{\text{def}}{=} \tag{270-A}$$

$$\left(\textit{mean-moon} + \textit{correction} + \textit{venus} + \textit{jupiter} + \textit{flat-earth} + \textbf{nutation}\,(t)\right) \bmod 360$$

where

$$c = \textbf{julian-centuries}\,(t)$$

$$\textit{mean-moon} = 218.3164477^\circ + 481267.88123421^\circ \times c - .0015786^\circ \times c^2 + \frac{1^\circ}{538841} \times c^3 - \frac{1^\circ}{65194000} \times c^4$$

$$\textit{elongation} = 297.8501921^\circ + 445267.1114034^\circ \times c - .0018819^\circ \times c^2 + \frac{1^\circ}{545868} \times c^3 - \frac{1^\circ}{113065000} \times c^4$$

$$\textit{solar-anomaly} = 357.5291092^\circ + 35999.0502909^\circ \times c - .0001536^\circ \times c^2 + \frac{1^\circ}{24490000} \times c^3$$

$$\textit{lunar-anomaly} = 134.9633964^\circ + 477198.8675055^\circ \times c + 0.0087414^\circ \times c^2 + \frac{1^\circ}{69699} \times c^3 - \frac{1^\circ}{14712000} \times c^4$$

$$\textit{moon-node} = 93.2720950^\circ + 483202.0175233^\circ \times c - .0036539^\circ \times c^2 - \frac{1^\circ}{3526000} \times c^3 + \frac{1^\circ}{863310000} \times c^4$$

$$E = 1 - 0.002516 \times c - 0.0000074 \times c^2$$

$$\textit{correction} = \frac{1^\circ}{1000000} \times \sum \Big(\tilde{v} \times E^{|\tilde{x}|} \times \sin\big(\tilde{w} \times \textit{elongation} + \tilde{x} \times \textit{solar-anomaly} + \tilde{y} \times \textit{lunar-anomaly} + \tilde{z} \times \textit{moon-node} \big) \Big)$$

$$\textit{venus} = \frac{3958^\circ}{1000000} \times \sin(119.75 + c \times 131.849)$$

$$\textit{jupiter} = \frac{318^\circ}{1000000} \times \sin(53.09 + c \times 479264.29)$$

$$\textit{flat-earth} = \frac{1962^\circ}{1000000} \times \sin(\textit{mean-moon} - \textit{moon-node})$$

$\tilde{v}$ = (see Table 270-A)

$\tilde{w}$ = (see Table 270-A)

$\tilde{x}$ = (see Table 270-A)

$\tilde{y}$ = (see Table 270-A)

$\tilde{z}$ = (see Table 270-A)

or in Lisp

```
(defun lunar-longitude (tee)
  ;; TYPE moment -> angle
  ;; Longitude of moon (in degrees) at moment tee.
  ;; Adapted from "Astronomical Algorithms" by Jean Meeus,
  ;; Willmann-Bell, Inc., 1991.
  (let* ((c (julian-centuries tee))
         (mean-moon
          (degrees
           (poly c
                 (deg (list 218.3164477l0 481267.88123421l0
                       -.0015786l0 1/538841 -1/65194000)))))
         (elongation
          (degrees
```

$\tilde{v}$	$\tilde{w}$	$\tilde{x}$	$\tilde{y}$	$\tilde{z}$	$\tilde{v}$	$\tilde{w}$	$\tilde{x}$	$\tilde{y}$	$\tilde{z}$
6288774	0	0	1	0	1274027	2	0	−1	0
658314	2	0	0	0	213618	0	0	2	0
−185116	0	1	0	0	−114332	0	0	0	2
58793	2	0	−2	0	57066	2	−1	−1	0
53322	2	0	1	0	45758	2	−1	0	0
−40923	0	1	−1	0	−34720	1	0	0	0
−30383	0	1	1	0	15327	2	0	0	−2
−12528	0	0	1	2	10980	0	0	1	−2
10675	4	0	−1	0	10034	0	0	3	0
8548	4	0	−2	0	−7888	2	1	−1	0
−6766	2	1	0	0	−5163	1	0	−1	0
4987	1	1	0	0	4036	2	−1	1	0
3994	2	0	2	0	3861	4	0	0	0
3665	2	0	−3	0	−2689	0	1	−2	0
−2602	2	0	−1	2	2390	2	−1	−2	0
−2348	1	0	1	0	2236	2	−2	0	0
−2120	0	1	2	0	−2069	0	2	0	0
2048	2	−2	−1	0	−1773	2	0	1	−2
−1595	2	0	0	2	1215	4	−1	−1	0
−1110	0	0	2	2	−892	3	0	−1	0
−810	2	1	1	0	759	4	−1	−2	0
−713	0	2	−1	0	−700	2	2	−1	0
691	2	1	−2	0	596	2	−1	0	−2
549	4	0	1	0	537	0	0	4	0
520	4	−1	0	0	−487	1	0	−2	0
−399	2	1	0	−2	−381	0	0	2	−2
351	1	1	1	0	−340	3	0	−2	0
330	4	0	−3	0	327	2	−1	2	0
−323	0	2	1	0	299	1	1	−1	0
294	2	0	3	0					

Table 270-A: Arguments for **lunar-longitude** (page 65).

```
          (poly c
                (deg (list 297.8501921l0 445267.1114034l0
                      -.0018819l0 1/545868 -1/113065000)))))
        (solar-anomaly
         (degrees
          (poly c
                (deg (list 357.5291092l0 35999.0502909l0
                      -.0001536l0 1/24490000)))))
        (lunar-anomaly
         (degrees
          (poly c
                (deg (list 134.9633964l0 477198.8675055l0
                      0.0087414l0 1/69699 -1/14712000)))))
        (moon-node
         (degrees
          (poly c
                (deg (list 93.2720950l0 483202.0175233l0
                      -.0036539l0 -1/3526000 1/863310000)))))
       (cap-E (poly c (list 1 -0.002516l0 -0.0000074l0)))
        (args-lunar-elongation
         (list 0 2 2 0 0 0 2 2 2 2 0 1 0 2 0 0 4 0 4 2 2 1
               1 2 2 4 2 0 2 2 1 2 0 0 2 2 2 4 0 3 2 4 0 2
               2 2 4 0 4 1 2 0 1 3 4 2 0 1 2))
        (args-solar-anomaly
         (list 0 0 0 0 1 0 0 -1 0 -1 1 0 1 0 0 0 0 0 0 1 1
               0 1 -1 0 0 0 1 0 -1 0 -2 1 2 -2 0 0 -1 0 0 1
               -1 2 2 1 -1 0 0 -1 0 1 0 1 0 0 -1 2 1 0))
        (args-lunar-anomaly
         (list 1 -1 0 2 0 0 -2 -1 1 0 -1 0 1 0 1 1 -1 3 -2
               -1 0 -1 0 1 2 0 -3 -2 -1 -2 1 0 2 0 -1 1 0
               -1 2 -1 1 -2 -1 -1 -2 0 1 4 0 -2 0 2 1 -2 -3
               2 1 -1 3))
        (args-moon-node
         (list 0 0 0 0 0 2 0 0 0 0 0 0 0 -2 2 -2 0 0 0 0 0
               0 0 0 0 0 0 0 2 0 0 0 0 0 0 -2 2 0 2 0 0 0 0
               0 0 -2 0 0 0 0 -2 -2 0 0 0 0 0 0 0 0))
        (sine-coefficients
         (list 6288774 1274027 658314 213618 -185116 -114332
               58793 57066 53322 45758 -40923 -34720 -30383
               15327 -12528 10980 10675 10034 8548 -7888
               -6766 -5163 4987 4036 3994 3861 3665 -2689
               -2602 2390 -2348 2236 -2120 -2069 2048 -1773
               -1595 1215 -1110 -892 -810 759 -713 -700 691
               596 549 537 520 -487 -399 -381 351 -340 330
               327 -323 299 294))
        (correction
         (* (/ (deg 1) 1000000)
            (sigma ((v sine-coefficients)
                    (w args-lunar-elongation)
                    (x args-solar-anomaly)
                    (y args-lunar-anomaly)
                    (z args-moon-node))
                   (* v (expt cap-E (abs x))
                      (sin-degrees
```

```
                         (+ (* w elongation)
                            (* x solar-anomaly)
                            (* y lunar-anomaly)
                            (* z moon-node)))))))
          (venus (* (/ (deg 3958) 1000000)
                    (sin-degrees
                     (+ 119.7510 (* c 131.84910)))))
          (jupiter (* (/ (deg 318) 1000000)
                      (sin-degrees
                       (+ 53.0910 (* c 479264.2910)))))
          (flat-earth
           (* (/ (deg 1962) 1000000)
              (sin-degrees (- mean-moon moon-node)))))
     (mod (+ mean-moon correction venus jupiter flat-earth
             (nutation tee))
          360)))
```

271. Page 191, lines 14–15: Add ° signs to the numbers 119.75, 131.849, 53.09, and 479264.29.

272. Page 192, caption of Table 12.5, second printing only: The page reference is wrong; it should be 190.

273. Page 193, **lunar-phase-before** and **lunar-phase-after**: Change the variables u and l to a and b, respectively. (Courtesy of Michael H. Deckers, August 7, 2006.)

274. Pages 194–5: For **lunar-latitude** we should use the updated mean arguments (*solar-anomaly*, *moon-node*, etc.) given in the second edition of Meeus (page 338, based on Chapront, et al. [1998]), which can make a difference in arcseconds. (Courtesy of Oscar van Vlijmen, May 27, 2002.) Also, lunar latitude is conventionally a small number ranging from slightly beyond $-5°$ to $+5°$ degrees, where a negative number is below the ecliptic. However we take the result modulo 360, so that latitudes below the ecliptic range from about 355° and higher. This has no adverse effect on any function that depends on lunar-latitude, but to use **lunar-latitude** as a stand-alone function it would be preferable not to take the result modulo 360. Negative degrees are compatible with our other functions that depend on lunar latitude. (Courtesy of Irv Bromberg, April 11, 2005.) Here is an updated version of **lunar-latitude**.

$$\textbf{lunar-latitude}\,(t) \stackrel{\text{def}}{=} \qquad (274\text{-A})$$

$$(\mathit{latitude} + \mathit{venus} + \mathit{flat\text{-}earth} + \mathit{extra}) \bmod 360$$

where

$$c = \textbf{julian-centuries}\,(t)$$

$$\mathit{mean\text{-}moon} = 218.3164477° + 481267.88123421° \times c - .0015786° \times c^2 + \frac{1°}{538841} \times c^3 - \frac{1°}{65194000} \times c^4$$

$$\mathit{elongation} = 297.8501921° + 445267.1114034° \times c - .0018819° \times c^2 + \frac{1°}{545868} \times c^3 - \frac{1°}{113065000} \times c^4$$

$$\textit{solar-anomaly} = 357.5291092^\circ + 35999.0502909^\circ \times c - .0001536^\circ \times c^2 + \frac{1^\circ}{24490000} \times c^3$$

$$\textit{lunar-anomaly} = 134.9633964^\circ + 477198.8675055^\circ \times c + 0.0087414^\circ \times c^2 + \frac{1^\circ}{69699} \times c^3 - \frac{1^\circ}{14712000} \times c^4$$

$$\textit{moon-node} = 93.2720950^\circ + 483202.0175233^\circ \times c - .0036539^\circ \times c^2 - \frac{1^\circ}{3526000} \times c^3 + \frac{1^\circ}{863310000} \times c^4$$

$$E = 1 - 0.002516 \times c - 0.0000074 \times c^2$$

$$\textit{latitude} = \frac{1^\circ}{1000000} \times \sum \Big(\tilde{v} \times E^{|\tilde{x}|} \times \sin\big(\tilde{w} \times \textit{elongation} + \tilde{x} \times \textit{solar-anomaly} + \tilde{y} \times \textit{lunar-anomaly} + \tilde{z} \times \textit{moon-node} \big) \Big)$$

$$\textit{venus} = \frac{175^\circ}{1000000} \times \big(\sin(119.75^\circ + c \times 131.849 + \textit{moon-node}) + \sin\big(119.75^\circ + c \times 131.849 - \textit{moon-node}\big) \big)$$

$$\textit{flat-earth} = \frac{-2235^\circ}{1000000} \times \sin \textit{mean-moon} + \frac{127^\circ}{1000000} \times \sin(\textit{mean-moon} - \textit{lunar-anomaly}) + \frac{-115^\circ}{1000000} \times \sin(\textit{mean-moon} + \textit{lunar-anomaly})$$

$$\textit{extra} = \frac{382^\circ}{1000000} \times \sin(313.45^\circ + c \times 481266.484^\circ)$$

$\tilde{v}$ = (see Table 274-A)

$\tilde{w}$ = (see Table 274-A)

$\tilde{x}$ = (see Table 274-A)

$\tilde{y}$ = (see Table 274-A)

$\tilde{v}$	$\tilde{w}$	$\tilde{x}$	$\tilde{y}$	$\tilde{z}$	$\tilde{v}$	$\tilde{w}$	$\tilde{x}$	$\tilde{y}$	$\tilde{z}$
5128122	0	0	0	1	280602	0	0	1	1
277693	0	0	1	−1	173237	2	0	0	−1
55413	2	0	−1	1	46271	2	0	−1	−1
32573	2	0	0	1	17198	0	0	2	1
9266	2	0	1	−1	8822	0	0	2	−1
8216	2	−1	0	−1	4324	2	0	−2	−1
4200	2	0	1	1	−3359	2	1	0	−1
2463	2	−1	−1	1	2211	2	−1	0	1
2065	2	−1	−1	−1	−1870	0	1	−1	−1
1828	4	0	−1	−1	−1794	0	1	0	1
−1749	0	0	0	3	−1565	0	1	−1	1
−1491	1	0	0	1	−1475	0	1	1	1
−1410	0	1	1	−1	−1344	0	1	0	−1
−1335	1	0	0	−1	1107	0	0	3	1
1021	4	0	0	−1	833	4	0	−1	1
777	0	0	1	−3	671	4	0	−2	1
607	2	0	0	−3	596	2	0	2	−1
491	2	−1	1	−1	−451	2	0	−2	1
439	0	0	3	−1	422	2	0	2	1
421	2	0	−3	−1	−366	2	1	−1	1
−351	2	1	0	1	331	4	0	0	1
315	2	−1	1	1	302	2	−2	0	−1
−283	0	0	1	3	−229	2	1	1	−1
223	1	1	0	−1	223	1	1	0	1
−220	0	1	−2	−1	−220	2	1	−1	−1
−185	1	0	1	1	181	2	−1	−2	−1
−177	0	1	2	1	176	4	0	−2	−1
166	4	−1	−1	−1	−164	1	0	1	−1
132	4	0	1	−1	−119	1	0	−2	−1
115	4	−1	0	−1	107	2	−2	0	1

Table 274-A: Arguments for **lunar-latitude** (page 71).

$$\tilde{z} = \text{(see Table 274-A)}$$

or in Lisp

```
(defun lunar-latitude (tee)
  ;; TYPE moment -> angle
  ;; Latitude of moon (in degrees) at moment tee.
  ;; Adapted from "Astronomical Algorithms" by Jean Meeus,
  ;; Willmann-Bell, Inc., 1998.
  (let* ((c (julian-centuries tee))
         (mean-moon
          (degrees
           (poly c
                 (deg (list 218.3164477l0 481267.88123421l0
                       -.0015786l0 1/538841 -1/65194000)))))
         (elongation
          (degrees
           (poly c
                 (deg (list 297.8501921l0 445267.1114034l0
                       -.0018819l0 1/545868 -1/113065000)))))
         (solar-anomaly
          (degrees
           (poly c
                 (deg (list 357.5291092l0 35999.0502909l0
                       -.0001536l0 1/24490000)))))
         (lunar-anomaly
          (degrees
           (poly c
                 (deg (list 134.9633964l0 477198.8675055l0
                       0.0087414l0 1/69699 -1/14712000)))))
         (moon-node
          (degrees
           (poly c
                 (deg (list 93.2720950l0 483202.0175233l0
                       -.0036539l0 -1/3526000 1/863310000)))))
         (cap-E (poly c (list 1 -0.002516l0 -0.0000074l0)))
         (args-lunar-elongation
          (list 0 0 0 2 2 2 2 0 2 0 2 2 2 2 2 2 2 0 4 0 0 0
                1 0 0 0 1 0 4 4 0 4 2 2 2 2 0 2 2 2 2 4 2 2
                0 2 1 1 0 2 1 2 0 4 4 1 4 1 4 2))
         (args-solar-anomaly
          (list 0 0 0 0 0 0 0 0 0 0 -1 0 0 1 -1 -1 -1 1 0 1
                0 1 0 1 1 1 0 0 0 0 0 0 0 0 -1 0 0 0 0 1 1
                0 -1 -2 0 1 1 1 1 1 0 -1 1 0 -1 0 0 0 -1 -2))
         (args-lunar-anomaly
          (list 0 1 1 0 -1 -1 0 2 1 2 0 -2 1 0 -1 0 -1 -1 -1
                0 0 -1 0 1 1 0 0 3 0 -1 1 -2 0 2 1 -2 3 2 -3
                -1 0 0 1 0 1 1 0 0 -2 -1 1 -2 2 -2 -1 1 1 -2
                0 0))
         (args-moon-node
          (list 1 1 -1 -1 1 -1 1 1 -1 -1 -1 -1 1 -1 1 1 -1 -1
                -1 1 3 1 1 1 -1 -1 -1 1 -1 1 -3 1 -3 -1 -1 1
                -1 1 -1 1 1 1 1 -1 3 -1 -1 1 -1 -1 1 -1 1 -1
                -1 -1 -1 -1 -1 1))
```

```
          (sine-coefficients
           (list 5128122 280602 277693 173237 55413 46271 32573
                 17198 9266 8822 8216 4324 4200 -3359 2463 2211
                 2065 -1870 1828 -1794 -1749 -1565 -1491 -1475
                 -1410 -1344 -1335 1107 1021 833 777 671 607
                 596 491 -451 439 422 421 -366 -351 331 315
                 302 -283 -229 223 223 -220 -220 -185 181
                 -177 176 166 -164 132 -119 115 107))
          (latitude
           (* (/ (deg 1) 1000000)
              (sigma ((v sine-coefficients)
                      (w args-lunar-elongation)
                      (x args-solar-anomaly)
                      (y args-lunar-anomaly)
                      (z args-moon-node))
                     (* v (expt cap-E (abs x))
                        (sin-degrees
                         (+ (* w elongation)
                            (* x solar-anomaly)
                            (* y lunar-anomaly)
                            (* z moon-node)))))))
          (venus (* (/ (deg 175) 1000000)
                    (+ (sin-degrees
                        (+ (deg 119.75l0) (* c 131.849l0)
                           moon-node))
                       (sin-degrees
                        (+ (deg 119.75l0) (* c 131.849l0)
                           (- moon-node))))))
          (flat-earth
           (+ (* (/ (deg -2235) 1000000)
                 (sin-degrees mean-moon))
              (* (/ (deg 127) 1000000) (sin-degrees
                                        (- mean-moon lunar-anomaly)))
              (* (/ (deg -115) 1000000) (sin-degrees
                                         (+ mean-moon lunar-anomaly)))))
          (extra (* (/ (deg 382) 1000000)
                    (sin-degrees
                     (+ (deg 313.45l0)
                        (* c (deg 481266.484l0)))))))
     (mod (+ latitude venus flat-earth extra) 360)))
```

275. Page 195, **lunar-altitude**, equation (12.47): We should stress that this function gives the altitude in vacuum, not corrected for parallax or refraction. (Courtesy of Oscar van Vlijmen, May 10, 2002.)

276. Section 12.6: Better introductory quote: “No man has the right to choose the time of the rising and setting of the sun, only God.” Told to the *Sydney Morning Herald* by Judith Hall of Gunnedah, spokeperson for the Abolish Daylight Saving Committee in New South Wales, Australia (see *New Scientist*, December 13, 2003, page 64).

277. Page 197, line −16: Change “length” to “lengths”. (Courtesy of Nicholas J. Cox, January 16, 2006.)

278. (3) Page 197, line −10: Change *shih* to *shí* and *ko* to *kè*. (Courtesy of Zhuo Meng, October 21, 2002.)

279. Page 197, line −10: We could expand the sentence on Chinese timekeeping to include a bit more detail. Ancient Chinese civilization divided a day into 10 *shí* and 100 *kè* based on marks on dripping pot; in the

first century B.C.E., Chinese astronomers started to divide a day into 12 *shí*. Although 100 *kè* can not be divided equally into 12 *shí*, the *kè* was not changed until the early Qīng dynasty (mid 17th centry), when the it was redefined as an eighth of a *shí*, making 96 *kè* per day. (Courtesy of Zhuo Meng, October 31, 2002.)

280. Page 198, line before (12.48): Change "either in" to "in either". (Courtesy of Nicholas J. Cox, January 16, 2006.)

281. Page 198, **moment-from-depression**, equation (12.48): This function would be better renamed **moment-of-depression**; we do this in the changes that follow.

We should mention that more information is available than simply **bogus** when the phenomenon does not occur: When *sine-offset* < -1 the sun does not set; similarly, when *sine-offset* > 1 the sun does not rise. (Courtesy of Oscar van Vlijmen, May 9, 2002.)

However, it would have been better and more robust to have an explicit parameter indicating whether one is interested in the eastern or western horizon. (Courtesy of Olivier Beltrami, June 22, 2003.) Thus one can delete the line setting the variable *morning* from this function, and add *morning?* as a fourth parameter. Then, define two new constants:

$$\textbf{morning} \stackrel{\text{def}}{=} \text{true} \tag{281-A}$$

$$\textbf{evening} \stackrel{\text{def}}{=} \text{false} \tag{281-B}$$

or in Lisp (page 359):

```
(defconstant morning true)
```

```
(defconstant evening false)
```

Each call to **moment-of-depression** in **dawn** on page 199 should have a fourth argument **morning**, and each call in **dusk** on page 199 should have **evening**. (See Erratum 285.)

More accurate times for high latitudes can be obtained using an iterative process, as in the following improved version of **moment-of-depression**:

$$\textbf{sine-offset}\,(t, \mathit{locale}, \alpha) \stackrel{\text{def}}{=} \tag{281-C}$$

$$\tan\phi \times \tan\delta + \frac{\sin\alpha}{\cos\delta \times \cos\phi}$$

where

$$\phi = \mathit{locale}_{\textbf{latitude}}$$

$$\delta = \arcsin\big(\sin(\textbf{obliquity}\,(t)) \times \sin(\textbf{solar-longitude}\,(t))\big)$$

approx-moment-of-depression (281-D)

$$(t, \mathit{locale}, \alpha, \mathit{morning?}) \stackrel{\text{def}}{=}$$

$$\begin{cases} \textbf{local-from-apparent} \\ \quad \left(\mathit{date} + 0.5 + \begin{Bmatrix} -1 & \textbf{if } \mathit{morning?} \\ 1 & \textbf{otherwise} \end{Bmatrix} \right. \\ \quad \left. \times \left(\left(\left(12^{\text{h}} + \dfrac{\arcsin \mathit{value}}{360^\circ} \right) \bmod 1 \right) - 6^{\text{h}} \right) \right) & \textbf{if } |\mathit{value}| \le 1 \\ \textbf{bogus} & \textbf{otherwise} \end{cases}$$

where

$$\mathit{try} = \textbf{sine-offset}\,(t, \mathit{locale}, \alpha)$$

$$\mathit{date} = \lfloor t \rfloor$$

$$\mathit{alt} = \begin{cases} \mathit{date} & \textbf{if } \alpha \ge 0 \text{ and } \mathit{morning?} \\ \mathit{date} + 1 & \textbf{if } \alpha \ge 0 \text{ and not } \mathit{morning?} \\ \mathit{date} + 12^{\text{h}} & \textbf{otherwise} \end{cases}$$

$$\mathit{value} = \begin{cases} \textbf{sine-offset}\,(\mathit{alt}, \mathit{locale}, \alpha) & \textbf{if } |\mathit{try}| > 1 \\ \mathit{try} & \textbf{otherwise} \end{cases}$$

moment-of-depression (12.48)

$$(\mathit{approx}, \mathit{locale}, \alpha, \mathit{morning?}) \stackrel{\text{def}}{=}$$

$$\begin{cases} \textbf{bogus} & \textbf{if } t = \textbf{bogus} \\ t & \textbf{if } t \ne \textbf{bogus} \text{ and } |\mathit{approx} - t| < \dfrac{1}{24 \times 60 \times 2} \\ \textbf{moment-of-depression}\,(t, \mathit{locale}, \alpha, \mathit{morning?}) & \textbf{otherwise} \end{cases}$$

where

$$t = \textbf{approx-moment-of-depression}\,(\mathit{approx}, \mathit{locale}, \alpha, \mathit{morning?})$$

In Lisp: (page 359):

```
(defun sine-offset (tee locale alpha)
   ;; TYPE (moment location angle) -> moment
   ;; Sine of angle between position of sun at tee and
   ;; when its depression is alpha (negative if above
   ;; horizon) at locale.
   (let* ((phi (latitude locale))
          (delta ; Declination of sun.
           (arcsin-degrees
            (* (sin-degrees (obliquity tee))
               (sin-degrees (solar-longitude tee))))))
     (+ (* (tangent-degrees phi)
           (tangent-degrees delta))
        (/ (sin-degrees alpha)
           (* (cosine-degrees delta)
              (cosine-degrees phi))))))
```

```
(defun approx-moment-of-depression (tee locale alpha morning?)
   ;; TYPE (moment location angle) -> moment
   ;; Moment in UT near tee when depression angle of sun
   ;; is alpha (negative if above horizon) at locale;
   ;; morning? is true when morning event is sought.
   ;; false returned if depression angle is not reached.
   (let* ((try (sine-offset tee locale alpha))
          (date (floor tee))
          (alt (if (>= alpha 0)
                   (if morning? date (1+ date))
                     (+ date (hr 12))))
          (value (if (> (abs try) 1)
                     (sine-offset alt locale alpha)
                   try)))
     (if (<= (abs value) 1) ; Event occurs
         (local-from-apparent
          (+ date 0.5l0
             (* (if morning? -1 1)
                (- (mod (+ (hr 12)
                           (/ (arcsin-degrees value)
                              (deg 360l0)))
                        1)
                   (hr 6)))))
       bogus)))
```

```
(defun moment-of-depression (approx locale alpha morning?)
   ;; TYPE (moment location angle) -> moment
   ;; Moment in Local Time near approx when depression
   ;; angle of sun is alpha (negative if above horizon) at
   ;; locale; morning? is true when morning event is
   ;; sought.  bogus returned if depression angle is not
   ;; reached.
   (let* ((tee (approx-moment-of-depression
                 approx locale alpha morning?)))
     (if (equal tee bogus)
         bogus
       (if (< (abs (- approx tee))
```

```
            (/ 1 24 60 2)) ; 1/2 minute
          tee
        (moment-of-depression tee locale alpha morning?)))))
```

282. Pages 198, last line/first line of page 199: We say that the "result cannot be perfectly accurate because the observed position of the sun depends on atmospheric conditions, such as atmospheric temperature, humidity, and pressure." In "Variability in the Astronomical Refraction of the Rising and Setting Sun," *Astronomical Society of the Pacific*, **115** (October 2003), pp. 1256–1261, Russell D. Sampson, Edward P. Lozowski, Arthur E. Peterson, and Douglas P. Hube, a twelve-minute variation between calculated and observed times of sunrise is documented. (Courtesy of Irv Bromberg, May 28, 2006.)

283. Page 199, line 5: Move the parenthetical comment "(above, if the angle is negative)" to page 198, line 12, just before the word "the".

284. Page 199, line 7: Replace "refined:" with "refined. The result (for nonpolar regions) is then converted to standard time, using **standard-from-local** (page 170):".

285. Page 199, **dawn** and **dusk**, equations (12.49) and (12.50): At high latitudes, and under rare conditions, these functions may return times that are a few minutes off—and not on the *date* requested—instead of returning **bogus**. Here are versions that use the improved **moment-of-depression** function described in Erratum 281:

$$\textbf{dawn}\,(date, locale, \alpha) \stackrel{\text{def}}{=} \tag{12.49}$$

$$\begin{cases} \textbf{bogus} & \textbf{if } result = \textbf{bogus} \\ \textbf{standard-from-local}\,(result, locale) & \textbf{otherwise} \end{cases}$$

where

$$result = \textbf{moment-of-depression}\left(date + 6^{\text{h}}, locale, \alpha, \textbf{morning}\right)$$

$$\textbf{dusk}\,(date, locale, \alpha) \stackrel{\text{def}}{=} \tag{12.50}$$

$$\begin{cases} \textbf{bogus} & \textbf{if } result = \textbf{bogus} \\ \textbf{standard-from-local}\,(result, locale) & \textbf{otherwise} \end{cases}$$

where

$$result = \textbf{moment-of-depression}\left(date + 18^{\text{h}}, locale, \alpha, \textbf{evening}\right)$$

or in Lisp (pages 359–360):

```
(defun dawn (date locale alpha)
   ;; TYPE (fixed-date location angle) -> moment
   ;; Standard time in morning on apparent fixed date at
   ;; locale when depression angle of sun is alpha.
   (let* ((result (moment-of-depression
                   (+ date (hr 6)) locale alpha morning)))
     (if (equal result bogus)
         bogus
       (standard-from-local result locale))))
```

```
(defun dusk (date locale alpha)
   ;; TYPE (fixed-date location angle) -> moment
   ;; Standard time in evening on apparent fixed date at
   ;; locale when depression angle of sun is alpha.
   (let* ((result (moment-of-depression
                   (+ date (hr 18)) locale alpha evening)))
     (if (equal result bogus)
       bogus
       (standard-from-local result locale))))
```

286. Pages 199, line −2 and page 200, formulas (12.51) and (12.52): A slightly more accurate adjustment for refraction due to G. G. Bennett, "The Calculation of Astronomical Refraction in Marine Navigation", *Journal of Navigation*, vol. 35 (1982), pp. 255-259 is given in Jean Meeus's *Astronomical Algorithms*, 2nd ed., formula 16.3 on page 106. The refraction expressed in minutes of arc is

$$\frac{1}{\tan\left(h_0 + \frac{7.31}{h_0+4.4}\right)} + 0.001351521723799,$$

where h_0 is the apparent altitude in degrees and 0.001351521723799 is the zenith adjustment. Calculating this value with $h_0 = 0^\circ$ of apparent altitude yields 34.478885263888294, or approximately $34'29''$. The effect on sunrise/sunset times is trivial—just a few seconds. (Courtesy of Richard P. Kelly, January 23, 2003.)

287. Page 200, lines 17–18: Move the sentence "To convert... (page 170)." to page 199, immediately after formula (12.49), omitting the word "would". (Courtesy of John Cross, February 13, 2002.)

288. Page 200, formulas (12.51) and (12.52). These formulas for sunrise and sunset do not take atmospheric refraction between an elevated observer and the horizon into account. To do so, for typical atmospheric conditions and for reasonable values of the observer's altitude h, we need to add $0'.19\sqrt{(h)}$ to α.

289. Page 200, lines −9: Add "It should be stressed that the depression angle used above, $50'$, is based on the average effect of refraction (the bending of the Sun's light by the Earth's atmosphere). Because the actual refraction depends on local temperature, atmospheric pressure, and other weather conditions, the times of sunrise and sunset can calculated only to the nearest minute; for polar regions the uncertainty will be several minutes." (Courtesy of Oscar van Vlijmen, August 20, 2003.)

290. Page 200, lines −9 and −8: Remove first sentence, "To convert ... (page 170)." See Erratum 284.

291. Page 200, line −2: The following paragraph should be added here:

At high latitudes, because of the discrepancies between apparent, local, and standard time, dawn—or even sunrise—of *date* can actually occur on *date* − 1 before midnight, and dusk or sunset can occur on $date+1$. The following functions can be used for determining the zero, one, or two occurrences of sunrise or sunset on a given civil day in such cases:

$$\textbf{sunrise-on-fixed}\,(\mathit{date}, \mathit{locale}) \stackrel{\text{def}}{=} \tag{291-A}$$

$$\left\{\begin{array}{ll} \langle \mathit{rise}_0 \rangle & \textbf{if } \mathit{rise}_0 \neq \textbf{bogus} \text{ and } \lfloor \mathit{rise}_0 \rfloor = \mathit{date} \\ \langle\ \rangle & \textbf{otherwise} \end{array}\right\}$$
$$\parallel \left\{\begin{array}{ll} \langle \mathit{rise}_1 \rangle & \textbf{if } \mathit{rise}_1 \neq \textbf{bogus} \text{ and } \lfloor \mathit{rise}_1 \rfloor = \mathit{date} \\ \langle\ \rangle & \textbf{otherwise} \end{array}\right\}$$
$$\parallel \left\{\begin{array}{ll} \langle \mathit{rise}_2 \rangle & \textbf{if } \mathit{rise}_2 \neq \textbf{bogus} \text{ and } \lfloor \mathit{rise}_2 \rfloor = \mathit{date} \\ \langle\ \rangle & \textbf{otherwise} \end{array}\right\}$$

where

$$\mathit{rise}_0 = \textbf{sunrise}\,(\mathit{date}-1, \mathit{locale})$$

$$\mathit{rise}_1 = \textbf{sunrise}\,(\mathit{date}, \mathit{locale})$$

$$\mathit{rise}_2 = \textbf{sunrise}\,(\mathit{date}+1, \mathit{locale})$$

$$\textbf{sunset-on-fixed}\,(\mathit{date}, \mathit{locale}) \stackrel{\text{def}}{=} \tag{291-B}$$

$$\left\{\begin{array}{ll} \langle \mathit{set}_0 \rangle & \textbf{if } \mathit{set}_0 \neq \textbf{bogus} \text{ and } \lfloor \mathit{set}_0 \rfloor = \mathit{date} \\ \langle\ \rangle & \textbf{otherwise} \end{array}\right\}$$
$$\parallel \left\{\begin{array}{ll} \langle \mathit{set}_1 \rangle & \textbf{if } \mathit{set}_1 \neq \textbf{bogus} \text{ and } \lfloor \mathit{set}_1 \rfloor = \mathit{date} \\ \langle\ \rangle & \textbf{otherwise} \end{array}\right\}$$
$$\parallel \left\{\begin{array}{ll} \langle \mathit{set}_2 \rangle & \textbf{if } \mathit{set}_2 \neq \textbf{bogus} \text{ and } \lfloor \mathit{set}_2 \rfloor = \mathit{date} \\ \langle\ \rangle & \textbf{otherwise} \end{array}\right\}$$

where

$$\mathit{set}_0 = \textbf{sunset}\,(\mathit{date}-1, \mathit{locale})$$

$$\mathit{set}_1 = \textbf{sunset}\,(\mathit{date}, \mathit{locale})$$

$$\mathit{set}_2 = \textbf{sunset}\,(\mathit{date}+1, \mathit{locale})$$

For regions of midnight sun, one needs to search for the date and time of the next sunrise or sunset:

$$\textbf{sunrise-on-or-after}\,(\mathit{date}, \mathit{locale}) \stackrel{\text{def}}{=} \tag{291-C}$$

$$\textbf{sunrise-on-fixed}\left(\underset{i\geq date}{\text{MIN}}\left\{\textbf{sunrise-on-fixed}\,(i, \mathit{locale}) \neq \langle\ \rangle\right\}, \mathit{locale}\right)_{[0]}$$

$$\textbf{sunset-on-or-after}\,(\mathit{date}, \mathit{locale}) \stackrel{\text{def}}{=} \qquad (291\text{-D})$$

$$\textbf{sunset-on-fixed}\left(\underset{i\geq date}{\text{MIN}}\left\{\textbf{sunset-on-fixed}\,(i, \mathit{locale}) \neq \langle\ \rangle\right\}, \mathit{locale}\right)_{[0]}$$

In Lisp:

```
(defun sunrise-on-fixed (date locale)
   ;; TYPE (fixed-date location) -> list-of-moments
   ;; Standard moments of 0-2 sunrises on fixed date at
   ;; locale.
   (let* ((rise0 (sunrise (1- date) locale))
          (rise1 (sunrise date locale))
          (rise2 (sunrise (1+ date) locale)))
     (append
      (if (and (not (equal rise0 bogus))
               (= (floor rise0) date))
          (list rise0)
        nil)
      (if (and (not (equal rise1 bogus))
               (= (floor rise1) date))
          (list rise1)
        nil)
      (if (and (not (equal rise2 bogus))
               (= (floor rise2) date))
          (list rise2)
        nil))))
```

```
(defun sunset-on-fixed (date locale)
   ;; TYPE (fixed-date location) -> list-of-moments
   ;; Standard moments of 0-2 sunsets on fixed date at
   ;; locale.
   (let* ((set0 (sunset (1- date) locale))
          (set1 (sunset date locale))
          (set2 (sunset (1+ date) locale)))
     (append
      (if (and (not (equal set0 bogus))
               (= (floor set0) date))
          (list set0)
        nil)
```

```
      (if (and (not (equal set1 bogus))
               (= (floor set1) date))
          (list set1)
        nil)
      (if (and (not (equal set2 bogus))
               (= (floor set2) date))
          (list set2)
        nil))))
```

```
(defun sunrise-on-or-after (date locale)
   ;; TYPE (fixed-date location) -> moment
   ;; Standard time of first sunrise at locale on or after
   ;; fixed date.
   (first (sunrise-on-fixed
           (next i date (not (equal (sunrise-on-fixed i locale) nil)))
           locale)))
```

```
(defun sunset-on-or-after (date locale)
   ;; TYPE (fixed-date location) -> moment
   ;; Standard time of first sunset at locale on or after
   ;; fixed date.
   (first (sunset-on-fixed
           (next i date (not (equal (sunset-on-fixed i locale) nil)))
           locale)))
```

A new type *list-of-moments* needs to be added. Also, the comments to `sunrise` and `sunset` can be made more precise:

```
(defun sunrise (date locale)
   ;; TYPE (fixed-date location) -> moment
   ;; Standard time of sunrise on apparent fixed date at
   ;; locale.
   (let* ((h (max 0 (elevation locale)))
          (cap-R (mt 6.372d6)) ; Radius of Earth.
          (dip ; Depression of visible horizon.
           (arccos-degrees (/ cap-R (+ cap-R h))))
          (alpha (+ (angle 0 50 0) dip)))
     (dawn date locale alpha)))
```

```
(defun sunset (date locale)
   ;; TYPE (fixed-date location) -> moment
   ;; Standard time of sunset on apparent fixed date at
   ;; locale.
   (let* ((h (max 0 (elevation locale)))
          (cap-R (mt 6.372d6)) ; Radius of Earth.
          (dip ; Depression of visible horizon.
           (arccos-degrees (/ cap-R (+ cap-R h))))
          (alpha (+ (angle 0 50 0) dip)))
     (dusk date locale alpha)))
```

292. (3) Page 201, line -3 of Table 12.7: Change “a.m.” to “p.m.”

*293. Pages 201–202: The function **standard-from-sundial** is incorrect for *hour* > 18 and very slightly inaccurate for *hour* < 6; the problem is that we should be using appropriate nighttime temporal-hours. To fix this we must rename **temporal-hour**, formula (12.56), more appropriately as **daytime-temporal-hour**:

$$\textbf{daytime-temporal-hour}\,(date, locale) \stackrel{\text{def}}{=} \tag{293-A}$$

$$\begin{cases} \textbf{bogus} & \textbf{if } \textbf{sunrise}\,(date, locale) = \textbf{bogus} \text{ or} \\ & \quad \textbf{sunset}\,(date, locale) = \textbf{bogus} \\ \dfrac{\textbf{sunset}\,(date, locale) - \textbf{sunrise}\,(date, locale)}{12} & \textbf{otherwise} \end{cases}$$

and add the function

$$\textbf{nighttime-temporal-hour}\,(date, locale) \stackrel{\text{def}}{=} \tag{293-B}$$

$$\begin{cases} \textbf{bogus} & \textbf{if } \textbf{sunrise}\,(date+1, locale) = \textbf{bogus} \text{ or} \\ & \quad \textbf{sunset}\,(date, locale) = \textbf{bogus} \\ \dfrac{\textbf{sunrise}\,(date+1, locale) - \textbf{sunset}\,(date, locale)}{12} & \textbf{otherwise} \end{cases}$$

This allows us to replace **standard-from-sundial** with

$$\textbf{standard-from-sundial}\,(date, hour, locale) \stackrel{\text{def}}{=} \tag{12.57}$$

$$\begin{cases} \textbf{bogus} & \textbf{if } h = \textbf{bogus} \\ \textbf{sunrise}\,(date, locale) + (hour - 6) \times h & \textbf{if } 6 \le hour \le 18 \\ \textbf{sunset}\,(date-1, locale) + (hour + 6) \times h & \textbf{if } hour < 6 \\ \textbf{sunset}\,(date, locale) + (hour - 18) \times h & \textbf{otherwise} \end{cases}$$

where

$$h = \begin{cases} \textbf{daytime-temporal-hour}\,(date, locale) & \textbf{if } 6 \le hour \le 18 \\ \textbf{nighttime-temporal-hour}\,(date-1, locale) & \textbf{if } hour < 6 \\ \textbf{nighttime-temporal-hour}\,(date, locale) & \textbf{otherwise} \end{cases}$$

Or, in Lisp (page 360):

```
(defun daytime-temporal-hour (date locale)
  ;; TYPE (fixed-date location) -> real
  ;; Length of daytime temporal hour on fixed date at
  ;; locale.
  (if (or (equal (sunrise date locale) bogus)
          (equal (sunset date locale) bogus))
      bogus
    (/ (- (sunset date locale)
          (sunrise date locale))
       12)))
```

```
(defun nighttime-temporal-hour (date locale)
  ;; TYPE (fixed-date location) -> real
  ;; Length of nighttime temporal hour on fixed date at
  ;; locale.
  (if (or (equal (sunrise (1+ date) locale) bogus)
          (equal (sunset date locale) bogus))
      bogus
    (/ (- (sunrise (1+ date) locale)
          (sunset date locale))
       12)))
```

```
(defun standard-from-sundial (date hour locale)
  ;; TYPE (fixed-date real location) -> moment
  ;; Standard time on fixed date of temporal hour at
  ;; locale.
  (let ((h (cond ((<= 6 hour 18); daytime today
                  (daytime-temporal-hour date locale))
                 ((< hour 6)    ; early this morning
                  (nighttime-temporal-hour (1- date) locale))
                 (t             ; this evening
                  (nighttime-temporal-hour date locale)))))
    (cond ((equal h bogus) bogus)
          ((<= 6 hour 18); daytime today
           (+ (sunrise date locale) (* (- hour 6) h)))
          ((< hour 6)    ; early this morning
           (+ (sunset (1- date) locale) (* (+ hour 6) h)))
          (t             ; this evening
           (+ (sunset date locale) (* (- hour 18) h))))))
```

(Courtesy of John Cross, February 14, 2002.)

294. Pages 202–203, **asr**: For some reason the function calls for **arcsin-degrees**, **sin-degrees**, **cos-degrees**, and **arctan-degrees** did not get typeset as in other places—see, for example, the way **arctan-degrees** was properly handled in line 3 of **direction**, (12.4) on page 167.

295. Pages 202, last line of **asr**: The cosine formula for the difference of two angles is

$$\cos(x - y) = \sin(x)\sin(y) + \cos(x)\cos(y),$$

and of course $\cos(x) = \sin(\pi/2 - x)$; thus the altitude simplifies to $90^\circ + \phi - \delta$. (Courtesy of Burghart Hoffrichter, June 9, 2005.)

296. Page 203: Quote for Section 12.7: "And the sun rises and the sun sets—then to its place it rushes; there it rises again. It goes toward the south and veers torward the north." *Ecclesiastes* 1, 5–6. This translation is per the Art Scroll series, following Rashi; Ibn Ezra and the *Midrash* take the latter part to refer to the wind, not the sun. Here, for example, is the new *JPS* translation:

> The sun rises, and the sun sets—
> And glides back to where it rises.
> Southward blowing,
> Turning northward,
> Ever turning.

297. (2) Page 203, line −3: Change "preceding" to "on".

**298. (2) Page 204, line 3: Delete the "−1" (see Errata 419 and 431).

299. (2) Page 204, line 6: Change "last" to "first".

300. (2) Page 205, line 12: The function **visible-crescent was meant to check if the moon was visible on the evening prior to *date*. Thus, this line should read

$$(\textbf{dusk}(\mathit{date} - 1, \mathit{locale}, 4.5^\circ), \mathit{locale})$$

In Lisp (page 368, lines 4 and 7) that is

```
;; visibility of the new moon on the eve of date at locale
...
(dusk (1- date) locale (deg 4.5l0))
```

This change has far-reaching effect: all the dates in the column "Islamic: Observational" on page 397 should be one day earlier and all the dates of Passover in Table 8.1 on page 123 are off by at least one day.

301. (2) Page 205, line 16: Change "the day the new moon" to "the day after the new moon".

302. Page 205, equation (12.65): The function **phasis-on-or-before** should be rewritten as **visible-crescent-before** and should accept moments (instead of just fixed dates); in its present form it goes into an infinite loop for non-integer dates. Perhaps, in parallel to **new-moon-before**, it should return moments also. The word "phasis," though correct, is obscure.

303. Page 207, lines 2–6: Moslems in India, Pakistan, and Bangladesh base their calendar on reported Moon sightings; in Saudi Arabia and most of the Gulf countries they have simplified the calendar in which they start the lunar month if moonset is after sunset on the 29th day of the previous month, as seen from Mecca (see `http://www.phys.uu.nl/~vgent/islam/mecca/ummalqura.htm`). In Egypt they require moonset to be at least 5 minutes after sunset. In the United States, according to Khalid Shaukat, national coordinator and consultant for the Islamic Shura Council of North America (which consists of the Islamic Society of North America, the Islamic Circle of North America, the Ministry of Imam W. Deen Mohammed, and the Jamaat Community of Imam Jamil Al-Amin) "a confirmed crescent sighting report in North America will be accepted as long as such a report does not contradict indisputable astronomical information." (Courtesy of Helmer Aslaksen, November 13, 2001.)

304. Page 207, lines 2–6: Khalid Shaukat and numerous others have continued working on improved criteria for predicting visibility based on topocentric altitude. To convert geocentric altitude, as computed by **lunar-altitude**, into topocentric, we would need the following:

$$\textbf{lunar-distance}\,(t) \stackrel{\text{def}}{=} 385000.56 + \mathit{correction} \qquad \text{(304-A)}$$

where

$$
\begin{aligned}
c &= \textbf{julian-centuries}\,(t)\\
\mathit{elongation} &= 297.8501921^\circ + \\
&\quad 445267.1114034^\circ \times c - .0018819^\circ \times c^2 + \\
&\quad \tfrac{1^\circ}{545868} \times c^3 - \tfrac{1^\circ}{113065000} \times c^4\\
\mathit{solar\text{-}anomaly} &= 357.5291092^\circ + \\
&\quad 35999.0502909^\circ \times c - .0001536^\circ \times c^2 + \\
&\quad \tfrac{1^\circ}{24490000} \times c^3\\
\mathit{lunar\text{-}anomaly} &= 134.9633964^\circ + \\
&\quad 477198.8675055^\circ \times c + 0.0087414^\circ \times c^2 \\
&\quad + \tfrac{1^\circ}{69699} \times c^3 - \tfrac{1^\circ}{14712000} \times c^4\\
\mathit{moon\text{-}node} &= 93.2720950^\circ + \\
&\quad 483202.0175233^\circ \times c - .0036539^\circ \times c^2 \\
&\quad - \tfrac{1^\circ}{3526000} \times c^3 + \tfrac{1^\circ}{863310000} \times c^4\\
E &= 1 - 0.002516 \times c - 0.0000074 \times c^2\\
\mathit{correction} &= \tfrac{1}{1000} \times \sum \Big(\tilde{v} \times E^{|\tilde{x}|} \\
&\qquad \times \cos\big(\tilde{w} \times \mathit{elongation} + \\
&\qquad\qquad \tilde{x} \times \mathit{solar\text{-}anomaly} + \\
&\qquad\qquad \tilde{y} \times \mathit{lunar\text{-}anomaly} + \\
&\qquad\qquad \tilde{z} \times \mathit{moon\text{-}node} \big) \Big)\\
\tilde{v} &= \text{(see Table 304-A)}\\
\tilde{w} &= \text{(see Table 304-A)}\\
\tilde{x} &= \text{(see Table 304-A)}\\
\tilde{y} &= \text{(see Table 304-A)}\\
\tilde{z} &= \text{(see Table 304-A)}
\end{aligned}
$$

$$\textbf{lunar-parallax}\,(t, \mathit{locale}) \stackrel{\text{def}}{=} \arcsin \mathit{arg} \tag{304-B}$$

$\tilde{v}$	$\tilde{w}$	$\tilde{x}$	$\tilde{y}$	$\tilde{z}$	$\tilde{v}$	$\tilde{w}$	$\tilde{x}$	$\tilde{y}$	$\tilde{z}$
−20905355	0	0	1	0	−3699111	2	0	−1	0
−2955968	2	0	0	0	−569925	0	0	2	0
48888	0	1	0	0	−3149	0	0	0	2
246158	2	0	−2	0	−152138	2	−1	−1	0
−170733	2	0	1	0	−204586	2	−1	0	0
−129620	0	1	−1	0	108743	1	0	0	0
104755	0	1	1	0	10321	2	0	0	−2
0	0	0	1	2	79661	0	0	1	−2
−34782	4	0	−1	0	−23210	0	0	3	0
−21636	4	0	−2	0	24208	2	1	−1	0
30824	2	1	0	0	−8379	1	0	−1	0
−16675	1	1	0	0	−12831	2	−1	1	0
−10445	2	0	2	0	−11650	4	0	0	0
14403	2	0	−3	0	−7003	0	1	−2	0
0	2	0	−1	2	10056	2	−1	−2	0
6322	1	0	1	0	−9884	2	−2	0	0
5751	0	1	2	0	0	0	2	0	0
−4950	2	−2	−1	0	4130	2	0	1	−2
0	2	0	0	2	−3958	4	−1	−1	0
0	0	0	2	2	3258	3	0	−1	0
2616	2	1	1	0	−1897	4	−1	−2	0
−2117	0	2	−1	0	2354	2	2	−1	0
0	2	1	−2	0	0	2	−1	0	−2
−1423	4	0	1	0	−1117	0	0	4	0
−1571	4	−1	0	0	−1739	1	0	−2	0
0	2	1	0	−2	−4421	0	0	2	−2
0	1	1	1	0	0	3	0	−2	0
0	4	0	−3	0	0	2	−1	2	0
1165	0	2	1	0	0	1	1	−1	0
0	2	0	3	0	8752	2	0	−1	−2

Table 304-A: Arguments for **lunar-distance** (page 84).

where

$$geo = \textbf{lunar-altitude}\,(t, \mathit{locale})$$

$$\delta = \textbf{lunar-distance}\,(t)$$

$$alt = \frac{6378.14}{\delta}$$

$$arg = alt \times \cos geo$$

$$\textbf{topocentric-lunar-altitude}\,(t, \mathit{locale}) \stackrel{\text{def}}{=} \qquad \text{(304-C)}$$

$$\textbf{lunar-altitude}\,(t, \mathit{locale}) - \textbf{lunar-parallax}\,(t, \mathit{locale})$$

or in Lisp:

```
(defun lunar-distance (tee)
  ;; TYPE moment -> angle
  ;; Longitude of moon (in degrees) at moment tee.
  ;; Adapted from "Astronomical Algorithms" by Jean Meeus,
  ;; Willmann-Bell, Inc., 2nd ed.
  (let* ((c (julian-centuries tee))
         (elongation
          (degrees
           (poly c
                 (deg (list 297.850192110 445267.111403410
                            -.001881910 1/545868 -1/113065000)))))
         (solar-anomaly
          (degrees
           (poly c
                 (deg (list 357.529109210 35999.050290910
                            -.000153610 1/24490000)))))
         (lunar-anomaly
          (degrees
           (poly c
                 (deg (list 134.963396410 477198.867505510
                            0.008741410 1/69699 -1/14712000)))))
         (moon-node
          (degrees
           (poly c
                 (deg (list 93.272095010 483202.017523310
                            -.003653910 -1/3526000 1/863310000)))))
         (cap-E (poly c (list 1 -0.00251610 -0.000007410)))
         (args-lunar-elongation
          (list 0 2 2 0 0 0 2 2 2 2 0 1 0 2 0 0 4 0 4 2 2 1
                1 2 2 4 2 0 2 2 1 2 0 0 2 2 2 4 0 3 2 4 0 2
                2 2 4 0 4 1 2 0 1 3 4 2 0 1 2 2))
         (args-solar-anomaly
          (list 0 0 0 0 1 0 0 -1 0 -1 1 0 1 0 0 0 0 0 0 1 1
```

```
                 0 1 -1 0 0 0 1 0 -1 0 -2 1 2 -2 0 0 -1 0 0 1
                 -1 2 2 1 -1 0 0 -1 0 1 0 1 0 0 -1 2 1 0 0))
          (args-lunar-anomaly
           (list 1 -1 0 2 0 0 -2 -1 1 0 -1 0 1 0 1 1 -1 3 -2
                 -1 0 -1 0 1 2 0 -3 -2 -1 -2 1 0 2 0 -1 1 0
                 -1 2 -1 1 -2 -1 -1 -2 0 1 4 0 -2 0 2 1 -2 -3
                 2 1 -1 3 -1))
          (args-moon-node
           (list 0 0 0 0 0 2 0 0 0 0 0 0 0 -2 2 -2 0 0 0 0 0
                 0 0 0 0 0 0 0 2 0 0 0 0 0 0 -2 2 0 2 0 0 0 0
                 0 0 -2 0 0 0 0 -2 -2 0 0 0 0 0 0 0 -2))
          (cosine-coefficients
           (list -20905355 -3699111 -2955968 -569925 48888 -3149
                 246158 -152138 -170733 -204586 -129620 108743 104755
                 10321 0 79661 -34782 -23210 -21636 24208 30824 -8379
                 -16675 -12831 -10445 -11650 14403 -7003 0 10056 6322
                 -9884 5751 0 -4950 4130 0 -3958 0 3258 2616 -1897
                 -2117 2354 0 0 -1423 -1117 -1571 -1739 0 -4421 0 0 0
                 0 1165 0 0 8752))
          (correction
           (* 1/1000
              (sigma ((v cosine-coefficients)
                      (w args-lunar-elongation)
                      (x args-solar-anomaly)
                      (y args-lunar-anomaly)
                      (z args-moon-node))
                     (* v (expt cap-E (abs x))
                        (cosine-degrees
                         (+ (* w elongation)
                            (* x solar-anomaly)
                            (* y lunar-anomaly)
                            (* z moon-node))))))))
     (+ 385000.56l0 correction)))
```

```
(defun lunar-parallax (tee locale)
  (let* ((geo (lunar-altitude tee locale))
         (Delta (lunar-distance tee))
         (alt (/ 6378.14l0  Delta))
         (arg (* alt (cosine-degrees geo))))
    (arcsin-degrees arg)))
```

```
(defun topocentric-lunar-altitude (tee locale)
  ;; Topocentric; ignoring refraction
  (- (lunar-altitude tee locale)
     (lunar-parallax tee locale)))
```

305. Page 207, lines 2–6: One might also want to take lunar diameter into account for determining lunar visibility. We could use the approximation for the geocentric apparent lunar diameter (in degrees):

$$\textbf{lunar-diameter}\,(t) \stackrel{\text{def}}{=} \frac{1792367}{9 \times \textbf{lunar-distance}\,(t)} \tag{305-A}$$

from Jean Meeus, *Astronomical Algorithms*, 2nd ed., pp. 390–391. In Lisp:

```
(defun lunar-diameter (tee)
  ;; TYPE moment -> angle
  ;; Geocentric apparent lunar diameter of the moon (in degrees)
  ;; at moment tee.
  ;; Adapted from "Astronomical Algorithms" by Jean Meeus,
  ;; Willmann-Bell, Inc., 2nd ed.
  (/ 1792367
     (* 9 (lunar-distance tee))))
```

(Courtesy of Irv Bromberg, July 20, 2006.)

306. Page 207, line −4 : Add the following parenthetical note before the word "Using". "(The method of determining the day of the equinox and the exact cutoff date are uncertain. Also, the courts had leeway to declare a leap year when spring came late.)" (Courtesy of Svante Janson, May 19, 2003.)

307. Section 12.9: Good quote from Shakespeare's *A Midsummer Night's Dream*, Act III, scene i (1600):

> Snout: Doth the moon shine that night we play our play?
> Bottom: A calendar, a calendar! look in the almanac; find out moonshine, find out moonshine.
> Quince: Yes, it doth shine that night.

308. Section 12.9: Here is a more complete rendition of the observational Hebrew calendar, revised based on comments by Michael Deckers (August 16, 2005) and Irv Bromberg (August 18, 2005):

$$\textbf{phasis-on-or-after}\,(t, \mathit{locale}) \stackrel{\text{def}}{=} \tag{308-A}$$

$$\underset{d \geq \tau}{\text{MIN}} \left\{ \textbf{visible-crescent}\,(d, \mathit{locale}) \right\}$$

where

$$\mathit{date} = \lfloor t \rfloor$$

$$\mathit{mean} = \mathit{date} - \left\lfloor \frac{\textbf{lunar-phase}\,(\mathit{date}+1)}{360^\circ} \times \textbf{mean-synodic-month} \right\rfloor$$

$$\tau = \begin{cases} \mathit{date} & \textbf{if } \mathit{date} - \mathit{mean} \leq 3 \text{ and} \\ & \quad \text{not } \textbf{visible-crescent} \\ & \qquad (\mathit{date} - 1, \mathit{locale}) \\ \mathit{mean} + 29 & \qquad \textbf{otherwise} \end{cases}$$

$$\textbf{jaffa} \stackrel{\text{def}}{=} \tag{308-B}$$

$32^\circ 1' 60''$	$34^\circ 45'$	$0m$	2

$$\textbf{observational-hebrew-new-year}\,(\textit{g-year}) \stackrel{\text{def}}{=} \tag{308-C}$$

$$\textbf{phasis-on-or-after}\left(\lfloor \textit{equinox} \rfloor - \begin{cases} 14 & \textbf{if } \textit{equinox} < \textit{set} \\ 13 & \textbf{otherwise} \end{cases}, \textbf{jaffa}\right)$$

where

$$\textit{jan}_1 = \textbf{fixed-from-gregorian}\left(\boxed{\textit{g-year} \mid \textbf{january} \mid 1}\right)$$

$$\textit{equinox} = \textbf{solar-longitude-after}\,(\textit{jan}_1, \textbf{spring})$$

$$\textit{set} = \textbf{universal-from-standard}\left(\textbf{sunset}\,(\lfloor \textit{equinox} \rfloor, \textbf{jerusalem}), \textbf{jerusalem}\right)$$

$$\textbf{observational-hebrew-from-fixed}\,(\textit{date}) \stackrel{\text{def}}{=} \tag{308-D}$$

$$\boxed{\textit{year} \mid \textit{month} \mid \textit{day}}$$

where

$$\textit{crescent} = \textbf{phasis-on-or-before}\,(\textit{date}, \textbf{jerusalem})$$

$$\textit{g-year} = \textbf{gregorian-year-from-fixed}\,(\textit{date})$$

$$\textit{ny} = \textbf{observational-hebrew-new-year}\,(\textit{g-year})$$

$$\textit{new-year} = \begin{cases} \textbf{observational-hebrew-new-year}\,(\textit{g-year} - 1) & \textbf{if } \textit{date} < \textit{ny} \\ \textit{ny} & \textbf{otherwise} \end{cases}$$

$$\textit{month} = \text{round}\left(\frac{\textit{crescent} - \textit{new-year}}{29.5}\right) + 1$$

$$\textit{year} = \textbf{hebrew-from-fixed}\,(\textit{new-year})_{\textbf{year}} + \begin{cases} 1 & \textbf{if } \textit{month} \geq \textbf{tishri} \\ 0 & \textbf{otherwise} \end{cases}$$

$$day = date - crescent + 1$$

fixed-from-observational-hebrew (308-E)

$$\left(\boxed{year \mid month \mid day}\right) \stackrel{\text{def}}{=}$$

$$\textbf{phasis-on-or-before}\,(midmonth, \textbf{jerusalem}) + day - 1$$

where

$$year_1 = \begin{cases} year - 1 & \textbf{if } month \geq \textbf{tishri} \\ year & \textbf{otherwise} \end{cases}$$

$$start = \textbf{fixed-from-hebrew}\left(\boxed{year_1 \mid \textbf{nisan} \mid 1}\right)$$

$$g\text{-}year = \textbf{gregorian-year-from-fixed}\,(start + 60)$$

$$new\text{-}year = \textbf{observational-hebrew-new-year}\,(g\text{-}year)$$

$$midmonth = new\text{-}year + \text{round}\,(29.5 \times (month - 1)) + 15$$

$$\textbf{classical-passover-eve}\,(g\text{-}year) \stackrel{\text{def}}{=}$$ (308-F)

$$\textbf{observational-hebrew-new-year}\,(g\text{-}year) + 13$$

or in Lisp:

```
(defun phasis-on-or-after (tee locale)
   ;; TYPE (moment location) -> fixed-date
   ;; Closest fixed date on or after day of tee on the eve of which
   ;; crescent moon first became visible at locale.
   (let* ((date (floor tee))
          (mean ; Mean date of prior new moon.
           (- date
              (floor (* (/ (lunar-phase (1+ date)) (deg 360))
                        mean-synodic-month))))
          (tau ; Check if not visible yet on date.
           (if (and (<= (- date mean) 3)
                    (not (visible-crescent (1- date) locale)))
             date
             (+ mean 29)))) ; next new moon
     (next d tau (visible-crescent d locale))))
```

```
(defconstant jaffa (location (angle 32 1 60) (angle 34 45 0) (mt 0) 2))
```

```
(defun observational-hebrew-new-year (g-year)
   ;; TYPE gregorian-year -> fixed-date
   ;; Fixed date of Observational (classical)
   ;; Nisan 1 occurring in Gregorian year g-year.
   (let* ((jan1 (fixed-from-gregorian
                 (gregorian-date g-year january 1)))
          (equinox ; Moment (UT) of spring of g-year.
           (solar-longitude-after jan1 spring))
          (set ; Moment (UT) of sunset on day of equinox.
           (universal-from-standard
            (sunset (floor equinox) jerusalem)
            jerusalem)))
     (phasis-on-or-after
        (- (floor equinox) ; Day of equinox
            (if ; Spring starts before sunset.
                      (< equinox set) 14 13))
        jaffa)))
```

```
(defun observational-hebrew-from-fixed (date)
  ;; TYPE fixed-date -> hebrew-date
  ;; Observational Hebrew date (year month day)
  ;; corresponding to fixed date.
  (let* ((crescent ; Most recent new moon.
          (phasis-on-or-before date jerusalem))
         (g-year (gregorian-year-from-fixed date))
         (ny (observational-hebrew-new-year g-year))
         (new-year (if (< date ny)
                       (observational-hebrew-new-year
                        (1- g-year))
                     ny))
         (month (1+ (round (/ (- crescent new-year) 29.5))))
         (year (+ (standard-year (hebrew-from-fixed new-year))
                  (if (>= month tishri) 1 0)))
         (day (- date crescent -1)))
    (hebrew-date year month day)))
```

```
(defun fixed-from-observational-hebrew (h-date)
  ;; TYPE hebrew-date -> fixed-date
  ;; Fixed date equivalent to Observational Hebrew date.
  (let* ((month (standard-month h-date))
         (day (standard-day h-date))
         (year (standard-year h-date))
         (year1 (if (>= month tishri) (1- year) year))
         (start (fixed-from-hebrew (hebrew-date year1 nisan 1)))
         (g-year (gregorian-year-from-fixed
                  (+ start 60)))
         (new-year (observational-hebrew-new-year g-year))
         (midmonth ; Middle of given month.
          (+ new-year (round (* 29.5 (1- month))) 15)))
    (+ (phasis-on-or-before ; First day of month.
        midmonth jerusalem)
       day -1)))
```

```
(defun classical-passover-eve (g-year)
  (+ (observational-hebrew-new-year g-year) 13))
```

CHAPTER 13: THE PERSIAN CALENDAR

309. Page 211: The opening chapter quote is the translation by John C. Rolfe, Harvard University Press, 1946.

310. Page 211: Much historical information about the calendar, along with extensive astronomical details, can be found in "A Concise Review of the Iranian Calendar" by M. Heydari-Malayeri of the Paris Observatory; a preprint can be found at `http://wwwusr.obspm.fr/~heydari/divers/ir-cal-eng.html` (Courtesy of Paul Eggert, March 31, 2005.) Similarly, see "Iranische Zeitrechnungen" by Nikolaus A. Bär at `http://www.nabkal.de/irankal.html` (Courtesy of Oscar van Vlijmen, March 30, 2005.)

311. Possible quote (if we knew what it meant!):

    > Ah, but my Computations, People say, Have squared the Year to human compass, eh? If so, by striking from the Calendar Unborn To-morrow, and dead Yesterday.

    Omar Khayyam, *The Rubiayat*, LIX (translation by Edward Fitzgerald).

312. Page 211, lines −7 and −6: Change "the Zoroastrian. . . were" to "the Yazdergerd calendar, whose structure is described in Section 1.9, was". (Courtesy of Oscar van Vlijmen, September 18, 2003.)

313. Page 212, line 20. The Farsi for Āzar is incorrect; it should be آذر. (Courtesy of Armond Avanes, December 19, 2003.)

314. 3 Page 213, line 13: Change "true noon" to "true (apparent) noon". (Courtesy of Robert H. Douglass, June 15, 2002.)

315. Page 213, lines −12 and −11: We had read that the location used for the Persian calendar calculations was not fixed in the 1925 law. However, in a letter dated March 7, 1998 to E.M.R., Masahallah Ali-Ahyaie of Tehran said "The exact time of equinox (in Iranian Standard Time, i.e., U.T.+3.5 hours) is compared to the time of the apparent or true solar noon on longitude 52.5 E (3.5 hours). Then if the time of the equinox (to the nearest second) is before the true solar noon, that year is not a leap year. But if the equinox time happens exactly at the time of the true solar noon, as defined above, or after the true solar noon, that particular year will be considered as a leap year (366 days)." He repeated this claim in email messages on October 2–3, 2003, saying that the fixing of the longitude *is* part of the 1925 law. We ought to verify what the 1925 law says (a French translation of the law in `http://www.nabkal.de/irankal.html` does not specify the location). There are eight years in the range 0–3000 C.E. in which the difference causes the date of Persian new year to be be one day later: In 688, 1274, 1600, 1699, 2091, and 2157 Persian new year would occur on March 21 instead of March 20; in 721 and 1274 Persian new year would occur on March 22 instead of March 21.

316. 3 Page 213, line −7: Change "14.3" to "12.7".

317. 3 Page 216, line 19: Change "year of Persian cycle" to "year of the Persian cycle".

318. Page 216–219: The values $l = 682$ and $c = 2816$ in the ad hoc leap year rule are not relatively prime. This is not wrong, and it does not lead to any errors, but it means that some formulas can be simplified. We have $682 = 22 \times 31$ and $2816 = 22 \times 128$, we can just as well take $l = 31$ and $c = 128$ (keeping

$\Delta = 38$). In other words, the ad hoc rule is identical to Abdollahy's given on page 217! This enables smaller numbers in (13.7), (13.8) and the formula for y_{2820} on page 218. (For the latter, 1031337 is not divisible by 22, but the remainder can be ignored, as also follows by using (1.64) directly with the smaller c and l.) The last simplification is perhaps the most important, since it avoids the problem with 32-bit arithmetic without the work around at the top of page 219.

Moreover, recognizing the ad hoc rule as the 128-year subcycle makes it easy to see why it works: It works for all 21 128-year subcycles and the first 128 years of the final 132-year subcycle. It is also clear that it works for the next 3 years, so it works for all years but the last in the first 2820-year cycle (that is, 475–3293 A.P.). Furthermore, going backwards, it works for the final 32 years of the preceding cycle, and hence, as we state, for 443–3293 A.P.

All of this is (perhaps) unimportant because to regard Birashk's 2820-year cycle has never been officially adopted. The *Encyclopedia Iranica* gives several proposed arithmetic cycles for the medieval Jalali calendar, but does not mention any 2820-year cycle. Furthermore, Seyyid Taqizadeh [4] rejects arithmetic cycles altogether, claiming that the rule is astronomical, both for the medieval calendar and for the modern. (However, various cycles may have been used in the past, or present, for limited periods to implement or approximate the astronomical rule.) Like Birashk, Taqizadeh was an influential politican; he was a member of parliament and in some years a government minister, and a member of the parliament committee that introduced the new calendar 1925. So he ought to be relied upon for the intentions of the 1925 law.

Another simple arithmetic cycle used for the Persian calendar is a 33-year cycle with 8 leap years. The leap years are years 1, 5, 9, 13, 17, 22, 26, 30; this is (1.57) with $c = 33$, $l = 8$, $\Delta = 16$. At present, this cycle is in phase with the 33-year sub-subcycles in the current 128-year subcycle of Birashk's cycle—hence it agrees with both the 2820-cycle and the 128-year cycle for 1244–1403 A.P. (1865–2024). Because $3658/33 = 365.242424\cdots$, the 33-year cycle is an excellent approximation to the year measured from vernal equinox to vernal equinox, currently 365.242374 days; the 33-year cycle agrees with the astronomical calendar over an even longer period, 1046–1468 A.P. (1667–2089). (Courtesy of Svante Janson, July 17, 2003.)

319. (3) Page 217, line 12: Change "before 474 A.P." to "since 474 A.P.". (Courtesy of John Cross, February 20, 2002.)

CHAPTER 14: THE BAHÁ'Í CALENDAR

320. Page 223, chapter quote: Add a disclaimer footnote in Farsi:

نویسندگان لزوماً با نقطه نظرهای در عبارت موافقت ندارند.

(Courtesy of Nazli Goharian, July 25, 2002.)

321. (2) Page 223, Section 14.1, line 1: Delete "at sunset".

322. Page 223, lines -3 and -2 of the second printing only: The Farsi for Beauty and Perfection are corrupted. They should be جمال and کمال, respectively. (Courtesy of Anoop Chaturvedi, February 26, 2004.)

323. (2) Page 228, Section 14.3, line 1: Change "following" to "preceding".

CHAPTER 15: THE FRENCH REVOLUTIONARY CALENDAR

324. Page 233, line −7: May 6–23, 1871 was during the "Paris Commune," an insurrection that occurred after the collapse of Napoleon III's Second Empire.

325. Page 233, line −2: Give Fabre d'Églantine's real name, Philippe François Nazaire Fabre. Fix the index entries accordingly. (Courtesy of Michael H. Deckers, August 7, 2006.)

326. Page 234, lines 5–7: We have spelled the month names Nivôse, Pluviôse, and Ventôse in modern French. In the original proclamation establishing the calendar, these names are written without a circumflex. (Courtesy of Oscar van Vlijmen, April 3, 2005.)

327. Page 234, line −16: Add an acute accent to "Décadi". (Courtesy of Michael H. Deckers, August 7, 2006.)

328. (3) Page 235, lines 1–6: Replace these lines with:

(1) Fête de la Vertu (Virtue Day)
(2) Fête du Génie (Genius Day)
(3) Fête du Travail (Labor Day)
(4) Fête de l'Opinion (Opinion Day)
(5) Fête de la Récompense (Reward Day)
{(6) Jour de la Révolution (Revolution Day)}

(Courtesy of Claus Tondering, May 27, 2003.)

*329. (2) Page 235, line −10 through (15.1): Change "Paris is. . . (15.1)" to "The Paris Observatory is 48°50′11″ (= 175811°/3600) north, 2°20′15″ (= 187°/80) east, 27 meters above sea level, and 1 hour after Universal Time, so we define

$$\textbf{paris} \stackrel{\text{def}}{=} \boxed{48°50'11'' \mid 2°20'15'' \mid 27m \mid 1} \tag{15.1}$$

See also Errata 400 and 423. (Courtesy of Ehssan Dabal, April 10, 2002.)

330. (3) Page 235, line −7: Change "used local mean time," to "used apparent solar time,". (Courtesy of Robert H. Douglass, April 30, 2002.)

331. (2) Page 238, equation (15.9): This function was correct in our files, but somehow an old version got into the book! Replace (15.9) with:

$$\textbf{modified-french-from-fixed}\,(date) \stackrel{\text{def}}{=} \boxed{year \mid month \mid day} \tag{15.9}$$

where

$$approx = \left\lfloor \frac{date - \textbf{french-epoch} + 2}{\frac{1460969}{4000}} \right\rfloor + 1$$

$$
\begin{aligned}
\mathit{year} &= \begin{cases} \mathit{approx} - 1 & \textbf{if } \mathit{date} < \textbf{fixed-from-modified-french}\left(\begin{array}{|c|c|c|}\hline \mathit{approx} & 1 & 1 \\ \hline\end{array}\right) \\ \mathit{approx} & \textbf{otherwise} \end{cases} \\
\mathit{month} &= \left\lfloor \frac{\mathit{date} - \textbf{fixed-from-modified-french}\left(\begin{array}{|c|c|c|}\hline \mathit{year} & 1 & 1 \\ \hline\end{array}\right)}{30} \right\rfloor + 1 \\
\mathit{day} &= \mathit{date} - \textbf{fixed-from-modified-french}\left(\begin{array}{|c|c|c|}\hline \mathit{year} & \mathit{month} & 1 \\ \hline\end{array}\right) + 1
\end{aligned}
$$

See also Erratum 424.

CHAPTER 16: THE CHINESE CALENDAR

332. (3) Page 242, line 19: Change "(12.4)" to "(12.25)". (Courtesy of Robert H. Douglass, June 13, 2002.)

333. (2) Page 243, line −11: The second Chinese character of Chŭshŭ should be 暑, the same as in the second and third lines above it. (Courtesy of Helmer Aslaksen, January 14, 2002.)

334. Page 243, lines 7 and 9: Our Japanese transliterations are not in the present commonly-used form. Change "Kēchitsu" to "Keichitsu" and "Sēmē" to "Seimei" (Courtesy of Eiiti Wada, February 27, 2006.)

335. Page 245, **current-minor-solar-term**. This function, which we never needed, is wrong; we do need it for **chinese-year-marriage-augury** in Erratum 349. Replace it with

$$\textbf{current-minor-solar-term}\,(\mathit{date}) \stackrel{\text{def}}{=} \tag{335-A}$$

$$\left(3 + \left\lfloor \frac{s - 15^\circ}{30^\circ} \right\rfloor\right) \text{ amod } 12$$

where

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

or in Lisp

```
(defun current-minor-solar-term (date)
  ;; TYPE fixed-date -> integer
  ;; Last Chinese minor solar term (jieqi) before date.
  (let ((s (solar-longitude
             (universal-from-standard
```

```
                date
                (chinese-location date)))))
     (adjusted-mod (+ 3 (quotient (- s (deg 15)) (deg 30)))
                   12)))
```

336. Page 246, **chinese-winter-solstice-on-or-before**, line 5: Change "**winter** $\leq$" to "**winter** $<$". This change, while theoretically needed for fidelity to the algorithm, has no known effect on the calculations of the Chinese, Japanese, or Korean calendars—to have such any effect, one would have to have either $date + 1$ be *exactly* the winter solstice, or *approx* be *exactly* $date + 1$; the likelyhood of either case occurring is negligible. (Courtesy of Michael H. Deckers, August 7, 2006.)

**337. (2) Page 246. Because of Erratum 269, the calculated dates for Chinese new moons can be wrong very rarely (the only known instance is in January, 2481), leading to failure of the Chinese calendar algorithms (for dates in January 30, 2481–February 17, 2482). (Courtesy of Nigel Richards, January 30, 2002.)

338. (3) Page 249, Figure 16.1: The light gray arrow from month 12 to leap 12 should be labeled 0.000 and the gray arrow from month 9 to leap 9 should be labeled 0.008. The last sentence of the caption should read "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 [1] for the Chinese calendar for the thousand years 1645–2644." The corrected figure and caption are shown in Figure 338-A. (Courtesy of Svante Janson, January 31, 2003.)

*339. (2) Page 257, formula (16.19): The boxed arguments to **chinese-name-difference** should be, $\boxed{\textit{stem}_1 \mid \textit{branch}_1}$ and $\boxed{\textit{stem}_2 \mid \textit{branch}_2}$, respectively. This is an error in the automatic translation. (Courtesy of John Cross, February 20, 2002.)

340. Page 258, equations (16.21) and (16.23): Explain that (16.21), **chinese-month-name-epoch**, is the name of of the zeroth elapsed month on the Chinese calendar, and (16.23), **chinese-day-name-epoch**, is the Chinese name for R.D. 0. (Courtesy of Robert H. Douglass, May 15, 2002.)

341. (2) Page 258, line −13: Change "(1.45)" to "(1.42)".

342. (2) Page 258, line −3: Change "1 a.m. to 1 a.m." to "11 p.m. to 11 p.m." (Courtesy of Robert H. Douglass, April 29, 2002.)

343. Page 258, last line (line −2 in the first printing): Change "everyday" to "every day". (Courtesy of Nicholas J. Cox, January 16, 2006.)

344. Page 259, line 8: For example, the Chinese year 4664 (overlapping Gregorian years 1966–67) was a leap year, but 19 years later Chinese year 4683 (overlapping Gregorian years 1985–86) was a common year.

345. Section 16.6: Many interesting holiday customs are described in Tun Li-Ch'en, *Annual Customs and Festivals in Peking*, translated and annotated by Derk Bodde, Henri Vetch, Peiping, 1936 and in *The Moon Year*, Juliet Bredon and Igor Mitrophanow, Kelly & Walsh, Limited, Shanghai, 1927.

346. Page 260: Chinese New Year falls in the range January 21 through February 21 on the Gregorian calendar. Figure 346-A shows the relative frequency with which it falls on the various Gregorian dates for 1645–2644. (Courtesy of Helmer Aslaksen, September 10, 2004.)

347. (2) Page 260, line −13: Change "winter of year 1" to "winter of year 0". (Courtesy of Robert H. Douglass, April 26, 2002.)

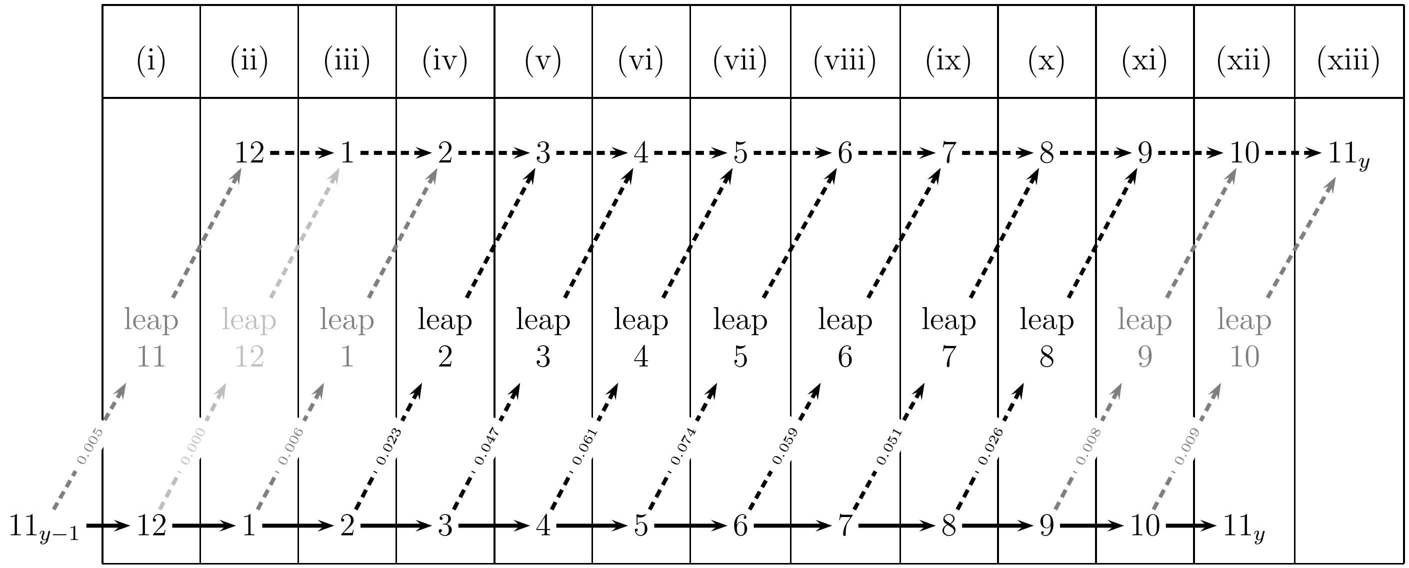

Figure 338-A: The theoretical possible numberings of the lunar months (i)–(xiii) for the Chinese calendar in the solstice to solstice period of year y. Each column corresponds to the new moon beginning a lunar month and each column contains the number of that lunar month. The winter solstice of Gregorian 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. 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 [1] for the Chinese calendar for the thousand years 1645–2644.

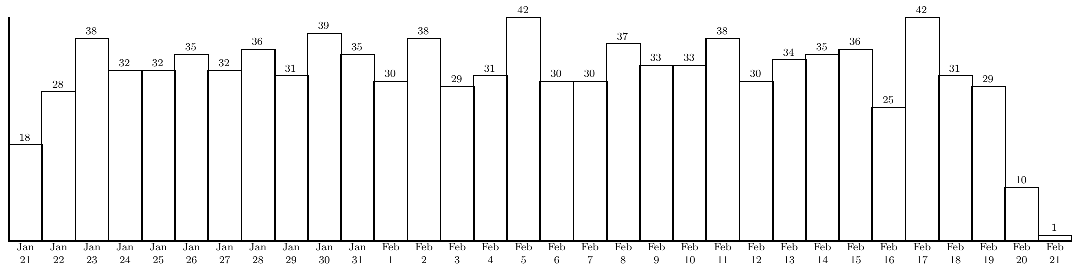

Figure 346-A: Distribution of Chinese New Year dates, 1645–2644 (courtesy of Helmer Aslaksen).

348. Page 260, line −1: Add "Gautama Buddha's Birthday (observed by washing his statue) 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 Thailand and some other countries it is celebrated on the 15th of the month, in Japan it is celebrated on April 8, and in India and Nepal on the 15th of the Hindu lunar month of Vaiś/=akkha."

349. Page 261: 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, 1991, 1994, 1997, 2000, 2002, 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; 1990, 1993, 1995, 1998, 2001, 2004, 2006, and 2009 are such years [*Shanghai Star*, February 21, 2002]. Years missing the first Lìchūn but containing the second are "blind"; years containing the first but not the second are called "bright". (Courtesy of Nicolas Herran, January 9, 2005.) Letting 3 mean a double-bright year, 2 a bright year, 1 a blind year, and 0 a widow year, we determine the character of a year on the Chinese calendar with

$$\textbf{chinese-year-marriage-augury}\,(\textit{cycle}, \textit{year}) \stackrel{\text{def}}{=} \tag{349-A}$$

$$\begin{cases} 0 & \textbf{if } \textit{first-minor-term} = 1 \text{ and} \\ & \quad \textit{next-first-minor-term} = 12 \\ 1 & \textbf{if } \textit{first-minor-term} = 1 \text{ and} \\ & \quad \textit{next-first-minor-term} \neq 12 \\ 2 & \textbf{if } \textit{first-minor-term} \neq 1 \text{ and} \\ & \quad \textit{next-first-minor-term} = 12 \\ 3 & \qquad\qquad \textbf{otherwise} \end{cases}$$

where

$$\textit{new-year} = \textbf{fixed-from-chinese}\left(\begin{array}{|c|c|c|c|c|}\hline \textit{cycle} & \textit{year} & 1 & \text{false} & 1 \\ \hline\end{array}\right)$$

$$c = \begin{cases} \textit{cycle} + 1 & \textbf{if } \textit{year} = 60 \\ \textit{cycle} & \textbf{otherwise} \end{cases}$$

$$y = \begin{cases} 1 & \textbf{if } \mathit{year} = 60 \\ \mathit{year} + 1 & \textbf{otherwise} \end{cases}$$

$$\mathit{next\text{-}new\text{-}year} = \textbf{fixed-from-chinese}\left(\begin{array}{|c|c|c|c|c|}\hline c & y & 1 & \text{false} & 1 \\ \hline \end{array}\right)$$

$$\mathit{first\text{-}minor\text{-}term} = \textbf{current-minor-solar-term}(\mathit{new\text{-}year})$$

$$\mathit{next\text{-}first\text{-}minor\text{-}term} = \textbf{current-minor-solar-term}(\mathit{next\text{-}new\text{-}year})$$

or in Lisp

```
(defun chinese-year-marriage-augury (cycle year)
  ;; TYPE (chinese-cycle chinese-year) ->  {0,1,2,3}
  ;; The marriage augury type of Chinese year in cycle.
  ;; 0 means lichun does not occur (widow or double-blind
  ;; years), 1 means it occurs once at the end (blind), 2
  ;; means it occurs once at the start (bright), and 3 means
  ;; it occurs twice (double-bright or double-happiness).
  (let* ((new-year (fixed-from-chinese
                    (chinese-date cycle year 1 false 1)))
         (c (if (= year 60); next year's cycle
                (1+ cycle)
              cycle))
         (y (if (= year 60); next year's number
                1
              (1+ year)))
         (next-new-year (fixed-from-chinese
                         (chinese-date c y 1 false 1)))
         (first-minor-term
          (current-minor-solar-term new-year))
         (next-first-minor-term
          (current-minor-solar-term next-new-year)))
    (cond
     ((and (= first-minor-term 1)        ; no lichun at start...
           (= next-first-minor-term 12)) ; ...or at end
      0)    ; double blind
     ((and (= first-minor-term 1)        ; no lichun at start...
           (/= next-first-minor-term 12)); ...only at end
      1)     ; blind
     ((and (/= first-minor-term 1)       ; lichun at start...
           (= next-first-minor-term 12)) ; ... not at end
      2)     ; bright
     (t 3)))); double-bright             lichun at start and end
```

350. Page 262–263: Our Japanese transliterations are not in the present commonly used form. Moreover, the nengō changes when the emperor dies, even if that in the middle of the year. Thus the table of eras should read:

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, 1911
Keio (慶應)	April 7, 1865–December 31, 1866

(Courtesy of Eiiti Wada, February 27, 2006.)

351. Page 263: Add to the Japanese holidays that Buddha's Birthday is the "flower Festival"celebrated on April 8.

352. Page 263: Add the following discussion of the Korean calendar which is based on material provided by Dr. Young Sook Ahn and Dr. Sangmo Tony Sohn of the Korea Astronomy & Space Science Institute (KASI). Thanks to Jungmin Lee for the Korean typesetting.

During the Chosun dynasty, from 1653 until 1896, 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. 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; 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:

$$\textbf{korean-location}\,(t) \stackrel{\text{def}}{=} \qquad (352\text{-A})$$

$$\boxed{37^\circ 34' \mid 126^\circ 58' \mid 0m \mid z}$$

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

$$\textbf{korean-year}\,(cycle, year) \stackrel{\text{def}}{=} 60 \times cycle + year - 364 \qquad (352\text{-B})$$

In Korean the solar terms are as follows (the translations are the same as those given in Table 16.1 on page 243):

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 the 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 the 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), 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.

The most reliable tables of the Korean calendar for the modern era are *Man Se Ryuk* by researchers of the Korean Astronomy Observatory, published by Myoung Moon Dang, 2004. There tables, however have two peculiarities: All calculations in the book 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** above gives perfect agreement with *Man Se Ryuk* for all dates after 1911 *except* March 21, 1954 until August 9, 1961.

Or, in Lisp:

```
(defun korean-location (tee)
  ;; TYPE moment -> location
```

```
  ;; Location for Korean calendar is Seoul city hall.
  ;; Time zone has changed over the years.
  (let* ((z (cond
             ((< tee
                 (fixed-from-gregorian
                  (gregorian-date 1908 april 1)))
              ;; local mean time for longitude 126 deg 58 min
              3809/450)
             ((< tee
                 (fixed-from-gregorian
                  (gregorian-date 1912 january 1)))
              8.5)
             ((< tee
                 (fixed-from-gregorian
                  (gregorian-date 1954 march 21)))
              9)
             ((< tee
                 (fixed-from-gregorian
                  (gregorian-date 1961 august 10)))
              8.5)
             (t 9))))
    (location (angle 37 34 0) (angle 126 58 0) (mt 0) z)))
```

```
(defun korean-year (cycle year)
  ;; TYPE (chinese-cycle chinese-year) -> korean-year
  ;; Equivalent Korean year to Chinese cycle and year
  (+ (* 60 cycle) year -364))
```

353. Page 263: Add the following discussion of the Vietnamese calendar which is based on material provided by Hồ Ngọc Đức of the Institut für Informationssysteme, Universität zu Lübeck. The history of Vietnamese calendars is discussed in Lê Thành Lân's *Vietnamese Old-Time Calendars*, Band 6, SEACOM Studien zur Südostasienkunde, SEACOM, Berlin, 2003. Thanks to Trần Đức Ngọc for the Vietnamese typesetting.

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):

$$\textbf{vietnamese-location}\,(t) \stackrel{\text{def}}{=} \qquad (353\text{-A})$$

$$\boxed{21^\circ 2'}\boxed{105^\circ 51'}\boxed{12m}\boxed{z}$$

where

$$z = \begin{cases} 8 & \textbf{if } t < \textbf{fixed-from-gregorian}\left(\boxed{1968}\boxed{\textbf{january}}\boxed{1}\right) \\ 7 & \textbf{otherwise} \end{cases}$$

or in Lisp

```
(defun vietnamese-location (tee)
  ;; TYPE moment -> location
  ;; Location for Vietnamese calendar is Hanoi.
  ;; Time zone has changed over the years.
  (let* ((z (if (< tee
                   (fixed-from-gregorian
                    (gregorian-date 1968 january 1)))
                8
              7)))
    (location (angle 21 2 0) (angle 105 51 0) (mt 12) z)))
```

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 formulae/tables, so it differs from the Chinese calendar on several occasions, especially in the period 1645–1813. The calendar as computed by our functions has complete agreement with Đức's calculations of for 1891–2100. As is in the case of the historical Chinese calendar compared to our calculations, our code differs from Đức's calculations occasionally from 1800–1890, but all Vietnamese New Year dates agree.

The years are not counted, but named. The names of the stems and branches are translations of the Chinese names. The animals are different from the ones in 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 branches

(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 sexadecimal system as on the Chinese calendar or by the name of 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) never called "the first month". Leap months are indicated with "nhuận", for example "Tháng Tám nhuận".

354. (3) Page 263, line 2 of reference [1]: Delete "maunscript,". A more recent version of Helmer Aslaksen's paper can be found at `http://www.math.nus.edu.sg/aslaksen/calendar/cal.pdf`. A shortened version was published as "When is Chinese New Year?," *Griffith Observer* **66**, 2 (February, 2002), 1–17.

CHAPTER 17: THE MODERN HINDU CALENDARS

355. Chapter 17: Make sure all function names begin **hindu-**. For example, **true-position**, **lunar-day**, and **lunar-day-after** are all missing that prefix.

356. Chapter 17: Give all the rational values for the Hindu calendars as decimal numbers as well as rational numbers (we do this only for some), but make it clear that they are defined in the texts as the rational values.

357. (2) Page 269, line 1 of footnote 3: Replace this line with "From 1300 C.E. until 1980 C.E., only Mārgaśīrsha (in the years beginning in 1315, 1380, 1521), Pausha (1334, 1399, 1540, 1681, 1822, 1963), and Māgha (1418, 1475) have been skipped. The omission of Māgha (and concomitant intercalation of Phālguna) in 1418 is not listed in [9] (only 4 minutes separate the start of the solar and lunar months). Also, according". (Courtesy of Akshay Regulagedda, September 6, 2002.)

358. Chapter 17: Mention that today the Hindu solar year usually begins with Vaiśākha, the second month of the lunar year.

359. Page 270, Table 17.1 caption, lines 2–3: Change "Greek letters" to "Greek letters (and the number 35) in the middle column".

360. (3) Page 272, line 14: The "+" sign should be "−". (Courtesy of Svante Janson, July 5, 2003.)

361. (3) Page 272, line −15: Replace "for angles given in degrees" with "for angles given in units of 225′".

362. (3) Page 272, line −4: Replace the equation with

$$\sin(n\alpha) = n\alpha - \frac{1}{225}\sum_{i<n}(n-i)\sin(i\alpha),$$

(Courtesy of Svante Janson, July 5, 2003.)

363. Page 272, footnote 4: Add at end "Ptolemaic astronomy also included eccentric orbits to account for the off-center position of Earth and equants to model the uneven speeds."

364. (3) Page 272, bottom line: Instead of "precise" say "quite accurate". (Courtesy of Svante Janson, July 5, 2003.)

365. (2) Page 272, bottom line: Replace "$\approx 1/223.5$" with "$\approx 1/233.5$". (Courtesy of Robert H. Douglass, April 29, 2002.)

366. (3) Page 273, caption, line 10: There is a missing "−" sign after the second "=" sign. (Courtesy of Svante Janson, July 5, 2003.)

367. (2) Page 275, line 16: Replace "(= 15,779,178,828 days)" with "(= 1,577,917,828 days)". (Courtesy of Robert H. Douglass, April 24, 2002.)

368. Page 277, **hindu-new-moon-before**: This function is misnamed since it stops bisecting once it has determined the zodiac sign. A better name would be **hindu-new-moon-sign-before**. (Courtesy of Helmer Aslaksen, August 19, 2002.)

369. Page 277, **hindu-new-moon-before**: The value $\epsilon = 2^{-1000}$ should be replaced by a very small, but representable, positive real number when used in a programming environment that does not support arbitrary-precision rational arithmetic. (Courtesy of Michael H. Deckers, August 7, 2006.)

370. (2) Page 279, last line on page of **fixed-from-hindu-solar (17.22): Change $\tau - 1$ to $\tau - 2$ in the lower limit of the MIN.

371. (2) Page 280, line −8: Change "which begins in 57 C.E.," to "which begins in 58 B.C.E.,". (Courtesy of John Cross, April 24, 2002.)

372. Page 280–281, **hindu-lunar-from-fixed**: A more robust version of **hindu-lunar-from-fixed**, one which calculates the year number correctly regardless of which month may be expunged, is

$$\textbf{hindu-lunar-from-fixed}\,(date) \stackrel{\text{def}}{=} \qquad (17.24)$$

year	*month*	*leapmonth*	*day*	*leapday*

where

$$
\begin{aligned}
critical &= \textbf{hindu-sunrise}\,(date) \\
day &= \textbf{lunar-day}\,(critical) \\
leapday &= day = \textbf{lunar-day} \\
&\qquad (\textbf{hindu-sunrise}\,(date-1)) \\
last\text{-}new\text{-}moon &= \textbf{hindu-new-moon-before}\,(critical) \\
next\text{-}new\text{-}moon &= \textbf{hindu-new-moon-before} \\
&\qquad (\lfloor last\text{-}new\text{-}moon \rfloor + 35) \\
solar\text{-}month &= \textbf{hindu-zodiac}\,(last\text{-}new\text{-}moon) \\
leapmonth &= solar\text{-}month \\
&\qquad = \textbf{hindu-zodiac}\,(next\text{-}new\text{-}moon) \\
month &= (solar\text{-}month + 1) \ \ \text{amod} \ \ 12 \\
year &= \textbf{hindu-calendar-year}\left(\left\{ \begin{array}{ll} date + 180 & \textbf{if } month \le 2 \\ date & \textbf{otherwise} \end{array} \right\}\right) \\
&\qquad - \textbf{hindu-lunar-era}
\end{aligned}
$$

or in Lisp (page 387):

```
(defun hindu-lunar-from-fixed (date)
   ;; TYPE fixed-date -> hindu-lunar-date
   ;; Hindu lunar date equivalent to fixed date.
   (let* ((critical (hindu-sunrise date)) ; Sunrise that day.
          (day (lunar-day critical)); Day of month.
          (leapday             ; If previous day the same.
           (= day (lunar-day (hindu-sunrise (- date 1)))))
          (last-new-moon
           (hindu-new-moon-before critical))
          (next-new-moon
           (hindu-new-moon-before
            (+ (floor last-new-moon) 35)))
          (solar-month         ; Solar month name.
           (hindu-zodiac last-new-moon))
          (leapmonth       ; If begins and ends in same sign.
           (= solar-month (hindu-zodiac next-new-moon)))
          (month                       ; Month of lunar year.
           (adjusted-mod (1+ solar-month) 12))
          (year ; Solar year at end of month.
           (- (hindu-calendar-year
               (if (<= month 2) ; date might precede solar new year.
                   (+ date 180)
                 date))
              hindu-lunar-era)))
     (hindu-lunar-date year month leapmonth day leapday)))
```

(Courtesy of Svante Janson, July 2, 2003.)

373. 2 Page 281, lines 16–17: Change "year number *year*" to "K.Y. year". (Courtesy of John Cross, April 24, 2002.)

*374. 2 Page 282, lines 3–4: The first occurrence of $leapday_1$ and $leapday_2$ should be day_1 and day_2, respectively. This is an error in the automatic translation.

*375. 2 Page 282, lines −4 and −8: The boxed date should read | *year* | *month* | *leap* | *day* | *leapday* |. This is an error in the automatic translation.

376. Page 283: Explain approximation.

377. 2 Page 283, top line: There is a minus sign missing between "*approx*" and "$\frac{1}{360°}$". This error was introduced somehow by the compositor. (Courtesy of Richard P. Kelly, December 3, 2001.)

378. Page 286, line 3: Change "civil" to "apparent".

379. Page 286, equation (17.34): The sign of **hindu-equation-of-time** should be reversed for consistency with modern usage (see the parenthetical note about sundials at bottom of page 176), as in the astronomical **equation-of-time** on page 177. **hindu-sunrise**, equation (17.35), must change correspondingly.

380. Page 286, line 15: Change "affect" to "affects".

381. Page 287, line −3: A correspondent claims that the Hindu sunrise is defined by the center of the Sun, not its upper limb, so we should use:

$$\textbf{alt-hindu-sunrise}\,(date) \stackrel{\text{def}}{=} \qquad \text{(381-A)}$$

$$\frac{1/60}{24} \times \text{round}\,(rise \times 24 \times 60)$$

where

$$rise \quad = \quad \textbf{dawn}\,(date, \textbf{hindu-locale}, 0^\circ)$$

Or, in Lisp (page 390):

```
(defun alt-hindu-sunrise (date)
  ;; TYPE fixed-date -> rational-moment
  ;; Hindu sunrise at Hindu locale on date ,
  ;; rounded to nearest minute, as a rational number.
  (let* ((rise (dawn date hindu-locale (deg 0))))
    (* 1/24 1/60 (round (* rise 24 60)))))
```

We also take refraction into account (and the radius of Earth), which may or may not be used by Hindus today.

382. Page 289, **hindu-solar-longitude-after**: Change the variables u and l to a and b, respectively. (Courtesy of Michael H. Deckers, August 7, 2006.)

383. (2) Page 292, line 9: Delete "of".

384. Page 292, end of the first paragraph: Add "Buddha's Birthday is celebrated on the 15th of the Hindu lunar month of Vaiś/=akkha."

385. Page 292, line 18: Insert a comma after "*nakṣatra*". (Courtesy of Nicholas J. Cox, January 16, 2006.)

386. Page 292, **lunar-station**, formula (17.41) For clarity, replace the denominator 800°/60 with 800' (800 arcminutes). In the code (page 390), that would be

```

                    (angle 0 800 0)))))
```

(Courtesy of Svante Janson, July 5, 2003.)

387. (3) Page 292, line −7: Remove the spurious third argument by changing **lunar-day-after**$(d, (n+1)/2, \varepsilon)$ to **lunar-day-after**$(d, (n+1)/2)$. (Courtesy of Svante Janson, July 5, 2003.)

388. Page 293, last line of Table 17.3: Interchange the last two entries, Nāga and Catuṣpada. (Courtesy of Shriramana Sharma, December 1, 2005.)

389. Page 294, **yoga**, formula (17.43): For clarity, divide by $800'$ (800 arcminutes) instead of multiplying by 60/800 and remove the degree sign from the 27. (Courtesy of Svante Janson, July 5, 2003.)

390. Section 17.5: Determining the fixed date of a Hindu lunar holiday is not easy because of expunged days and months. The following functions do it correctly (these functions are not in the book, and they do not follow our usual naming conventions, but we needed them for *Calendrical Tabulations: 1900–2200*):

$$\textbf{almost-equal}\,(h, l) \quad \stackrel{\text{def}}{=} \qquad \text{(390-A)}$$

$$h_{\textbf{leap-month}} = l_{\textbf{leap-month}} \text{ and } h_{\textbf{month}} = l_{\textbf{month}}$$

$$\textbf{adjusted-hindu}\,(h) \stackrel{\text{def}}{=} \tag{390-B}$$

$$\begin{cases} d & \textbf{if almost-equal}\,(h, l) \text{ and } \{\text{not } h_{\textbf{leap-day}} \text{ or } l_{\textbf{leap-day}}\} \\ d-1 & \textbf{if } \{\textbf{almost-equal}\,(h, l) \text{ and } h_{\textbf{leap-day}} \text{ and not } l_{\textbf{leap-day}}\} \text{ or} \\ & \quad \textbf{almost-equal}\,(h, k) \\ \textbf{bogus} & \textbf{otherwise} \end{cases}$$

where

$$d = \textbf{fixed-from-hindu-lunar}\,(h)$$

$$l = \textbf{hindu-lunar-from-fixed}\,(d)$$

$$k = \textbf{hindu-lunar-from-fixed}\,(d-1)$$

$$\textbf{expunged}\left(\boxed{\textit{year} \mid \textit{month}}\right) \stackrel{\text{def}}{=} \tag{390-C}$$

$$\textit{month} \neq \textbf{hindu-lunar-from-fixed}\,(\textit{date})_{\textbf{month}}$$

where

$$\textit{date} = \textbf{fixed-from-hindu-lunar}\left(\boxed{\textit{year} \mid \textit{month} \mid \text{false} \mid 15 \mid \text{false}}\right)$$

$$\textbf{hindu-lunar-holiday}\,(\textit{year}, m, l, d, a) \stackrel{\text{def}}{=} \tag{390-D}$$

$$\left\{\begin{array}{ll} \langle \textit{date}_1 \rangle & \textbf{if } \textit{date}_1 \neq \textbf{bogus} \text{ and} \\ & \quad \textit{jan}_1 \leq \textit{date}_1 \leq \textit{dec}_{31} \text{ and not } \textbf{expunged}\,(\textit{try}_1) \\ \langle\,\rangle & \textbf{otherwise} \end{array}\right\}$$
$$\Vert \left\{\begin{array}{ll} \langle \textit{date}_2 \rangle & \textbf{if } \textit{date}_2 \neq \textbf{bogus} \text{ and} \\ & \quad \textit{jan}_1 \leq \textit{date}_2 \leq \textit{dec}_{31} \text{ and} \\ & \quad \text{not } \textbf{expunged}\,(\textit{try}_2) \\ \langle\,\rangle & \textbf{otherwise} \end{array}\right\}$$

where

$$\textit{jan}_1 = \textbf{fixed-from-gregorian}\left(\boxed{\textit{year} \mid \textbf{january} \mid 1}\right)$$

$$\textit{dec}_{31} = \textbf{fixed-from-gregorian}\left(\boxed{\textit{year} \mid \textbf{december} \mid 31}\right)$$

$$year_1 = \textbf{hindu-lunar-from-fixed}\,(jan_1)_{\textbf{year}}$$

$$year_2 = \textbf{hindu-lunar-from-fixed}\,(dec_{31})_{\textbf{year}}$$

$$try_1 = \begin{array}{|c|c|c|c|c|}\hline year_1 & m & l & d & \mathbf{t} \\ \hline \end{array}$$

$$try_2 = \begin{array}{|c|c|c|c|c|}\hline year_2 & m & l & d & \mathbf{t} \\ \hline \end{array}$$

$$date_1 = \textbf{adjusted-hindu}\,(try_1)$$

$$date_2 = \begin{cases} \textbf{adjusted-hindu}\,(try_2) & \textbf{if } year_1 \neq year_2 \\ \textbf{bogus} & \textbf{otherwise} \end{cases}$$

or in Lisp:

```
(defun almost-equal (h l)
  (and (equal (hindu-lunar-leap-month h) (hindu-lunar-leap-month l))
       (= (hindu-lunar-month h) (hindu-lunar-month l))))
```

```
(defun adjusted-hindu (h)
  (let* ((d (fixed-from-hindu-lunar h))
         (l (hindu-lunar-from-fixed d))
         (k (hindu-lunar-from-fixed (1- d))))
    (cond ((and (almost-equal h l)
                (or (not (hindu-lunar-leap-day h))
                    (hindu-lunar-leap-day l)))
           d)
          ((or (and (almost-equal h l)
                    (hindu-lunar-leap-day h)
                    (not (hindu-lunar-leap-day l)))
               (almost-equal h k))
           (1- d))
          (t bogus))))
```

```
(defun expunged (h-date)
  (let* ((year (hindu-lunar-year h-date))
         (month (hindu-lunar-month h-date))
         (date (fixed-from-hindu-lunar
                (hindu-lunar-date year month false 15 false))))
    (/= month (hindu-lunar-month (hindu-lunar-from-fixed date)))))
```

```
(defun hindu-lunar-holiday (year m l d a)
  (let* ((jan1 (fixed-from-gregorian (gregorian-date year january 1)))
         (dec31 (fixed-from-gregorian (gregorian-date year december 31)))
         (year1 (hindu-lunar-year (hindu-lunar-from-fixed jan1)))
         (year2 (hindu-lunar-year (hindu-lunar-from-fixed dec31)))
         (try1 (hindu-lunar-date year1 m l d t))
         (try2 (hindu-lunar-date year2 m l d t))
         (date1 (adjusted-hindu try1))
```

```
          (date2 (if (/= year1 year2)
                     (adjusted-hindu try2)
                   bogus)))
     (append (if (and (not (equal date1 bogus))
                      (<= jan1 date1 dec31)
                      (not (expunged try1)))
                 (list date1)
               nil)
             (if (and (not (equal date2 bogus))
                      (<= jan1 date2 dec31)
                      (not (expunged try2)))
                 (list date2)
               nil))))
```

BACKMATTER & COMPACT DISK

391. (3) Page 304, line −6: Delete the line for the type *julian-centuries*. (Courtesy of Jonathan Leffler, April 8, 2002.)

392. (3) Page 306, line 2: The type of *roman-year* should be *nonzero-integer*.

393. (2) Page 306, line 11: The entry in the "Type or Range" column for *time* is missing; it should be ⟨*hour*, *minute*, *second*⟩. (Courtesy of Jonathan Leffler, April 8, 2002.)

394. Page 306, line 12: Delete the type *weekday*.

395. Pages 306–314: Change all 16 occurrences of the type *weekday* to the type *day-of-week*.

396. (2) Page 309, line 19 (result type of **hindu-day-count**): Change *rational-moment* to *integer*.

397. (2) Page 311, line 17 (type of **moment-of-depression**): Change parameter types to ⟨*moment*, *location*, *angle*⟩. (Courtesy of Ehssan Dabal, April 10, 2002.)

398. (3) Page 312, line 7: **sacred-wednesdays** should have parameter type ⟨*fixed-date, fixed-date*⟩ not *gregorian-year*. (Courtesy of Jonathan Leffler, March 22, 2002.)

399. (3) Page 313, line −11 (value of **mecca**): Change value to ⟨6427/300, 11947/300, 298, 3⟩. See also Errata 233 and 414. (Courtesy of Robert A. Saunders, April 8, 2003.)

*400. (2) Page 313, line −3 (value of **paris**): Change value to ⟨175811/3600, 187/80, 27, 1⟩. See See also Errata 329 and 423. (Courtesy of Ehssan Dabal, April 10, 2002.)

401. (2) Page 317, second paragraph: Change "Please bear in mind. . . output." to "Please bear in mind the limits of the License and that the copyright on this book includes the code."

402. Page 318, line 13: Add "The predicate `evenp` tests whether an integer is even."

403. Page 320, line 11: We should take advantage of the case-insensitive nature of Lisp and use `L0` instead of the confusing looking lower case ell. (Courtesy of Oscar van Vlijmen, May 8, 2002.)

404. Page 322, line 14: Change "Two additional. . . searching:" to read "Two additional `sum`-like macros are used for searching; the first implements the MIN function, equation (1.19), and the second implements MAX, equation (1.20):".

405. Page 324, line 2 of `kday-on-or-before`, `kday-on-or-after`, `kday-nearest`, `kday-after`, and `kday-before`: Change the type `weekday` to `day-of-week`. (Courtesy of Jonathan Leffler, March 28, 2002.)

406. Pages 328–329, line 2 of `nth-kday`, `first-kday`, and `last-kday`: Change the type `weekday` to `day-of-week`. (Courtesy of Jonathan Leffler, March 28, 2002.)

407. (3) Page 329, line 2 of both `first-kday` and `last-kday`: There is a missing closing parenthesis after the `gregorian-date`. (Courtesy of Jonathan Leffler, April 1, 2002.)

408. (3) Page 338, lines 3–4 of `molad`: In the correction made in the second printing the variables *h-month* and *h-year* were not italicized.

*409. Page 338 of the second printing only, `long-marheshvan?`: C.U.P botched the second printing, omitting this function at the bottom of the page. The function is

```
(defun long-marheshvan? (h-year)
  ;; TYPE hebrew-year -> boolean
  ;; True if Marheshvan is long in Hebrew year.
  (member (days-in-hebrew-year h-year) (list 355 385)))
```

This code is on the revised CD. (Courtesy of Anoop Chaturvedi, February 26, 2004.)

410. (3) Page 343, line 3 of `alt-orthodox-easter`: Change "alternate" to "alternative". (Courtesy of Jonathan Leffler, April 25, 2002.)

411. (2) Page 344, line 2 of `hindu-day-count`: Change `hindu-moment` to `integer`.

*412. Page 345 of the second printing only, `arya-lunar-day`: C.U.P botched the second printing, omitting this function at the bottom of the page. The function is

```
(defconstant arya-lunar-day
  ;; TYPE rational
  ;; Length of Old Hindu lunar day.
  (/ arya-lunar-month 30))
```

This code is on the revised CD. (Courtesy of Anoop Chaturvedi, February 26, 2004.)

413. Page 351, line 2 of `bali-week-from-fixed`: There is a missing blank space before the `->`. (Courtesy of Jonathan Leffler, March 28, 2002.)

414. (3) Page 354, `mecca`: Replace with

```
(defconstant mecca
  ;; TYPE location
  ;; Location of Mecca.
  (location (angle 21 25 24) (angle 39 49 24) (mt 298) 3))
```

See also Errata 233 and 399. (Courtesy of Robert A. Saunders, April 8, 2003.)

*415. Page 357 of the second printing only, `solar-longitude`: C.U.P. botched the second printing, omitting lines 29–33 at the bottom of the page. The missing lines are:

```
29                  -4.578l0 26895.292l0 -39.127l0 12297.536l0
30                  90073.778l0))
31           (addends
32            (list 270.54861l0 340.19128l0 63.91854l0 331.26220l0
33                  317.843l0 86.631l0 240.052l0 310.26l0 247.23l0
```

The Lisp code on the revised CD is correct. (Courtesy of Anoop Chaturvedi, February 26, 2004.)

416. Page 358, just before `solar-longitude-after`: Add the sentence "The Lisp construct `1d-5` is the double-precision value 10^{-5}." (It would probably be better to define and use a global constant *accuracy* with that value and to do so with a long-float `1L-5` so as not to introduce an unneeded Lisp data type.)

*417. Page 363 of the second printing only, `lunar-longitude`: C.U.P. botched the second printing, omitting line 61 at the bottom of the page. The missing line is:

```
61               (sigma ((v sine-coefficients)
```

The Lisp code on the revised CD is correct. (Courtesy of Anoop Chaturvedi, February 26, 2004.)

*418. Page 366–367 of the second printing only, `lunar-altitude`: C.U.P. botched the second printing, duplicating lines 16–19 at the bottom of page 366 and the top of page 367. The Lisp code on the revised CD is correct. (Courtesy of Anoop Chaturvedi, February 26, 2004.)

419. (2) Page 367, line 6 of **sunset-in-haifa: Change this line to

```
6       (sunset date haifa)
```

(see Errata 298 and 431).

420. Page 368 `visible-crescent`, line 3: Change the comment to read

```
3    ;; S. K. Shaukat's 1996 criterion for likely
```

*421. Page 368 of the second printing only, `observational-islamic-from-fixed`: C.U.P. botched the second printing, omitting lines 7–11 at the bottom of the page. The missing lines are:

```
7           (elapsed-months
8            (round (/ (- crescent islamic-epoch)
9                      mean-synodic-month)))
10          (year (1+ (quotient elapsed-months 12)))
11          (month (1+ (mod elapsed-months 12)))
```

The Lisp code on the revised CD is correct. (Courtesy of Anoop Chaturvedi, February 26, 2004.)

*422. Page 374–375 of the second printing only, `future-bahai-from-fixed`: C.U.P. botched the second printing, duplicating lines 21–27 at the bottom of page 374 and the top of page 375. The Lisp code on the revised CD is correct. (Courtesy of Anoop Chaturvedi, February 26, 2004.)

*423. (2) Page 375, **paris**: Replace with

```
1  (defconstant paris
2    ;; TYPE location
3    ;; Location of Paris Observatory.  Longitude corresponds
4    ;; to difference of 9m 21s between Paris time zone and
5    ;; Universal Time.
6    (location (angle 48 50 11) (angle 2 20 15) (mt 27) 1))
```

See also Errata 329 and 400. (Courtesy of Ehssan Dabal, April 10, 2002.)

424. (2) Page 376, **modified-french-from-fixed**: This function was correct in our files (and on the CD), but somehow an old version got into the book! Replace with:

```
1  (defun modified-french-from-fixed (date)
2    ;; TYPE fixed-date -> french-date
3    ;; French Revolutionary date (year month day) of fixed
4    ;; date.
5    (let* ((approx   ; Approximate year (may be off by 1).
6            (1+ (quotient (- date french-epoch -2)
7                          1460969/4000)))
8           (year (if (< date
9                        (fixed-from-modified-french
10                        (french-date approx 1 1)))
11                    (1- approx)
12                  approx))
13          (month    ; Calculate the month by division.
14           (1+ (quotient
15                (- date (fixed-from-modified-french
16                         (french-date year 1 1)))
17                30)))
18          (day      ; Calculate the day by subtraction.
19           (1+ (- date
20                  (fixed-from-modified-french
21                   (french-date year month 1))))))
22     (french-date year month day)))
```

See also Erratum 331.

*425. Page 376 of the second printing only, `modified-french-from-fixed`: C.U.P. botched the second printing, omitting lines 18–22 at the bottom of the page. The missing lines are:

```
18          (day      ; Calculate the day by subtraction.
19           (1+ (- date
20                  (fixed-from-modified-french
21                   (french-date year month 1))))))
22     (french-date year month day)))
```

The Lisp code on the revised CD is correct. (Courtesy of Anoop Chaturvedi, February 26, 2004.)

426. Page 379, `chinese-new-year-in-sui`: The type of the parameter is wrong; it should be `fixed-date` (not a list):

```
2    ;; TYPE fixed-date -> fixed-date
```

**427. (2) Page 386, line 26 of `fixed-from-hindu-solar`: Change this line to

```
26       (next d (- tau 2)
```

428. (3) Page 392, line 2 of `sacred-wednesdays`: Change parameter type from `gregorian-year` to `(fixed-date fixed-date)`. (Courtesy of Jonathan Leffler, March 22, 2002.)

429. Page 395: For an explanation of our choice of dates in Appendix C, send an empty email message to `reingold@iit.edu` with subject field “send-dates-explanation”.

430. Pages 396–400: Add the equation numbers and pages to the column headings to indicate which functions' output is given. It would be a nice idea to number the tables too. (Courtesy of Peter Zilahy Ingerman, May 20, 2002.)

**431. (2) Page 397: All the future Bahai dates need to be incremented by 1, to agree with the change indicated in Errata 298 and 419. All the Islamic Observational dates need to be decremented by 1 to agree with the change indicated in Erratum 300. The corrected table is given as Table 431-A.

*432. (2) Page 399: There are minor changes for "Next Zhongqi" for R.D. 626596 and R.D. 645554 caused by the error in **ephemeris-correction** for 1701–1799 (Erratum 246). The correct values are 626626.467423 and 645556.325334, respectively.

*433. (2) Page 400: There are several problems with the table. First, because of the correction to the latitude of Paris (see Errata 329, 400, and 423), the column with subheading "Dawn in Paris" is wrong and all the entries change in that column (there are now three dates for which astronomical dawn does not occur in Paris). Second, because of careless rounding, all fractional times are 1/2 second off. Third, there are minor changes in all columns for R.D. 626596 and R.D. 645554 caused by the error in **ephemeris-correction** for 1700–1799 (Erratum 246). Finally, the heading "Next Summer Solstice" is wrong, it should be "Next Solstice/Equinox" and it and the heading "Next New Moon" should say "(R.D. Moment)", not "(U.T.)". The corrected table is given as Table 433-A.

434. (2) Page 403, line 3 of second quote: Delete extraneous "of". (Courtesy of Idan Dershowitz, November 28, 2001.)

435. Page 406: Delete the index entry for the Zoroastrian calendar under the entry for "Calendar"..

436. Page 416: The Lisp code for **molad** is on page 338, not page 337 as given in the index entry.

437. Add index entries for Easter (page 116), Mayan New Year (page 140), Kamasan, Bali (page 152), Paris (page 232), and Stewart Brand (page 302).

438. Page 419, index entry for Shallit: Spell his first name correctly and give his middle initial, "Shallit, Jeffrey O.". (Courtesy of Nicholas J. Cox, January 16, 2006.)

439. Page 420: Delete page 114 from the index entry for Spier.

440. Page 421, index entry for von Dechend: Change "Herta" to "Hertha". (Courtesy of Nicholas J. Cox, January 16, 2006.)

441. Page 422: Delete the index entry for the Zoroastrian calendar.

442. Page 423: Another quotation that would be fine here is from Ambrose Bierce, "The covers of this book are too far apart." This quoted in Clinton H. Grattan's *Bitter Bierce*: *A Mystery Man of American Letters*, Doubleday, Doran & Co., New York (1929).

443. Add index entries for Nathan ben Meir Hademer, Henri Bach, Jean-Pierre Rieb, Robert Wilhelm, and James F. Brison (back cover).

444. Back cover, lower lefthand corner: Nathan ben Meir Hademer's dials cover the range of years 1598–1770. (Courtesy of John Cross, February 18, 2002.)

445. CD: In addition to all the starred code changes above, the following items refer specifically to the compact disc supplied with the book:

   (i) (2) In the Java code `HinduSolar.java`, the definition

				Islamic						Bahá'í										Mayan								
R.D.	Ethiopic			Arithmetic			Observational			Western					Future					Long Count					Haab		Tzolkin	
−214193	−594	12	6	−1245	12	9	−1245	12	11	−6	6	3	7	12	−6	6	3	7	11	6	8	3	13	9	11	12	5	9
−61387	−175	4	12	−813	2	23	−813	2	25	−5	9	3	14	13	−5	9	3	14	13	7	9	8	3	15	5	3	9	15
25469	63	1	29	−568	4	1	−568	4	2	−4	2	13	10	17	−4	2	13	10	18	8	1	9	8	11	4	9	12	11
49217	128	2	5	−501	4	6	−501	4	7	−4	6	2	11	6	−4	6	2	11	6	8	4	15	7	19	5	12	9	19
171307	462	5	12	−157	10	17	−157	10	18	−3	4	13	16	9	−3	4	13	16	10	9	1	14	10	9	14	12	3	9
210155	568	9	23	−47	6	3	−47	6	3	−3	10	6	4	4	−3	10	6	4	5	9	7	2	8	17	4	5	7	17
253427	687	3	11	75	7	13	75	7	13	−3	16	10	13	7	−3	16	10	13	7	9	13	2	12	9	14	7	2	9
369740	1005	8	24	403	10	5	403	10	5	−2	14	6	2	17	−2	14	6	2	17	10	9	5	14	2	8	5	4	2
400085	1088	9	23	489	5	22	489	5	22	−2	18	13	4	8	−2	18	13	4	9	10	13	10	1	7	10	15	7	7
434355	1182	7	20	586	2	7	586	2	7	−1	4	12	1	3	−1	4	12	1	3	10	18	5	4	17	8	15	9	17
452605	1232	7	7	637	8	7	637	8	7	−1	7	4	19	9	−1	7	4	19	10	11	0	15	17	7	8	15	7	7
470160	1280	7	30	687	2	20	687	2	21	−1	9	15	1	13	−1	9	15	1	14	11	3	4	13	2	10	10	12	2
473837	1290	8	25	697	7	7	697	7	7	−1	10	6	2	19	−1	10	6	3	1	11	3	14	16	19	11	17	10	19
507850	1383	10	10	793	7	1	793	6	30	−1	15	4	5	8	−1	15	4	5	8	11	8	9	7	12	15	5	2	12
524156	1428	5	29	839	7	6	839	7	6	−1	17	10	17	16	−1	17	10	17	16	11	10	14	12	18	9	6	6	18
544676	1484	8	5	897	6	1	897	6	2	0	1	10	2	1	0	1	10	2	2	11	13	11	12	18	13	6	12	18
567118	1546	1	12	960	9	30	960	9	30	0	4	14	10	12	0	4	14	10	12	11	16	14	1	0	3	18	3	20
569477	1552	6	29	967	5	27	967	5	27	0	5	1	19	4	0	5	1	19	4	11	17	0	10	19	12	7	9	19
601716	1640	10	6	1058	5	18	1058	5	18	0	9	14	5	6	0	9	14	5	7	12	1	10	2	18	18	6	8	18
613424	1672	10	26	1091	6	2	1091	6	3	0	11	8	6	7	0	11	8	6	8	12	3	2	12	6	1	9	3	6
626596	1708	11	19	1128	8	4	1128	8	4	0	13	6	7	12	0	13	6	7	13	12	4	19	4	18	3	1	6	18
645554	1760	10	14	1182	2	3	1182	2	4	0	16	1	5	15	0	16	1	5	16	12	7	11	16	16	1	19	10	16
664224	1811	11	27	1234	10	10	1234	10	10	0	18	14	8	2	0	18	14	8	2	12	10	3	14	6	4	14	12	6
671401	1831	7	19	1255	1	11	1255	1	11	0	19	15	1	7	0	19	15	1	7	12	11	3	13	3	16	16	13	3
694799	1895	8	11	1321	1	21	1321	1	20	1	4	3	2	11	1	4	3	2	10	12	14	8	13	1	18	14	11	1
704424	1921	12	19	1348	3	19	1348	3	19	1	5	10	9	6	1	5	10	9	6	12	15	15	8	6	7	4	3	6
708842	1934	1	19	1360	9	8	1360	9	7	1	6	3	11	3	1	6	3	11	3	12	16	7	13	4	9	2	1	4
709409	1935	8	11	1362	4	13	1362	4	14	1	6	5	2	11	1	6	5	2	11	12	16	9	5	11	19	4	9	11
709580	1936	1	26	1362	10	7	1362	10	7	1	6	5	11	11	1	6	5	11	11	12	16	9	14	2	9	10	11	2
727274	1984	7	8	1412	9	13	1412	9	12	1	8	15	19	16	1	8	15	19	17	12	18	18	16	16	18	4	12	16
728714	1988	6	17	1416	10	5	1416	10	5	1	8	19	18	19	1	8	19	18	19	12	19	2	16	16	17	4	9	16
744313	2031	3	1	1460	10	12	1460	10	12	1	11	5	13	7	1	11	5	13	8	13	1	6	4	15	12	8	8	15
764652	2086	11	11	1518	3	5	1518	3	5	1	14	4	7	6	1	14	4	7	7	13	4	2	13	14	7	7	2	14

Table 431-A: Replacement for page 397 (see Erratum 431).

R.D.	Solar Longitude at 12:00:00 U.T. (degrees)	Next Solstice/Equinox (R.D. Moment)	Lunar Longitude at 00:00:00 U.T. (degrees)	Next New Moon (R.D. Moment)	Dawn in Paris 48.84° N, 2.34° E, 27m (Standard Time)	Sunset in Jerusalem 31.8° N, 35.2° E, 800m (Standard Time)
−214193	119.474975	−213857.885383	245.036581	−214174.621008	0.095291 = 02:17:13	0.780311 = 18:43:39
−61387	254.252390	−61094.447554	209.009373	−61383.008248	0.277377 = 06:39:25	0.697040 = 16:43:44
25469	181.435260	25833.305203	213.821493	25495.802668	0.203567 = 04:53:08	0.734627 = 17:37:52
49217	188.662093	49574.080827	292.104807	49238.497566	0.212228 = 05:05:36	0.728250 = 17:28:41
171307	289.089403	171653.984713	156.851211	171318.433031	0.286372 = 06:52:23	0.708501 = 17:00:15
210155	59.119357	210459.464587	108.104381	210180.687915	0.096282 = 02:18:39	0.773952 = 18:34:29
253427	228.316498	253744.632597	39.417290	253442.854298	0.253733 = 06:05:23	0.700597 = 16:48:52
369740	34.466872	370070.362106	98.661798	369763.737893	0.149459 = 03:35:13	0.762484 = 18:17:59
400085	63.193926	400385.467959	333.062297	400091.570277	0.088475 = 02:07:24	0.776532 = 18:38:12
434355	2.462920	434718.238937	92.338110	434376.571202	0.209207 = 05:01:15	0.747826 = 17:56:52
452605	350.480679	452891.033496	78.211911	452627.186209	0.228544 = 05:29:06	0.742269 = 17:48:52
470160	13.502229	470512.003485	275.018078	470167.573455	0.189851 = 04:33:23	0.752843 = 18:04:06
473837	37.407733	474164.418920	128.420669	473858.848230	0.143912 = 03:27:14	0.764151 = 18:20:23
507850	81.030567	508131.957615	89.563254	507878.663442	**bogus**	0.783796 = 18:48:40
524156	313.862451	524478.621610	24.636880	524179.244329	0.272360 = 06:32:12	0.722257 = 17:20:03
544676	19.955639	545021.433864	53.507927	544702.752301	0.178064 = 04:16:25	0.755877 = 18:08:28
567118	176.060000	567394.307115	187.910712	567146.512283	0.196839 = 04:43:27	0.739393 = 17:44:44
569477	344.923458	569768.743350	320.182580	569479.202529	0.236577 = 05:40:40	0.739394 = 17:44:44
601716	79.964907	601999.244898	314.044964	601727.033423	0.045754 = 01:05:53	0.783812 = 18:48:41
613424	99.302275	613779.989199	145.475718	613449.761986	**bogus**	0.786840 = 18:53:03
626596	121.535304	626928.688049	185.032179	626620.369647	0.105596 = 02:32:04	0.781720 = 18:45:41
645554	88.567429	645828.317248	142.190205	645579.076668	**bogus**	0.786063 = 18:51:56
664224	129.289884	664548.570941	253.744068	664242.886600	0.122463 = 02:56:21	0.777882 = 18:40:09
671401	6.146911	671760.527969	151.649135	671418.970437	0.202855 = 04:52:07	0.749426 = 17:59:10
694799	28.251993	695136.040368	287.987873	694807.563367	0.162578 = 03:54:07	0.759976 = 18:14:22
704424	151.780633	704725.161646	25.626767	704433.491161	0.163288 = 03:55:08	0.761652 = 18:16:47
708842	185.945867	709201.678015	290.288335	708863.596972	0.208697 = 05:00:31	0.730378 = 17:31:45
709409	28.555608	709745.741746	189.913174	709424.404926	0.162019 = 03:53:18	0.760136 = 18:14:36
709580	193.347892	709932.167421	284.931761	709602.082675	0.216911 = 05:12:21	0.723741 = 17:22:11
727274	357.151263	727553.613128	152.339165	727291.209381	0.217686 = 05:13:28	0.745097 = 17:52:56
728714	336.170709	729014.587352	51.662475	728737.447666	0.247980 = 05:57:05	0.734479 = 17:37:39
744313	228.185702	744630.158285	26.691872	744329.573169	0.251892 = 06:02:43	0.699539 = 16:47:20
764652	116.439301	764990.025958	175.500487	764676.191300	0.094957 = 02:16:44	0.784233 = 18:49:18

Table 433-A: Replacement for page 400 (see Erratum 433).

```
public static final Location UJJAIN =
new Location("Ujjain, India", angle(23, 9, 0), angle(75, 46, 0),
              mt(0), 5 + 8d/75);
```

should be

```
public static final Location UJJAIN =
new Location("Ujjain, India", angle(23, 9, 0), angle(75, 46, 6),
             mt(0), 5 + 461d/9000);
```

This only affects the computation of `altSunrise` (which is not otherwise used in the code). Similarly, in the Mathematica code, instead of

```
Ujjain = Location["Ujjain, India", Angle[23, 9, 0], Angle[75, 46, 0],
                  Mt[0], 5 + 8/75]
```

we need

```
Ujjain = Location["Ujjain, India", Angle[23, 9, 0], Angle[75, 46, 6],
                  Mt[0], 5 + 461/9000]
```

which affects `AltHinduSunrise`.

(ii) The CD will probably not work under Windows 95 because of insufficient support for long names.

(iii) (2) Four Java documentation files have names that are too long for the Macintosh, so links to them do not work.

(iv) Some files may not have the ideal creator codes for the Macintosh.

(v) Some text files have newlines; others do not.

(vi) As in the book, all date conversions by the applet are as of noon.

(vii) The applet will not always work for dates that are more than 10,000 years before/after the present.

(viii) As emphasized in the book, the Observational Islamic code based on visibility from Cairo in the applet can only approximate actual practice.

(ix) As emphasized in the book, the modern Hindu calendars are subject to many regional differences; our applet follows one variant.

(x) Viewing the applet requires a Java-enabled browser or an applet viewer.

(xi) Netscape on a Macintosh needs to be set up properly for the applet to work (because of insufficient Java support). Make certain that Netscape is using a full Java runtime environment (available at `http://www.apple.com/java`) and that your browser is using the required Netscape MRJ plugin (`http://www.mozilla.org/oji/MRJPlugin.html`).

(xii) The iCAB browser for the Mac does not size the applet properly.

(xiii) The applet does not necessarily print the displayed date on your browser.

(xiv) The applet will not work on the Hebrew-enabled Mac Explorer because it does not support Java. An unofficial patch is at `http://purl.oclc.org/NET/Mitz/mrjfix`.

(xv) Unicode fonts are needed to view the month names all the languages, but no available font is complete.

(xvi) We mainly use a visual left-to-right encoding of the month names, without ligatures. So some languages may not display properly with some browsers and/or some systems.

(xvii) Netscape under Hebrew-enabled Windows does not display right-to-left month names as desired.

(xviii) We should "freeze" the row and column headers in the spreadsheets on the CD.

(xix) In the Java code `Ecclesiastical.java`, replace the line

```
+ 30 * quotient((7 * gYear) - 8, 19)
```

in the definition of the function `altOrthodoxEaster` with

```
+ 30 * quotient((7 * gYear) + 8, 19)
```

(Courtesy of Mark Woolcott, November 5, 2002.)

(xx) In the Java code `French.java`, replace the lines

```
public static final String[] specialDayNames = new String[] {
        "Jour de la Vertu",
        "Jour du Genie",
        "Jour du Labour",
        "Jour de la Raison",
        "Jour de la Recompense",
        "Jour de la Revolution"};
```

in the definition of the constant `decadeNames` with

```
public static final String[] specialDayNames = new String[] {
        "Fete de la Vertu",
        "Fete du Genie",
        "Fete du Travail",
        "Fete de l'Opinion",
        "Fete de la Recompense",
        "Jour de la Revolution"};
```

The same change is needed in the Mathematica code in `SpecialDayNames[French, ASCII]`. See Erratum 328.

(xxi) The links to Lotus's Calendrica-based applet, given in the file `Calendrica/Lotus.html` on the CD, are no longer operational. To view the applet use `http://emr.cs.iit.edu/home/reingold/calendar-book/lotus/sample.html`

(xxii) In the Java code `Roman.java`, replace the line

```
long yearPrime = monthPrime == 1 ? year + 1 : year;
```

in the function `fromFixed` by the lines

```
long yearPrime = (monthPrime != 1 ? year :
                            (year != -1 ? year + 1 : 1));
```

See Erratum 123.

(xxiii) In the Java code `Chinese.java`, replace the line

```
return sexagesimalName(elapsedMonths + DAY_NAME_EPOCH);
```

in the definition of the function `nameOfMonth` with

```
return sexagesimalName(elapsedMonths + MONTH_NAME_EPOCH);
```

(Courtesy of Peter Schulz, February 1, 2005.)

(xxiv) Years on the French Revolutionary Calendar should be called "an de la République" not "de la Révolution" (Courtesy of Ilan Vardi, June 13, 2006.)

Copies of the revised CD are available from the authors.

ERRATA BY FUNCTION NAME

The following errata mention the indicated functions and constants. Erratum numbers are of three types: The erratum number with the definition is shown in **boldface**. The erratum number with the corresponding Lisp code is shown in *italics*. Erratum numbers of other occurrences are given in roman.

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ERRATA BY CONTRIBUTOR

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Young Sook Ahn: 352.
Birgir T. Arnar: Errata corrections.
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Nicolas Herran: 21, 349.
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Jungmin Lee: 352.
Jonathan Leffler: 223, 391, 393, 398, 405–407, 410, 413, 428.
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