On the search for a source for the Jewish tradition that the Sun was created at zero hours (Jewish time) on Wednesday by Motti Yarchinai

Note: Times of week are expressed here as **w,hh:pppp**, where:
w = weekday 1 to 7 (Sun to Sat), **hh** = 00 to 23 hours and **pppp** = 0 to 1079 parts (1 hour = 1080 parts).
A time span is expressed in the same units, but the notation is: days,hh,pppp.

Why the search

The basis for Jewish tradition associating the creation of the Sun with Wednesday, is well known. In the biblical account of creation in chapter 1 of Genesis (the first book of the Torah), the Sun was created on the fourth day of the week of creation. In the same account, the seventh day of that week was blessed and sanctified by God as a day of rest when He ceased the work of creation after its completion at the end of the sixth day. Since Jews forever commemorate that day with their Sabbath, which has always been observed on Saturday, the fourth day of creation is associated with Wednesday of the seven-day week. On the other hand, it is harder to find a definitive source for the notion that God created the Sun at the very beginning of Wednesday, i.e. at exactly zero hours (Jewish Mean Time) on that day.

The source most commonly cited for the notion that the Sun was created at zero hours is the statement of Abbaye in Berachot 59b where he gives 28 years as the cycle length for the recurrences of Birkat Hachama, which is observed whenever the Shmuelian tekufat Nisan (the approximate March equinox as determined by the calculation devised by Shmuel) falls at zero hours on a Wednesday. This only occurs in Jewish years of the form 28n+1. The Shmuelian tekufat Nisan also falls on a Wednesday in Jewish years of the form 28n+7, 28n+18 and 28n+24, but on those three occasions, the tekufa falls at the (Jewish mean) times of 12:00 (mean sunrise), 06:00 (midnight) and 18:00 (noon), respectively. From this, Rashi assumes that the reason Birkat Hachama is observed only in Jewish years of the form 28n+1 is because the (Jewish) time-of-week at which the Sun was created was 4,00:0000.

But:

(a) Rashi's conclusion does not necessarily follow from the premise as a matter of strict logical necessity. There may be some other significance to the time of zero hours that could account for Birkat Hachama being observed only when the tekufa falls at that hour on a Wednesday. I have suggested two possible reasons for the special significance of that time in my article Myths and Maths of the Blessing of the Sun.

(b) To cite this Talmudic passage as the chief evidence for the existence of such a Jewish tradition, is to put it on very shaky grounds logically, because it sets up a circular argument: i.e. we "know" that the Sun was created at that time of day because that is the reason for the length of the Birkat Hachama cycle as stated by Abbaye. And why is the cycle that long? Because of the tradition that the Sun was created at that time of day.

I am quite certain that if Abbaye had been asked "whence do we know that the Sun was created at that time of day," he would not have answered, "we know it from Abbaye's statement." There must have been some other source for this tradition – hence my search for some other evidence for its existence.

Molad VYD

The molad (calendric mean new moon) at the beginning of Jewish year 2 (by our present-day year count), traditionally known as Molad VYD ד"ו-ו, coincides with the moment that, according to Jewish legend, Adam's body was fully formed. According to that same legend, this did not happen instantaneously as soon as God willed it, rather there was quite a process involved in God's fashioning of Adam from the earth of which he was made:

Creation of Adam on day 6 according to the "timetable" given in Sanhedrin 38b

During 13th hour (1st hr of daytime) = 6,12:0000 to 6,12:1079	God gathered the earth
During 14th hour (2nd hr of daytime) = 6,13:0000 to 6,13:1079	He prepared the earth
At end of 14th hr (end of 2nd hr of daytime) = 6,14:0000	Man's body fully formed

The moment at which the first man's body was fully formed was the molad of Tishrei of year 2 (Molad VYD).
From this, we compute the molad of year 1 (Molad Tohu) as follows. (Note: 1 synodic lunation = 29.5 days + 793p.)

6,14:0000	Molad VYD (Note: A molad time is always expressed as a time of week.)
– 4,08,0876	excess of 12 lunations above 50 whole weeks (350 days)
= 2,05:0204	Molad Tohu (BHRD) at beginning of year 1.

But, by the time Adam was fully formed (at Molad VYD) the Moon was already about two days old?

To explain this, there is a **Jewish legend** that the Moon remonstrated with God that one luminary was enough for the world. God became angry with the Moon and diminished her in size (Hulin 60b), or, alternatively, shut her up in darkness (i.e. she was not permitted to shine) for a period of 47 hours ending with Molad VYD. The alternative version[1] was, perhaps, occasioned by the observation that, as seen from Earth, the apparent diameters of the Sun and Moon are about equal. The second version of this legend puts the creation of the Moon at 4,15:0000.

I have not yet found the original source for the second version of this legend. (Please email me if you know it.)

תרגום יונתן על בראשית א',ט"ז:
ועבד י' ית תרין נהוריא רברביא והוון שוין באיקרהון עשרין וחד שעין בציר מנהון שית מאה ותרין שובעין חולקי שעתא, ומן בתר כן אשתעית סיהרא עילוי שמשא לישון תליתאי ואזדערת, ומני ית שמשא דהוה נהורא רבא למשלט ביממא וית סיהרא דהוה נהורא זעירא למשלט בליליא, וית כוכביא.

פירוש יונתן (מקראות גדולות מכון "המאור")
באיקרהון פירוש בכבודן, לשון יקר. **עשרין וחד שעין וכו'** הג"ה צריך לומר וחד שעין בצר מינה תלת מאה וארבע וחמשא יומין ושבעין ושית (כן הגיה הגאון מוהר"ר דוד, ומבואר בבפרקי דרבי אליעזר פ"ז). **ומן בתר כן אשתעית וכו'** ספרה. **לישון תליתאי** רוצה לומר לשון הרע ורכילות ההורג ג' האומר והמקבלו ומי שנאמר עליו (ערכין טו:) **ואזדערת** פירוש נתמעטה.

Targum Yonatan on Bereshit 1:16 [Bracketed insertions are mine]
Note: this is the work of an unknown author. It is not the work of Hillel's student, Yonatan Ben Uziel (early 1st century), who wrote an Aramaic translation of the Neviim. (So says Rabbi Mattis Kantor.)

> *God made two great luminaries – which, for a period of 21 hours less 672 parts of an hour* [i.e. for 20 hours, 408 parts]*, were equal in greatness, after which the Moon remonstrated* [with God] *against the Sun, whereupon she was diminished – and He appointed the Sun, which was the greater luminary, to rule over the day and the Moon, which was the lesser luminary, to rule over the night; and the stars.*

Pirush Yonatan (author unspecified) [Bracketed insertions are mine]
> ***"21 hours"*** *this should read 21 hours minus 354 days and* […] *76* […] *(so amended by the Gaon, Rabbi David, and this is explained in Pirkei de Rabbi Eliezer, ch 7.)*
>
> The number translated here (for the reason given later) as 354 appears in the original text in Aramaic form as תלת מאה וארבע וחמשא. It is translated so assuming that the third word in the number is the units value and the last word is the tens value and that either those two words were transposed or the number follows the peculiar old Hebrew grammar of numbering, which is similar to the numerical grammar used in the German language.

Molad D-Kh-TCh

The time span mentioned by **Targum Yonatan** as the interval between the Moon's creation and her diminishment, coincides with the Jewish epoch used in an alternative chronological system of the Jewish calendar. It is based on an epoch of 4,20:0408, exactly 12 calendric synodic lunations prior to our epoch BHRD:

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  4,20:0408   Molad D-Kh-TCh ד-כ-ת"ח (≈ Wed, 14:22:40, civil time)
+ 4,08,0876   excess of common year above 50 whole weeks (350 days)
= 2,05:0204   Molad Tohu (BHRD ב-ה-ר"ד)
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Although this system uses an epoch 12 months earlier than our epoch BHRD, the counting of years by that system does not start at that epoch but from the Molad BHRD, 12 months later (i.e. its first year is year 0). However, according to that chronology Adam was already 1 year old at Molad BHRD. This system puts the creation of the world 2 years earlier than the three mainstream methods of counting the years from creation that were more commonly known in Jewish chronology. This method is wrong because its epoch (Molad D-Kh-TCh) precedes Molad BHRD by exactly 12 lunar months, whereas it should have preceded Molad BHRD by exactly 13 lunar months. The year prior to what we nowadays call year 1 was a (theoretical) leap year.

The above description of the chronology based on epoch D-Kh-TCh is from Edgar Frank in *Talmudic and Rabbinical Chronology*. He quotes, as the source for this system, a manuscript found in the Cairo Genizah (S. Schechter, *Saadyana*, p. 103), where we read (translation by Frank, p. 29) as follows:

> *Why do we count BHRD? On the fourth day God created the Sun in order to shine and precede the Moon. At the beginning of the fourth night God put them in the sky and they both served until the Moon at 20 hours and 408 halakim on that day overcame the Sun. And God became angry at the Moon and diminished her size to molad (New Moon) … and in the second year the Moon stood in (i.e. the molad took place at) BHRD.*

Pirkei de Rabbi Eliezer

Let us now examine the above quoted amendment by **Pirush Yonatan** to Targum Yonatan. (I have no idea as to the identity of the mysterious "Rabbi David" that he cites. If anyone knows who this is, or, for that matter, who the author of Pirush Yonatan is, would you please let me know.) I finally managed to get a copy of *Pirkei de Rabbi Eliezer* and I believe I have found the passage in chapter seven that he refers to. The chapter begins with a discussion about the creation of the heavenly bodies and then focuses on the Sun and Moon. He writes:

כל הכוכבים והמזלות ושני המאורות נבראו בתחילת ליל רביעי, ולא קדם זה לזה אלא שתי ידות שעה.

> *All the stars, planets and the two luminaries were created at the beginning of the fourth day, and one preceded the other by only two thirds of an hour.*

I think it is important to digress for a moment here to make an important point about how this sentence should be understood. The last phrase clearly refers to the Sun and the Moon. The general context is a discussion of the moladot (lunar conjunctions) and the west to east motions of the Sun and the Moon (apparent motion in the case of the former, real motion of the latter). In my opinion, the precedence of which the author speaks is not a precedence in terms of the times of their creation, but in terms of their positions relative to one another as seen from Earth. In other words we should understand the last phrase to mean that at the time of their creation, the Moon was some distance further west of the Sun, so that in terms of their apparent diurnal motions from east to west, the Moon would have appeared to be "ahead" of the Sun.

This interpretation is implied by the general thrust of the lengthy comment on this phrase that is contained in the פירוש מהרז"ו by Rabbi Zev Wolf Einhorn (circa 1830)[2]. Though he does not explicitly ascribe this meaning to the phrase, he discusses the relative positions of the two bodies in great detail in the context of the time span to their next conjunction. In this context, he further suggests that the words שתי ידות שעה may be a copyist's error and that it should read שתי שעות (two hours, not two thirds of an hour). (He suggests that the error may have come about because the same phrase is used several times later in the same chapter.) He points out that if the Moon was "ahead" of the Sun by two hours – i.e. if it was about 30° west of the Sun, so that moonset would have preceded sunset by about two hours – then the Moon, whose mean easterly motion relative to the Sun has a rate of about half a degree per hour, would take about two and a half days to reach conjunction – approximately the same as the time span between then and Molad VYD.

This is followed by a lengthy explanation of the "great and small lunar cycles" (machzor hagadol and machzor hakatan) of, respectively, 3 and 21 years' duration, in terms of the recurrences of approximate moladot on the same weekdays and the same hour – not the calendric conjunctions actually used in the calculation of the calendar months but rough approximations of them. This is an exercise remarkably reminiscent of the calculations of Shmuel's great and small solar cycles in relation to the occurrences of Birkat Hachama.

Then, about a third of the way through the chapter, the following, rather awkwardly worded text appears:

> אין בכל מולד לראש מולד לשנה הבאה אלא ארבעה ימים ושמונה שעות ושמונה מאות ושבעים וששה חלקים.
>
> This, in paraphrase, means that the duration of 12 calendric synodic lunations exceeds 50 whole weeks by 4 days, 8 hours and 876 parts (where 1 part = 1/1080th of an hour).

This would seem to be the target of the reference to Pirkei de Rabbi Eliezer in Pirush Yonatan. (I have not found a more likely one.) If so, then the text of **Pirush Yonatan**'s amendment has some words missing corresponding to the underlined parts of the above quote. There can be little doubt that the author of Pirush Yonatan was ignorant of the true meaning and intent (as explained above) behind the arithmetic given in Targum Yonatan, and this is why he felt it necessary to say that it should be amended. He was unaware that the author of Targum Yonatan subscribed to a different calendar epoch from the one in general use nowadays, and he may well have been unaware of the existence of such a chronology altogether.[3]

(Following the above statement in Pirkei de Rabbi Eliezer, the author gives a description (also rather awkwardly worded) of how the path followed by the Moon in its apparent diurnal motion moves northward and southward of the equator over the course of a year in a manner similar to that of the Sun but opposite in direction, so that the arc it follows in the sky in its diurnal motion is about the same as the arc that was followed by the Sun six months earlier. (This is because the plane of the ecliptic and the plane of the Moon's orbit are both tilted with respect to the Earth's equatorial plane but in opposite directions to one another.)

Shmuelian Day Number

The next part of our investigation will be made much simpler if I first introduce the concept of the **Shmuelian Day Number (SDN)**, which I have named in honour of Shmuel *Yarchinai*, a third-century rabbi and astronomer of the Talmud. The SDN is a continuous count of the days of the Jewish calendar commencing with its first day, Tishrei 1 of Jewish year 1 (the day of Molad Tohu), as SDN 1. (See glossary for more details.)

By our present-day fixed calendar, (the largely theoretical) year 1 was a long, common year of 355 days. (Year 1 is largely theoretical because most of it precedes the supposed week of creation which, Jewish tradition holds, was the last week of that year.) It commenced on a Monday and ended on a Friday, and Rosh Hashanah of year 2 was on Saturday. By this calculation, the last Wednesday of year 1 (Elul 27th) was **SDN 353**.

On the other hand, those dates are proleptic. The calendric rules by which they are calculated are the rules of the present-day, fixed Jewish calendar (which did not yet exist then) applied retrospectively back to year 1. And counter to this calculation, there is a Jewish tradition that the day on which Adam was created was Rosh Hashanah of year 2 – i.e. contrary to the rules of the present calendar, Rosh Hashanah of year 2 was the Friday of the week of creation, the same day as the molad of that year. If so, year 1 was a regular, common year of 354 days, and the last Wednesday of that year was **SDN 352**.

Calendar Arithmetic of Pirush Yonatan

For the purpose of working through the calendar arithmetic given in Pirush Yonatan, we will use the former of the two alternatives just mentioned as the assumed form of calendar year 1.

Also, since it seems likely (as we have shown above) that the author of Pirush Yonatan was ignorant of the fact that Targum Yonatan is using a different calendar epoch (had he known this, he would not have proffered his amendment), we use as the base date for this arithmetic, the last Wednesday of year 1, SDN 353, the date, according to the chronology used today, on which the Sun and Moon are thought to have been created.

Calendar arithmetic of amendment by Pirush Yonatan to Targum Yonatan

Using subtrahend as amended above by comparison with the text of Pirkei de Rabbi Eliezer	Using subtrahend as given literally in Pirush Yonatan (we assume that 76 means 76 parts)
SDN 353, 21:0000 minus 354, 08,0876 (d,h,p) equals SDN −1, 12:0204	SDN 353, 21:0000 minus 354, 00,0076 (d,h,p) equals SDN −1, 20:1004
SDN 353, 00:0000 minus 354, 08,0876 (d,h,p) equals SDN −2, 15:0204	SDN 353, 00:0000 minus 354, 00,0076 (d,h,p) equals SDN −2, 23:1004

Looking at the results shown in row 1, either way, we end up with a time on the (non-existent) SDN −1, which is the Saturday immediately preceding the week of molad Tohu. To my knowledge, there is no calendric significance to this day, nor does it tie in with any Jewish tradition about the creation of the Sun and the Moon. In addition, it makes no sense in this context to be working from a base time of 21:0000 on the last Wednesday of year 1. Therefore, in row 2, I have recalculated the results working from a base time of zero hours on that Wednesday. The results, a time on the Friday preceding the week of molad Tohu are equally unhelpful.

It is an enigma to me what the author of Pirush Yonatan intended by his suggested amendment.

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Endnotes

1 The second version (only) of this legend appears in S.B. Burnaby, *Elements of the Jewish and Muhammedan Calendars …* (London, 1901), article 35, pp 42–45. He cites Scaliger and Petavius as secondary sources for this legend. The references in the footnotes appear as: (1) *De Emend. Temp.* viii. p. 631, C, and (2) *De Emend. Temp.*, lib ii. cap. xlv. p. 93. However, the title of (2) may be a misprint, for in his bibliography he has:

SCALIGER.	*De Emendatione Temporum*	Geneva	1629
PETAVIUS (Père Petau).	*Rationarii Temporum*	Franequerae	1700
"	*De Doctrina Temporum*	Venetiis	1757

It is the second version of the legend that is apparently intended to explain the seeming anomaly of the Moon being already two days old at the time of her first conjunction with the Sun at Molad VYD. The version in Hulin 60b is intended to explain why scripture (Gen 1:16) first calls the Sun and the Moon "the two large luminaries" then later in the same verse refers to the larger and the smaller of the two. It is interesting to note that the highly abridged version of this legend that appears in Targum Yonatan on this verse, which is quoted next, contains yet another variation to the tale told in Hulin – namely, that the Moon spoke slanderous words against the Sun. The text in Hulin does not say this, it says that the Moon argued with God that one luminary was sufficient for the world. This alone is evidence that there were different versions of the legend.

2 At the beginning of ch 6, he attributes the comments on chapters 6 and 7 printed in his *pirush* to a Rabbi Binyamin Diskin, Av Beit Din, Horadna: יען שבשני פרקים אלו, פרק שישי ופרק שביעי, מדבר בעניני תקופות ומולדות ולקויים אשר אין לי ידיע בענינים אלו, על כן היתה בקשתי מאת הרב הגאון החכם הכולל מוה' בנימין [דיסקין] נ"י ראב"ד דק"ק הוראדנא, שהוא ישים לבו הטהורה לבארם ... על כן אני מודיע נאמנה שהביאור על אלו ב' הפרקים מאת הרב הגאון הנ"ל ובלשונו הטהור.

3 Since Edgar Frank cites as the source for this chronology a manuscript from the Cairo Genizah (probably, from the language and context, a copy of one of Saadiah Gaon's writings in his polemic against Rabbi Ben Meir), knowledge of this chronology may have been lost until Solomon Schechter's exposition of the Genizah materials in the late 1890s. It would be interesting if the arithmetic of this Targum Yonatan (which must have been incomprehensible until then) turned out to be additional evidence of it.

Glossary:

Birkat Hachama A blessing thanking God for the creation of the Sun, recited once every 28 years. See: Myths and Maths of the Blessing of the Sun.

Epoch In a calendric context, this means the starting point of a calendar or calendar era. Usually, this is when the calendar was first introduced, but in the case of the present Jewish calendar, whose years are nowadays counted from the supposed date of creation, the epoch of the calendar is retrospective, for at the time of Jewish year 1, there was not even a Jewish people, and the present Jewish calendar is not the same as the original calendar used by Jews. It is the result of a transformation during the middle ages from an earlier, largely observation-based calendar to the fixed, rule-based calendar used nowadays.

Jewish Mean Time The time of day expressed in accordance with the way that the hours of the day are counted in the Jewish calendar, in which the date changes at mean sunset, not 6 hours later at midnight when the civil date changes. So, for example, Wednesday 00:00, Jewish Mean Time = Tuesday 18:00 civil time, and, in general, Jewish Mean Time (in all locations) = (your local) civil time + 6 hours.

Lunation The time taken by the Moon to return to a notional starting point (P) in its orbit. Astronomy recognizes several candidates for P. Consequently, there are different kinds of lunation, each with its own starting point, and each one has a different length. The length depends on whether P is stationary or moving as seen from Earth, and, if moving, its rate and direction of motion relative to the Moon's motion. For example, a **sidereal lunation** (the Moon's "real" orbital period) measures the Moon's motion against a fixed star and its mean length is only about 27.32 days, but the usual measure used for a calendric lunar month is a **synodic lunation**, which is a full cycle of lunar phases, whose mean length is a little longer – about 29.53 days. The notional starting point for a synodic lunation (and for a lunar month in the Jewish calendar) is the astronomical New Moon (also called a **lunar conjunction**), when the Moon passes between the Sun and the Earth and the three bodies are in line with one another. The Sun and Moon appear to "meet" at that time at the same celestial longitude – hence the name synodic, which comes from the Greek word for meeting.

The reason why it takes the Moon about 2.21 days longer than its real orbital period to complete a full cycle of phases is because the Moon's phases depend on its position relative to the Sun as seen from Earth. Because the Earth is in orbit around the Sun, it appears to circle the sky annually at a rate of about 1° per day from west to east – the same direction as the Moon's orbital motion. By the end of a lunar month, the Sun appears from Earth to have moved about 29° further east from its position at the beginning of the month. Consequently, for the Moon to return to the same position relative to Sun as seen from Earth, it must revolve through 360° + 29°, which is more than a single orbit (360°) around the Earth. There is a nice animation here demonstrating this.

Metonic cycle In 432 BCE, the Greek astronomer, Meton, publicized the fact (already known earlier to Babylonian astronomers) that 19 solar years is almost exactly equal to 235 synodic lunations. He used this correlation in a reformation of the Greek luni-solar calendar. This knowledge was held to be of such great importance that it was engraved in letters of gold upon a marble tablet in a temple at Athens. It was also inscribed on the pillars of many public buildings. (This kind of publicity would be akin, today, to banner headlines in all the major newspapers.) The 19-year cycle in Meton's revised Greek calendar was named the Metonic cycle after him. The Christian calendar uses the Metonic cycle for determining the date of Easter, and it calls the number (1 to 19) indicating a year's position within that cycle the golden number of the year.

The leap-year scheme of the Jewish calendar uses the Metonic cycle to keep its months, which are lunar, in approximate correlation with the seasons. It achieves this by inserting an extra month of 30 days into seven out of every 19 years. Such years are leap years of 13 months and they occur at intervals of 2 to 3 years. Common years have 12 months alternating in length between 30 and 29 days. In this way, 19 Jewish years have 235 months (19 × 12 + 7), making the mean length of a calendar year approximate the length of a solar year. The golden number of a year in the Christian calendar is not the same as the position of the corresponding Jewish year in the Metonic cycle of the Jewish calendar.

Molad Lunar conjunction (astronomical new moon). In the present context, it is a calendric, *mean* lunar conjunction of the Jewish calendar. Since it is a mean conjunction, the interval between successive moladot (plural) is constant. That interval (4 weeks, 1 day, 12 hours, 44 minutes, and 1 part) is the value of the mean synodic lunation found by the Greek astronomer and mathematician, Hipparchus, around 146 BCE, and from around the third century CE, it has been the mean month length of the Jewish calendar. A Jewish calendar month always begins on or soon after the day on which a molad is computed to have occurred. (The first day of a month is never more than three days after a molad.) The computed occurrence of a molad is traditionally expressed as a time of week (given as weekday and time of day), where the week commences at zero hours, Jewish Mean Time, on Sunday, and the time is for the meridian of Jerusalem. No date is required since the molad day is either the first of the month or within the three days immediately prior to the first. The year calendar of any Jewish year depends on its length and the weekday on which it starts, and in order to compute those, the molad at the beginning and end of that year must first be calculated.

Molad Tohu The epoch of the present-day Jewish calendar is the molad at the beginning of Jewish year 1. That molad (known as *Molad Tohu*) is computed to have occurred on a Monday, at 05:0204 (hours:parts), Jewish Mean Time. (It is therefore also known as Molad BHRD, which is a mnemonic formed from the Hebrew numerals for its weekday and time, ב-ה-ר"ד.) The word *tohu* comes from the Hebrew expression *tohu vavohu*, used at the beginning of the bible to describe the amorphous state of the world's existence at the beginning of its creation. It is used as the name for the molad of year 1 because the creation of the world is supposed, in traditional Jewish belief, to have occurred during the last week of that year, most of which is therefore purely theoretical (a mathematical construct) by that belief.

Since the interval between successive moladot is constant, the molad of any subsequent month can be computed by adding a multiple (M) of that period, modulo seven days, to the time of week of Molad Tohu and removing all whole weeks from the sum so that what is left will, like the original augend, be a time of week – that of the target molad. M is the number of months that have elapsed in the Jewish calendar up to the beginning of the subject month. The number of months (M) elapsed in the Jewish calendar up to the beginning of Jewish year Y can be obtained by the formula: M = (235Y − 234) \ 19 (where "\" denotes an integer division, discarding any remainder).

Part (Hebrew: *chelek*, plural *chalakim*). A time unit used in Jewish calendar arithmetic for subdividing the hour. There are 1080 parts to an hour. Thus, one part equals 1/18th minute or 3⅓ seconds. This unit was borrowed from earlier Babylonian usage in astronomy and time keeping. The *chelek* is divided into 76 *regaim* (moments), but the *rega* (moment) is used only rarely in Jewish calendar arithmetic.

Proleptic Anticipatory. Dates expressed in a certain calendar that precede the introduction of that calendar are said to be proleptic. For example, Gregorian dates prior to October 15, 1582 and Julian dates prior to January 1, 45 BCE are called Gregorian proleptic and Julian proleptic, respectively. They are theoretical dates (as opposed to historical dates), arrived at by projecting the relevant calendar backwards in time from the date of its introduction to the subject date, applying that calendar's rules retrospectively to the whole of the intervening period.

Shmuel Shmuel Yarchinai, a rabbi and astronomer of the Talmud who lived in the second century CE. Yarchinai is an honorific meaning something like "moon-gazer" or "lunar expert", bestowed upon him in recognition of his astronomical skills and for his interest in establishing rules for a fixed Jewish calendar – a process that did not even begin until a century later, but he was one of the pioneers of it. (The Jewish calendar then in use was largely an empirical calendar, based on observation, backed up by calculation.)

Shmuelian Day Number (SDN) A continuous count of the days of the Jewish calendar commencing with its first day, Tishrei 1 of Jewish year 1 (the day of Molad Tohu), as SDN 1. (This is my own invention, modelled on the Julian Day Number and named in honour of Shmuel *Yarchinai*.) The Julian Day Number (JDN) is a similar day count used in astronomy but commencing much earlier. SDN 1 = JDN 347,998, so SDN = JDN – 347997.

The range of Shmuelian Day Numbers is from 1 to 251,827,457, the latter number being the SDN of Sunday, Elul 29th, 689472. This upper limit comes from the dual fact that the number of the year which ends on that day is of the form 19n, and the molad Tishrei following it occurs on the next day, Monday, at 05:0204 (Jewish Mean Time), i.e. it is another molad BHRD occurring at the beginning of a 19-year Metonic cycle, and is therefore identical to the Molad Tohu of year 1. The year 689473 is therefore identical in all respects to year 1 and the Jewish calendar then starts to repeat itself. (In a computer implementation of this, SDN arithmetic would be modulo 251,827,457, so the highest SDN would actually be 251,827,456 (Elul 28th, 689472) and the following day (Elul 29th), would be SDN 0.)

Tekufa (plural tekufot). One of the four seasons, or, depending on the context, one of the four turning points of the tropical year that mark their beginnings, that is, the two equinoxes and the two solstices.

A **Shmuelian tekufa** is a calendric (not an astronomical) term. It is a nominal tekufa that only very roughly approximates the occurrence of the corresponding real tekufa. The Shmuelian tekufot are used to regulate the occurrences of two seasonal liturgical observances, Birkat Hachama and the annual commencement of the Diaspora *sh'elah* season, in which a request for rain is inserted into the daily prayers. Being seasonal, these two observances have no fixed dates in the Jewish calendar, whose months are lunar. Instead, they are governed by the equinoxes, and for this purpose, the Shmuelian equinoxes are used, not the real astronomical equinoxes, so that those two observances will recur on consistent dates in the solar (Julian) calendar. The computation on which these nominal tekufot are based was devised by Shmuel using the Julian calendar's mean year length, 365¼ days, as an approximation of the tropical year and 1/4 of that as a constant season length. Thus, the Shmuelian seasons are all 91 days, and 7.5 hours long, and the interval between a Shmuelian tekufa (equinox or solstice) and the next one of the same type one year later, is a constant 365.25 days. The mathematical beginning of all the Shmuelian seasons of the Jewish calendar is the Shmuelian March equinox of Jewish year 1, which is computed to have occurred at zero hours (Jewish Mean Time) on Wednesday, Adar 22 – Shmuelian Day Number 171.

Tropical Year A full cycle of seasons, as measured from the time of the March equinox.