Unlocking the Mystery of Birkat Hachamah & The Hebrew Calendar

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Sponsored by Jill & David Mogil in memory of Jill’s father, Saul Mirowitz, ob”m
Bibliography

- *Understanding the Jewish Calendar*, Rabbi Nathan Bushwick, Moznaim Publishing Corp. 1989
- *Bircas HaChamah*, Rabbi J. David Bleich, Artscroll, 2009
- Encyclopedia Judaica, *Calendar*
- [http://individual.utoronto.ca/aribrodsky](http://individual.utoronto.ca/aribrodsky)
- [http://www.geocities.com/Athens/1584](http://www.geocities.com/Athens/1584)
- *Mishnah Torah*, Laws of Sanctification of the Moon, ch. 6-10
Lift up your eyes on high and see: who created these? He who brings out their host by number, calling them all by name; by the greatness of His might and because He is strong in power, not one is missing... (Is. 40:26)
Course Outline

1. Terms & Definitions
2. The Leap Year Cycle – הממחור הקטן
3. Setting the Calendar
4. Setting the Holidays: The Four Dechiyot
5. The קביע (K’vi’a) – Year Types
6. Practical Calendar Issues (Anniversaries, Parshiyot)
7. Solar Calendar Mitzvoth:
   - Birkat Hachamah
   - Tal Umatar
And God made two great lights; the large light to rule the day, and the small light to rule the night; and he made the stars...and God saw that it was good. (Gen. 1)
The Astronomical Model

Lunar Phase Simulator

Moon Phase
New Moon

0.0% illuminated
time since new moon: 0 hours
hide

Horizon Diagram
observer's local time: 12:00 pm
hide

Animation and Time Controls
start animation
increment animation:
day: - +
hour: - +
minute: - +
animation rate:

Diagram Options
- show angle
- show lunar landmark
- show time tickmarks
Calendar Definitions

**ASTRONOMICAL**

- **DAY:** 1 complete rotation of the earth on its axis (divided into 24 equal units)
- **MONTH:** (synodic) “The mean interval between conjunctions of the Moon and Sun, corresponding to the cycle of lunar phases.” (~29.53 days)
- **YEAR:** 1 complete rotation of earth around the sun.

**HALACHIC**

- **DAY:** 1 complete cycle of setting, rising, and setting of the sun
- **MONTH:** Appearance of one new moon and the next
- **YEAR:** 1 cycle of long and short days = 1 cycle of seasons.
### Definitions (continued)

<table>
<thead>
<tr>
<th>Hebrew Term</th>
<th>English Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>תקופת תמוז</td>
<td>Summer Solstice</td>
<td>from the Latin sol (sun) and sistere (to stand still), because at the solstices, the Sun stands still in declination; longest day of the year, 1(^{st}) day of summer</td>
</tr>
<tr>
<td>Tekufat Tamuz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>תקופת טבת</td>
<td>Winter Solstice</td>
<td>shortest day of the year, 1(^{st}) day of winter</td>
</tr>
<tr>
<td>Tekufat Tevet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>תקופת ניסן</td>
<td>Spring (Vernal) Equinox</td>
<td>day=night, from Latin aequus (equal) and nox (night), 1(^{st}) day of Spring</td>
</tr>
<tr>
<td>Tekufat Nisan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>תקופת תשרי</td>
<td>Autuminal Equinox</td>
<td>day=night, 1(^{st}) day of Fall</td>
</tr>
<tr>
<td>Tekufat Tishrei</td>
<td></td>
<td></td>
</tr>
<tr>
<td>مولד</td>
<td>Conjunction of the moon between earth and sun</td>
<td>average time of appearance of moon from month to month (approximate definition, to be redefined later).</td>
</tr>
</tbody>
</table>
The Solar-Lunar Problem

The Problem

- 12 months (moon) = ~29½ x 12 = 354 d
- 1 year (sun) = 365¼ d
- Difference: 11¼ days

Alternative Solutions

- **Roman Calendar:** Solar Calendar
  - Month loses all connection to moon, 1/12th of Year.
- **Moslem Calendar:** Lunar Calendar
  - Month loses any connection to seasons.
The Ancient Egyptian Calendar

- Solar Year of 365 days
- 12 months x 30 days
- 5 days ‘added to the year by the god Thoth’
  - Birthdays of Osiris, Isis, Horus, Nephthys, and Set.
- Earliest civilization to accurately measure the solar year at 365\(\frac{1}{4}\) days, based on rising tides of the Nile.
- Julius Caesar's revolution of the Roman Calendar (46 BCE) based on his encounter with Cleopatra, and his enthrall with the simplicity and neatness of the Egyptian Calendar.
The Hebrew Calendar

- שָמֹר אַת הָעַשָׁתָה הָאָבִיָּב: Pesach must always fall after the spring/vernal equinox.
- Link solar and lunar calendars by intercalating one month into the year every ~3 years (GRAVID or LEAP YEARS).
- Add alternative Rabbinic Criteria for Holidays.
Attributed to Hillel II

Year 4111 to Creation or 351 CE

2 centuries after the destruction of the Temple.
R. Simeon b. Pazzi said in the name of R. Joshua b. Levi on the authority of Bar Kappara: He who knows how to calculate the cycles and planetary courses, but does not, of him Scripture says, ‘but they regard not the work of the Lord, neither have they considered the operation of his hands.’
Calendar Math

- **Molad** = The conjunction of the moon with the sun is the point in time at which the moon is directly between the earth and the sun (but not on the same plane) and is thus invisible (Encyclopeda Judaica).
  - Note: defined from Jerusalem.

- The **Length** of the Molad is the average length of the cycle of the moon, from Molad to Molad.

- **1 Hour = 1080 parts** (Chalakim)
  - Wholly divisible by: 2, 3, 4, 5, 6, 8, 9, 10, 12, 15, 18, 20, 24, 27, 30

- **1080 / 60 = 18**

- **18 parts = 1 minute**

- **1 part = 3⅓ seconds**

- **24 hour clock starting 6:00pm each day**
  - 2d 3h = Sunday 9:00pm!!
II. The Leap Year Cycle

המחזור הקסט
Safeguard the ‘springtime month’ so that you will be able to keep Passover to the Lord your G-d, since it was in the ‘springtime month’ that the Lord your G-d brought you out of Egypt, at night. (Deut 16:1)

G-d said to Moses and Aharon in Egypt:
This month shall be for you the ‘head month.’ It shall be the first month of the year. (Ex. 12:1-2)

Midrash Sod Ha’ibur
At that moment, G-d transmitted to Moshe Rabeinu the precise rules for calculating the new moon, and informed him how to intercalate the year and establish the months...

דברים פרק ט פסוק א
שמרו את חודש האביב ועשו פסח לה’ את החודש הראשון והационו יהיה
את הילויというもの לבדים:

שמות פרק יב
(א) אמרו לו אהל𝑥 את משה ואהרן בערי מצרים
לאמר: (ב) תודש חודש ה’ לפני ראש חדשים כראשו:
והנה כלשנים השניה:

מדרש סוד העיבור:
באותהשעה שעת מסר לحكיבא להמשה
ربيינו חוקותشو נהם הירת מסורות
דקודקי משפטים. והודיעו היאד הירא
מעבר שנים وكובעים ח申し込み.
The Dynamic Calendar & the Authority of the Beth Din

משנה ראש השנה כה ע”א: והם באים שניים אמרו: ראינוות בדמנה, והבליל עיבורי לא רואה. וקיבל אדם ורכו גמליאל. אמרו רבי דוסא בר

וואריכו: עדיו עניון: היות מעידים על האשה שידלוה, הלמהו

לבין יין? אמרו: לא רבי יושע: ראה אני את דבריך. שלו

כלא מהו? אמרו: גוזרני עלי: חלמתי עלו, אצלי, במחלק והמעוטר בים

הפורים שלח להו יי רבנו. הולך ומצא רבי עקיבא מјי. אמר:

ולו יש לי ללמד שלמה המ שעשיה הרב גמליאל עשים, שבאמר +יהרה הכנ

אלה מועדי, ה’ מקריא קדש אמרו תקרוא אתם - ביני בחכמה, ותרכם יי לכל זה

בכומן, אמרו: לא מועדו אלה艾滋...ונל של ממל הומועטיibir, ויהלך

ליבנה עצל הרב גמליאל בים שלח יי המפורים להו יי רבנו.

עמד הרב גמליאל נשאו על ראשיו, אמרו: לא בשלום רב

ותלמי! רב - תחתונה, ותלמיי - שבבלת את דברי.
Mishnah RH 25a
On another occasion two witnesses came and said, we saw it at its proper time, but on the night which should have been new moon it was not seen, and Rabban Gamaliel [had already] accepted their evidence. Rabbi Dosa b. Harkinas said: they are false witnesses. How can men testify that a woman has born a child when on the next day we see her belly still swollen? Said R. Joshua to him: I see [the force of] your argument. Thereupon Rabban Gamaliel sent to him to say, I enjoin upon you to appear before me with your staff and your money on the day which according to your reckoning should be the day of atonement. R. Akiba went [to R. Joshua] and found him in great distress. he said to him: I can bring proof that whatever Rabban Gamaliel has done is valid, because it says, these are the appointed seasons of the lord, holy convocations, which ye shall proclaim in their appointed seasons, [which means to say that] whether they are proclaimed at their proper time or not at their proper time, I have no appointed seasons save these... He [R. Joshua] thereupon took his staff and his money and went to Jabneh to Rabban Gamaliel on the day on which the day of atonement fell according to his reckoning. Rabban Gamaliel rose and kissed him on his head and said to him: come in peace, my teacher and my disciple — my teacher in wisdom and my disciple because you have accepted my decision.
Our Sages taught: Once the heavens were covered with clouds and the likeness of the moon was seen on the 29th of the month. The public thought to declare a 'new moon', and the Rabbinical Court wanted to sanctify it, but Rabban Gamliel said to them: 'I have it on the authority of my father's father that the renewal of the moon takes place after not less than twenty-nine and a half days, two-thirds of an hour, and seventy-three parts of an hour.'
Length of a Molad

The length of a Molad is 1080 p.

$29.5d + \frac{2}{3}h + 73p$

1 hour = 1080 p

$\frac{2}{3}h = 720 p$

MOLAD = 29d 12h 793p

כ"ט י"ב תשת'ג
Accuracy of Molad

Molad: 29d 12h 793p = 29d 12h 44m 3\(\frac{1}{3}\)s
Astronomical: 29d 12h 44m 2.8s \([1]\)

Difference:
- 0.5 seconds / month
- 6 seconds / year

In 2000 years the calendar would have lost 12,000 seconds, or 3\(\frac{1}{3}\) hours

1 day every 14,400 years!

## Length of Lunar Years

### Length of Lunar “Simple” year

<table>
<thead>
<tr>
<th></th>
<th>29d</th>
<th>12h</th>
<th>793p</th>
<th>1 month</th>
</tr>
</thead>
<tbody>
<tr>
<td>x 12 =</td>
<td>354d</td>
<td>8h</td>
<td>876p</td>
<td>Lunar Year</td>
</tr>
</tbody>
</table>

### Length of Lunar Gravid (Leap) year

<table>
<thead>
<tr>
<th></th>
<th>29d</th>
<th>12h</th>
<th>793p</th>
<th>1 month</th>
</tr>
</thead>
<tbody>
<tr>
<td>x 13 =</td>
<td>383d</td>
<td>21h</td>
<td>589p</td>
<td>Gravid Year</td>
</tr>
</tbody>
</table>
Modular Division (MOD 7)

- Modular arithmetic (sometimes called clock arithmetic) is a system of arithmetic for integers, where numbers "wrap around" after they reach a certain value — the modulus.

- Example: 12-hour clock: 7:00 o’clock pm + 8 hours = 3:00 o’clock. clock time "wraps around" every 12 hours - arithmetic modulo 12
Molad Shift over One Year

MOD 7 Molad shift by day of week

Simple Year: 4d 8h 876p – ד"ה תמת"ו
Gravid Year: 5d 21h 589p – ה"כ א תקף"ט
TEKUFAH SHIFT =
Difference between Lunar & Solar Year

<table>
<thead>
<tr>
<th>Tekufah Shift – Simple Years</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>365d 5h 1080 p Solar Year</td>
<td></td>
</tr>
<tr>
<td>- 354d 8h 876p Lunar Year</td>
<td></td>
</tr>
<tr>
<td>= 10d 21h 204p Tekufah Shift</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tekufah Shift - Leap Years</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>365d 6h Solar Year</td>
<td></td>
</tr>
<tr>
<td>- 383d 21h 589 p Lunar Year</td>
<td></td>
</tr>
<tr>
<td>= - 18d 15h 589 p Tekufah Shift</td>
<td></td>
</tr>
</tbody>
</table>
The Leap Year Rule

R. Huna b. Abin sent an instruction to Raba: When you see that the cycle of Tebeth extends to the sixteenth of Nisan, declare that year a leap year and have no doubts.

- Tekufat Nisan $\leq 15$th, month is Nisan, and the year = 'simple'
- If Tekufat Nisan $> 15$th, month is Adar II, the year is a Leap Year
Applying the TEKUFAH SHIFT

- Given \( tekufah \) of year \( x \)
- \( Tekufah \ x+1 = tekufah \ x + \) TEKUFAH SHIFT

Year 1: Tekufat Nisan = Molad Nisan
Year 2: Tekufat Nisan = 10d 21h 204p
Year 3: Tekufat Nisan = 21d 18h 408p later = LEAP YEAR
Tekufat Nisan in Relation to Molad Nisan

- When Tekufat Nisan falls later than the 15th, that month is Adar II, and apply the Gravid TEKUFAH SHIFT (subtract!) to calculate tekufat nisan the following year!!

Normal  +10d 21h 204p
Gravid   - 18d 15h 589p
In every 19 year cycle, 3, 6, 8, 11, 14, 17, 19 are leap years.
Where are we?

- **Calculate Year / 19**
- **Quotient (YR/19) = # of COMPLETED Cycles**
- **Remainder (YR/19) = Year within next Cycle**
- **Note: If remainder is zero = year 19!**
- **3, 6, 8, 11, 14, 17, 19** = ג"ח אדר"ט

<table>
<thead>
<tr>
<th>Year</th>
<th>Result of Division</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5757</td>
<td>303 r. 0</td>
<td>19th year of 303rd cycle, Simple Year</td>
</tr>
<tr>
<td>5768</td>
<td>303 r. 11</td>
<td>11th year of 304th cycle, Leap year</td>
</tr>
<tr>
<td>5769</td>
<td>303 r. 12</td>
<td>12th year - 304th cycle, Simple year</td>
</tr>
<tr>
<td>5770</td>
<td>303 r. 13</td>
<td>13th year of 304th cycle, Simple year</td>
</tr>
<tr>
<td>5771</td>
<td>303 r. 14</td>
<td>14th year of 304th cycle, Leap year</td>
</tr>
</tbody>
</table>
Unresolved questions

- $e = 1h \ 485p$ offset must be accounted for or it will accumulate!
- Year 16 (15d 14h 175p) – presumed ‘simple’, but depending on when $molad nisan$ falls, in some years this could be the 16th of Nisan!
- Is there a hypothetical year when $molad nisan = tekufat nisan$? If not, when did the calendar actually start?
Towards a More Precise Calendar!

2 measurements for calculating the length of a Tropical Year.

1. **Tekufat Shmuel**: Year = 365d 6h

2. **Tekufat Rav Ada**: Year = 1/19th of Machzor Katan
Calculation of Tekufat Rav Ada

Machzor Katan of 19 years
= 7x13 + 12x12 months = 235 months

**Tropical Year = 235 (29d 12h 793p) / 19**

<table>
<thead>
<tr>
<th>Tropical Year = 1/19 of Machzor Katan =</th>
<th>235 (29d 12h 793p) / 19</th>
</tr>
</thead>
<tbody>
<tr>
<td>365d 5h 997hp 48m</td>
<td>= (6815d 2820h 186355p) / 19</td>
</tr>
<tr>
<td>Conventional time</td>
<td>= (6939d 16h 595p) / 19</td>
</tr>
<tr>
<td></td>
<td>= 365d 5h 997p 48m* (m=1/76p)</td>
</tr>
<tr>
<td></td>
<td>= 365d 5h 55m 25.4386s</td>
</tr>
</tbody>
</table>

* m=moment
# Accuracy of Calculation of Tropical Year*

<table>
<thead>
<tr>
<th>Tropical Year</th>
<th>Precision</th>
<th>Diff. (Days)</th>
<th>Diff. (seconds)</th>
<th>1 Day accumulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shmuel</td>
<td>365d 6h</td>
<td>0.00780</td>
<td>674</td>
<td>128 years</td>
</tr>
<tr>
<td>R. Ada</td>
<td>365d 5h 55m 25.4386s = 365.24682d</td>
<td>0.00462</td>
<td>399</td>
<td>216 years</td>
</tr>
<tr>
<td>Gregorian</td>
<td>365d 5h 49m 12s = 365.24250d</td>
<td>0.00030</td>
<td>26</td>
<td>3323 years</td>
</tr>
<tr>
<td>Standard *</td>
<td>365d 5h 48m 46.069s = 365.2422d</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Pros & Cons of Tekufat Rav Ada

- **Pros**
  - No ‘remainder’ of 19 year cycle

- **Cons:**
  - Much more complicated to calculate
Which calculation to use?

- Lunisolar Leap Year Calculations are based on Tekufat Rav Ada, and pre-calculated by Hillel II.

- Calculations left to the people, namely Tal Umatar & Birkat HaChamah, would be simplified by using Tekufat Shmuel.

- Chazal, while aware of the inaccuracy of Tekufat Shmuel, were confident that the Moshiach would come long before this inaccuracy would pose any problem.

  (Perush, Rambam, KHC 9:3)
## Summary

<table>
<thead>
<tr>
<th>Tekufat Shmuel</th>
<th>365d 6h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tekufat Rav Ada</td>
<td>365d 5h 997p 48m</td>
</tr>
<tr>
<td>Length of Molad</td>
<td>29d 12h 793p</td>
</tr>
<tr>
<td>Molad Shift</td>
<td>1d 12h 793p</td>
</tr>
<tr>
<td>* Annual Molad Shift – Simple</td>
<td>4d 8h 867p</td>
</tr>
<tr>
<td>* Annual Molad Shift – Gravid</td>
<td>5d 21h 589p</td>
</tr>
<tr>
<td>** Annual Tekufah Shift – Simple</td>
<td>10d 21h 204p</td>
</tr>
<tr>
<td>** Annual Tekufah Shift – Gravid</td>
<td>-18d 15h 589p</td>
</tr>
<tr>
<td>Leap Years – “Machzor Hakatan”</td>
<td>3,6,8,11,14,17,19</td>
</tr>
</tbody>
</table>

* Length of Year MOD 7
** In relation to the Lunar Year