



Unlocking the Mystery of The Hebrew Calendar

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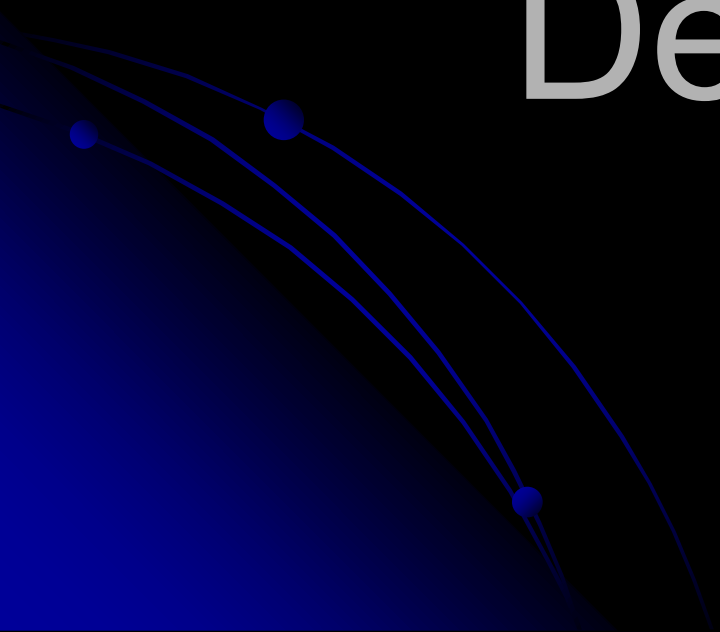
שְׂאוּ מְרוֹם עֵינֵיכֶם וּרְאוּ מִי בָרָא אֱלֹהֵי הַמּוֹצִיא בְּמִסְפָּר
צְבָאָם לְכֻלָּם בְּשֵׁם יְקָרָא מְרַב אוֹנִים וְאַמִּיץ כַּח אִישׁ
לֹא נֶעְדָּר (ישע' מ:כו)

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 – המחזור הקטן
3. Setting the Calendar
4. So What does the Calendar Look Like?
5. Setting the Holidays: The Four Dechiyot
6. The קביע (*K'vi'a*) – Year Types
7. Practical Calendar Issues
(Anniversaries, Parshiyot)
8. Solar Calendar Mitzvoth:
Birkat Hachamah
Tal Umatar

I. Terms & Definitions

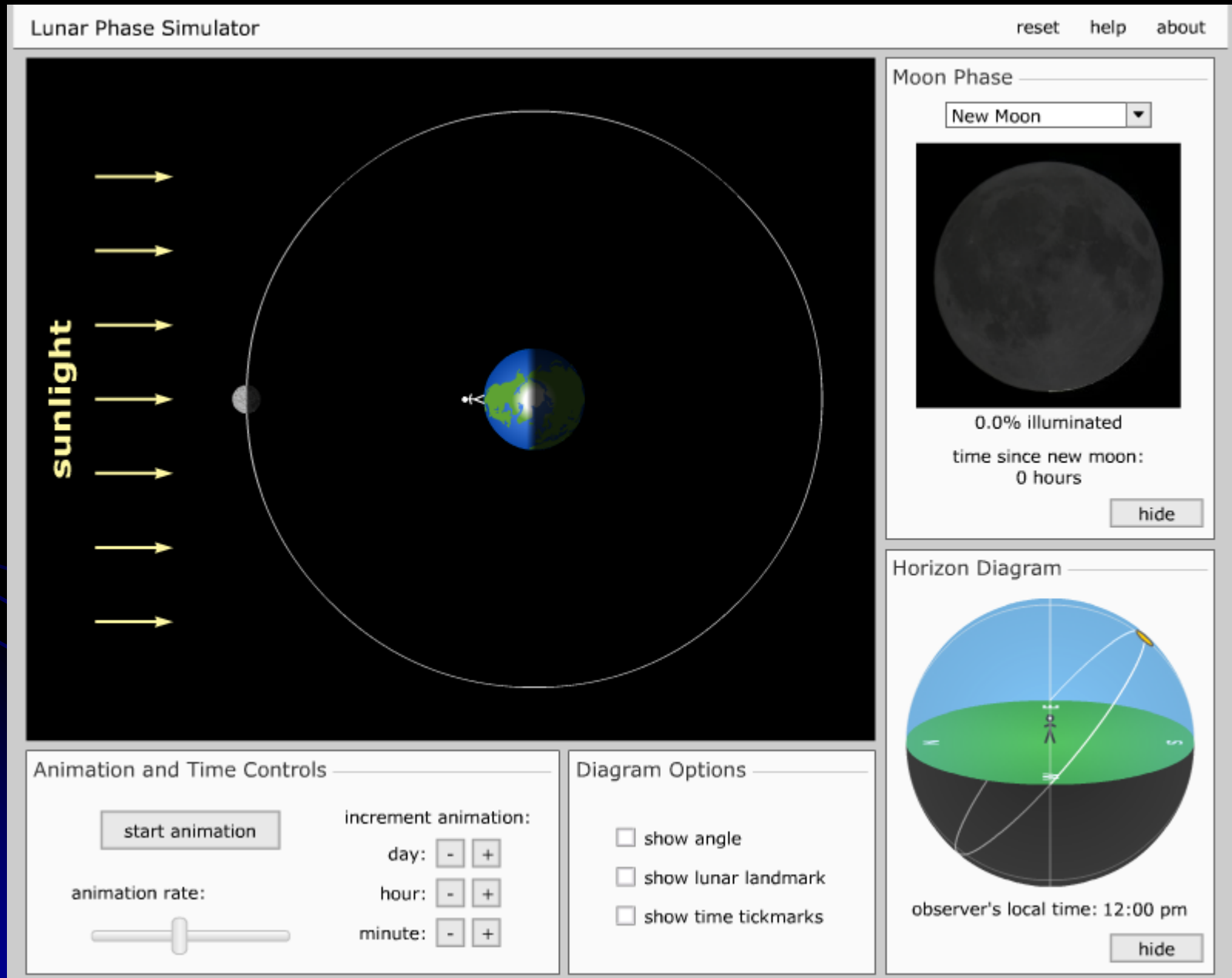


וַיַּעַשׂ אֱלֹהִים אֶת שְׁנֵי הַמָּאֹרֹת
הַגְּדֹלִים אֶת הַמָּאֹר הַגָּדֹל לְמַמְשֶׁלֶת
הַיּוֹם וְאֶת הַמָּאֹר הַקָּטָן לְמַמְשֶׁלֶת
הַלַּיְלָה וְאֵת הַכּוֹכָבִים... וַיֵּרָא
אֱלֹהִים כִּי טוֹב...

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. I)



The Astronomical Model



Calendar Definitions

ASTRONOMICAL

- DAY: 1 complete rotation of **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)

תקופת תמוז **Summer Solstice**

Tekufat Tamuz

Latin SOL (sun) + SISTERE (to stand still) - at the solstices, the Sun stands still in declination; longest day of the year, 1st day of summer.

תקופת טבת **Winter Solstice**

Tekufat Tevet

shortest day of the year, 1st day of winter

תקופת ניסן **Spring (Vernal) Equinox**

Tekufat Nisan

day=night, Latin AEQUUS (equal) + NOX (night), 1st day of Spring

תקופת תשרי **Autumnal Equinox**

Tekufat Tishrei

day=night, 1st day of Fall

מולד

Molad

Conjunction of the moon between earth and sun - average time of appearance of moon from month to month (approximate definition, to be redefined later).

The Solar-Lunar Problem

The Problem

- 12 months (moon) = $\sim 29\frac{1}{2} \times 12 = 354 \text{ d}$
- 1 year (sun) = $\sim 365\frac{1}{4} \text{ d}$
- Difference: $11\frac{1}{4} \text{ days}$

Alternative Solutions

- **Roman Calendar: SOLAR**

- Months lose connection to moon, $1/12^{\text{th}}$ of Year.

- **Moslem Calendar: LUNAR**

- Months lose 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

שְׁמֹר אֶת חֹדֶשׁ הָאָבִיב

- 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 criteria re Holidays TBD

Fixed Hebrew Luni-Solar Calendar

Attributed to Hillel II

Year 4111 to Creation
or 351 CE

2 centuries after the
destruction of the Temple.

כל היודע לחשב בתקופות ומזלות ואינו
חושב - עליו הכתוב אומר ^(ישע' ה) וְאֵת פְּעֵל ה' ^(גמ' שבת עה.)
לֹא יִבְיֹטוּ וּמַעֲשֵׂה יָדָיו לֹא יֵאָדָּו

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 - the point 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.
- **1 Hour = 1080 parts** (*Chalakim*)
 - *Wholly divisible by: 2, 3, 4, 5, 6, 8, 9, 10, 12, 15, 18, 20, 24, 27, 30*
- $1080 / 60 = 18$
- $18 \text{ parts} = 1 \text{ minute}$
- $1 \text{ part} = 3\frac{1}{3} \text{ seconds}$
- The Length of the Molad is the average length of the cycle of the moon, from Molad to Molad.

Calendar Clock!

24 hour clock

Arbitrarily Starting @ 6:00pm

2d 3h = Sunday 9:00pm

0d 0h = Friday 6:00pm

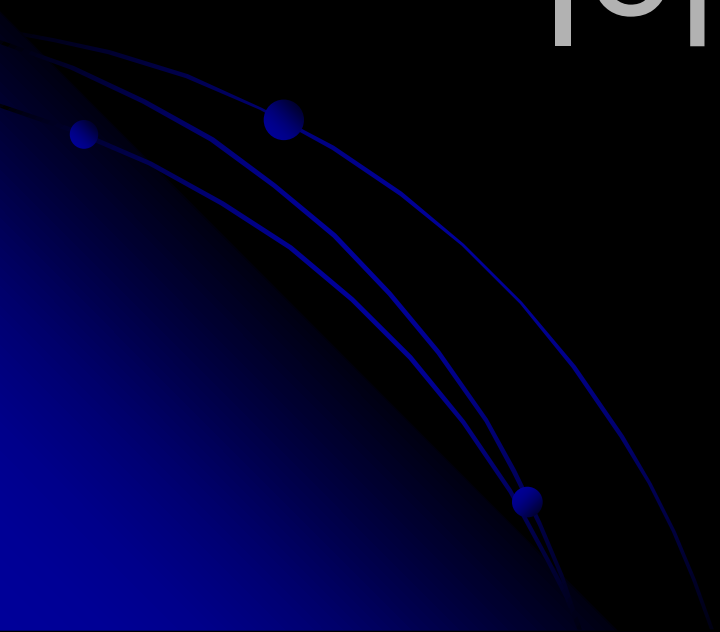
0d 6h = Saturday 12:00am

5d 18h = Thursday 12:00pm

6d 22h = Friday 4:00pm

II. The Leap Year Cycle

המחזור הקטן



Biblical Roots of the Lunar Calendar System

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 טז פסוק א

שָׁמֹר אֶת חֹדֶשׁ הָאָבִיב וְעָשִׂיתָ פֶּסַח
לַה' אֱלֹהֶיךָ כִּי בַחֹדֶשׁ הָאָבִיב הוֹצִיאָךְ
ה' אֱלֹהֶיךָ מִמִּצְרַיִם לַיְלָה:

שמות פרק יב

(א) וַיֹּאמֶר ה' אֶל מֹשֶׁה וְאֶל אֶהֱרֹן בְּאֶרֶץ
מִצְרַיִם לֵאמֹר: (ב) הַחֹדֶשׁ הַזֶּה לָכֶם רֹאשׁ
חֳדָשִׁים רִאשׁוֹן הוּא לָכֶם לְחֹדֶשִׁי הַשָּׁנָה:

מדרש סוד העיבור:

באותה שעה מסר לו הקב"ה למשה
רבינו חוקות חשבון הירח ומסורות
דקדוקי משפטיו. והודיעו היאך יהא
מעבר שנים וקובע חדשים

The Dynamic Calendar & the Authority of the Beth Din

משנה ראש השנה כה ע"א: ועוד באו שנים ואמרו: ראינוהו בזמנו, ובליל עיבורו לא נראה. וקיבלן רבן גמליאל. אמר רבי דוסא בן הורכינס: עדי שקר הן; היאך מעידים על האשה שילדה, ולמחר כריסה בין שיניה? אמר לו רבי יהושע: רואה אני את דברך. שלח לו רבן גמליאל: גוזרני עליך שתבא אצלי במקלך ובמעוטיך ביום הכפורים שחל להיות בחשבונך. הלך ומצאו רבי עקיבא מיצר. אמר לו: יש לי ללמוד שכל מה שעשה רבן גמליאל עשוי, שנאמר ^{+ויקרא כג+} אלה מועדי ה' ^{מקראי קדש} אשר תקראו אתם - בין בזמן בין שלא בזמן, אין לי מועדות אלא אלו...נטל מקלו ומעותיו בידו, והלך ליבנה אצל רבן גמליאל ביום שחל יום הכפורים להיות בחשבונו. עמד רבן גמליאל ונשקו על ראשו, אמר לו: בוא בשלום רבי ותלמידי! רבי - בחכמה, ותלמידי - שקבלת את דברי.

The Dynamic Calendar & the Authority of the Beth Din

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.

Sod Ha'ibur – The Molad

Talmud RH 25a

“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.’*”

תלמוד ראש השנה כה.

תנו רבנן: פעם אחת נתקשרו
שמים בעבים ונראית דמות
לבנה בעשרים ותשעה לחדש,
כסבורים העם לומר: ראש
חדש, ובקשו בית דין לקדשו.
אמר להם רבן גמליאל: כך
מקובלני מבית אבי אבא: אין
חדושה של לבנה פחותה
מעשרים ותשעה יום ומחצה
ושני שלישי שעה ושבעים
ושלשה חלקים

Length of a Molad

אין חדושה של לבנה פחותה מעשרים ותשעה יום ומחצה ושני
שלישי שעה ושבעים ושלושה חלקים (ר"ה כה.).

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

$$1 \text{ hour} = 1080 \text{ p}$$

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

$$\text{MOLAD} = 29d \ 12h \ 793p$$

כ"ט י"ב תשצ"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 second / 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!

[1] *Halachic Times for Home & Travel*, Levi, Jewish Chrononomy, p. 301, based on S.W. Allen, *Astrophysical Quantities*, 3rd Ed. (London 1973)

Length of Lunar Year

Length of Lunar “Simple” year

	29d	12h	793p	1 month
x 12 =	354d	8h	876p	Lunar Year

Length of Lunar Gravid (Leap) year

	29d	12h	793p	1 month
x 13 =	383d	21h	589p	Gravid Year

TEKUFAH SHIFT (Annual) = Difference between Lunar & Solar Year

Tekufah Shift – Simple Years				
	365d	5h	1080p	Solar Year
-	354d	8h	876p	Lunar Year
=	10d	21h	204p	Tekufah Shift

Tekufah Shift - Leap Years				
	365d	6h		Solar Year
-	383d	21h	589p	Lunar Year
=	- 18d	15h	589p	Tekufah Shift

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.

ראש השנה כא.

שלח ליה רב הונא בר אבין לרבא:
כד חזית דמשכה תקופת טבת עד
שיתסר בניסן - עברה לההיא
שתא, ולא תחוש לה.

- Tekufat Nisan $\leq 15^{\text{th}}$, month is Nisan, and the year = 'simple'
- If Tekufat Nisan $> 15^{\text{th}}$, month is Adar II, the year is a Leap Year

Applying the TEKUFAT SHIFT

- Given *tekufah* of year x
- $\text{Tekufah } x+1 = \text{tekufah } x + \text{TEKUFAT SHIFT}$

Year 1: Tekufat Nisan = Molad Nisan

● Year 2: Tekufat Nisan = 10d 21h 204p

Year 3: Tekufat Nisan = 21d 18h 408p

21d 18h 408p > 15d = LEAP YEAR

Tekufat Nisan in Relation to Molad Nisan

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

Normal +10d 21h 204p
Gravid - 18d 15h 589p

1	0d 0h 0p	Hypothetical Molad=Tekufah
2	10d 21h 204p	
3	<u>21d 18h 408p</u>	LEAP YEAR
4	3d 2h 899p	
5	14d 0h 23p	
6	<u>24d 21h 227p</u>	LEAP YEAR
7	6d 5h 718p	
8	<u>17d 2h 922p</u>	LEAP YEAR
9	-(1d 12h 333p)	
10	9d 8h 537p	
11	<u>20d 5h 741p</u>	LEAP YEAR
12	1d 14h 152p	
13	12d 11h 356p	
14	<u>23d 8h 560p</u>	LEAP YEAR
15	4d 16h 1051p	
16	15d 14h 175p	
17	<u>26d 11h 379p</u>	LEAP YEAR
18	7d 19h 870p	
19	<u>18d 16h 1074p</u>	LEAP YEAR
20	0d 1h 485p = e	= offset of 19 year cycle

מחזור קטן – Machzor Katan (Leap Year Cycle)

גו"ח אדז"ט

3	ג
6	ו
8	ח
11	יא
14	יד
17	יז
19	יט

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 = ט"ז ט"ח ט"ט פ"א פ"ב פ"ג

$$5776 / 19 = 304 \text{ r. } 0$$

$$5776 = 19^{\text{th}} \text{ year of cycle \#304}$$

$$5776 = \text{LEAP YEAR}$$

19 YEARS OF 305TH CYCLE

1. 5777	/ 19 = 304 r. 1	א
2. 5778	/ 19 = 304 r. 2	ב
3. 5779	/ 19 = 304 r. 3	ג
4. 5780	/ 19 = 304 r. 4	ד
5. 5781	/ 19 = 304 r. 5	ה
6. 5782	/ 19 = 304 r. 6	ו
7. 5783	/ 19 = 304 r. 7	ז
8. 5784	/ 19 = 304 r. 8	ח
9. 5785	/ 19 = 305 r. 9	ט
10. 5786	/ 19 = 304 r. 10	י
11. 5787	/ 19 = 304 r. 11	יא
12. 5788	/ 19 = 304 r. 12	יב
13. 5789	/ 19 = 304 r. 13	יג
14. 5790	/ 19 = 304 r. 14	יד
15. 5791	/ 19 = 304 r. 15	טו
16. 5792	/ 19 = 304 r. 16	טז
17. 5793	/ 19 = 304 r. 17	יז
18. 5794	/ 19 = 304 r. 18	יח
19. 5795	/ 19 = 305 r. 0	יט

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 = $1/19^{\text{th}}$ of Machzor Katan

Calculation of Tekufat Rav Ada

Machzor Katan of 19 years

= $7 \times 13 + 12 \times 12$ months = 235 months

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

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

* m=moment

Accuracy of Calculation of Tropical Year*

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

* Halachic Times for Home and Travel, Leo Levi, p. 301, based on S. W. Allen, *Astrophysical Quantities*, 3rd Ed. (London, 1973)

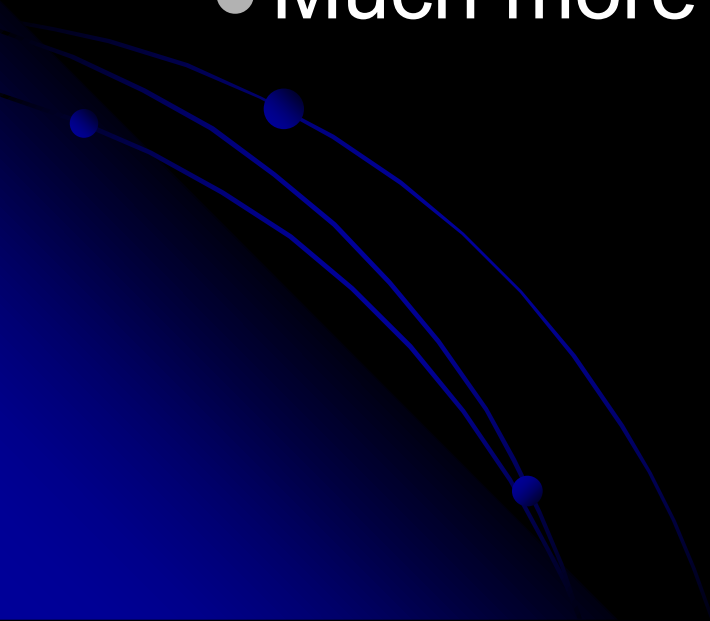
Pros & Cons of Tekufat Rav Ada

- Pros

- No 'remainder' of 19 year cycle

- Cons:

- Much more complicated to calculate



Which calculation to use?

- 📌 **Luni-solar 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

Tekufat Shmuel – Tropical Year	365d 6h	
Tekufat Rav Ada – Tropical Year	365d 5h 997p 48m	
Length of Molad	29d 12h 793p	כ"ט י"ב תשצ"ג
Molad Shift (monthly)	1d 12h 793p	אי"ב תשצ"ג
* Annual Molad Shift – Simple	4d 8h 867p	ד"ח תתע"ו
* Annual Molad Shift – Gravid	5d 21h 589p	הכ"א תקפ"ט
** Annual Tekufah Shift – Simple	10d 21h 204p	
** Annual Tekufah Shift – Gravid	-18d 15h 589p	
Leap Years – “Machzor Hakatan”	3,6,8,11,14,17,19	גו"ח אדז"ט

* Length of Year MOD 7

** In relation to the Lunar Year